Marine and Ocean Industry Technology Roadmap Special Report

Thinking Beyond Our Shoreline

March 13, 2003

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Photo credit: DFO Central & Arctic Region

The NRC Ice Tank at St. John's, NF
Photo credit: NRC

FOREWORD

The Marine and Ocean Industry Technology Roadmap (TRM) has been developed by a thirty member Steering Committee with strong industry representation as well as the participation and sponsorship by the National Research Council Canada, Industry Canada, Fisheries and Oceans Canada, Natural Resources Canada, National Defence, Transport Canada, Environment Canada and the Canadian Space Agency.

The objective of the TRM is to identify future technology markets and emerging technology opportunities and scope out the most effective methods of achieving them. The report covers a wide range of marine and ocean technologies over a fifteen-year time span. Technology drivers, which involve those sectors of the economy that provide the capital and human resources associated with the marine and ocean economy are also discussed.

Technology roadmapping is a practical forecasting tool, through which participants, suppliers and end users in marine and ocean industries identify future market needs. Later, technologies and products necessary to satisfy these needs are planned for and discussed strategically.

The roadmap (TRM) is a chronological and spatial representation of technology pathways. It involves a collaborative planning process, which brings partners or stakeholders together to chart the course for innovative technologies and processes that will meet future market demands. Stakeholders include industry, government, research laboratories, academia, and contribution and granting agencies. The process is industry-led, with government acting as a catalyst and facilitator.

Developing a Technology Roadmap requires three steps:

- Market requirements forecast;
- Product implications forecast; and,
- Technology implications forecast.

A *Special Report* or technology roadmap is prepared as the starting point. An implementation plan is then developed to guide how these technologies can best be realized and to identify the resources required. In essence, technology roadmapping connects technology to strategy.

This report focuses on the future market requirements, product implications and technology pathways for the marine and ocean industry. The implementation phase of the roadmap will evolve through the continued participation of the government, academic and industry players by filtering and assessing the opportunities identified. The emergence of select industry champions to develop and implement proposed action plans designed to capture specific opportunities is considered to be a strong priority by the TRM participants and sponsors.

The composition of the ocean technology industry is small to medium-sized, geographically dispersed and possesses limited infrastructure capacity from which to expand and grow markets. The technology roadmap has helped provide a national voice for Canadian marine and ocean technology firms, which helps to synthesize and integrate different views in a coherent, timely, and cost-effective manner.

Industry-government coordination of the implementation process is needed if the opportunities identified in this roadmap are to be pursued and captured. This needs to be done quickly in order to capitalize on the recent convergence of regional players in the industry. Implementation, together with the realization of timely policy and program opportunities set out in *Canada's Innovation Strategy*, *Canada's Oceans Strategy* would help the industry immensely.

Regulatory streamlining (or Smart Regulations) is considered to be another highly effective way of encouraging commercialization of products and getting them to market. In addition to Smart Regulations, the development of technology clusters, through private sector leadership and government facilitation may help provide Canadian marine and ocean firms to capture a greater share of the growing export market for new ocean technologies.

The Way Ahead

The TRM Steering Committee has expressed these thoughts regarding the next steps or the way ahead for the roadmap.

> *While developing the TRM we were conscious of a key part of our mandate – ensuring that there is a transition plan to an implementation phase and that key findings are communicated to those who can make a difference. We did not want the TRM to end with the publication of the report.*
>
> *We have already taken several important actions to fulfill this objective. First, meetings were held with senior officials of a number of key federal departments. All these officials expressed a strong interest in the TRM, noted the synergies between the various sectors that make up this industry and indicated that they wanted to follow up on the recommendations. There was also recognition of a requirement to work together as the issues raised in the TRM cross departmental mandates. The recent establishment of a Deputy Minister Committee on Oceans, chaired by Dr Peter Harrison, is providing a focal point for a coordinated approach to the TRM results. We plan to meet with this Committee to present this report and request that they review and follow up on the recommendations.*

On November 21, 2002 the Industry Minister announced the creation of a Shipbuilding and Industrial Marine Advisory Committee (SIMAC). This Committee will be considering innovation and other issues that affect the development of many segments of the industry that we have covered in the TRM. Consequently, we plan to present this report to SIMAC and hand it over to them for follow-up. It turns out that six members of the TRM will sit as members of SIMAC. In that position they will be able to contribute to a discussion by SIMAC of the issues raised in the TRM and to make innovation a key component of a sector action plan for this industry.

We will also strike a small working group who will promote a broader transition strategy and follow up with key stakeholders in the federal government, the provinces and other organizations. The whole TRM committee looks forward to meeting annually to review progress on implementation and discuss any actions that may be required. In addition, a web site is being established to facilitate and encourage dialogue among stakeholders. This dialogue will be an important part of the TRM implementation phase.

The complete TRM report described in this Executive Summary is being distributed to the hundreds of individuals and organizations across Canada that provided information, ideas and comments during the development of the TRM. We have tried to incorporate this input, which contributes to the richness of the final document.

The TRM report is based on a rich quantity of data involving some 1200 ideas arrived at during workshops in ten cities involving approximately 250 participants, five meetings of a select thirty-member steering committee and two special sessions and other consultations with individuals and groups.

Coastal Community: Photo credit, DFO

EXECUTIVE SUMMARY

Canada is a maritime country. Eight provinces and three territories all border on salt water. Many pressures and demands are being placed on Canada's ocean and marine environment. Traditional sectors such as fishing, shipbuilding and water transportation are being joined by other uses including offshore oil and gas, aquaculture, recreational fishing, pleasure boating and eco-tourism. The marine and ocean industries contribute $20 billion annually to the Canadian economy and add up to 350,000 part time and full time jobs, especially in coastal communities.

The dynamics of the ocean economy have been changing rapidly. The application of science and technology to increase the productivity and success of ocean-related industries impacts on both the ocean economy and the social fabric of coastal communities. Technological innovation is an essential part of business success and leads to improved international competitiveness.

The oceans are becoming more important both economically and environmentally. A recent extension of national jurisdictions to Exclusive Economic Zones (EEZs) in coastal waters, the awareness of potential scientific and technological advances and the opportunity to commercialize on these ideas are giving rise to new marine economies, all of which make this roadmap necessary.

Vision

By the year 2012 Canada will become an internationally recognized center for marine and ocean industry technologies. This vision will be accomplished by building on current strengths, e.g., cold-water technologies, and by broadening these strengths, e.g., marine industrial supply to offshore oil and gas. A key part of this vision is to identify additional opportunities in niche technologies and services markets that can support the strategic use of Canada's oceans and make a significant contribution to Canada's economic and social objectives. These emerging and future technologies will find applications in the following market areas.

Shipbuilding: The overall vision is for the Canadian shipbuilding and industrial marine industry to make a strong recovery based on sustained domestic demand fueled primarily by diverse fleet replacement needs and a designed and made-in-Canada *Future Ship* as well as success in related component manufacturing.

The Canadian industry has expertise in Roll-on/ Roll-off (RoRo) ferry and cargo ships and is gaining expertise in industrial marine. A strong need exists for a renewed Great Lakes Shipping fleet. The development of RoRo ships offers a strong niche opportunity for technology investment and innovation. The Canadian Coast Guard also is planning to replace its current fleet over the next 10 years with modern ships. Opportunities may also exist for the Canadian Navy to similarly modernize or grow its existing fleet, which may benefit Canadian shipyards.

Offshore Oil and Gas: High-end modules used in offshore drilling and production vessels are being increasingly designed and fabricated in Canada over the next ten years. Offshore exploration and development activities are moving to deeper waters and near shore areas in the Arctic. In the future, Canadian firms will be doing more business with oil companies

Marine Operations: Advances in marine communications and the increasing integration of shipboard and onshore information systems are dramatically changing ship and port operations. These technologies are providing new product and service opportunities for Canadian companies worldwide. During the next ten years, emphasis in marine safety, transportation and port operations will be on increased security and safety, reduction of environmental impact and efficiency. Vessels and shore-based infrastructure will increasingly use intelligent systems to contribute to these aspects.

Technology can be applied to improve levels of service while reducing high fleet costs through improved communications, remote sensing, and appropriate, timely information. Technology can be applied to reduce downtime, improve port turn-around and assist in the early identification of problem ships.

Fishing and Aquaculture: The vision in this industry would see coastal communities making a strong comeback through balance and sustainability. This comeback would be based largely on success in aquaculture and shell fishing. The traditional fin-fish industry is achieving success by minimizing by-catch and through more selective fishing techniques. There is also potential for a substantial revival of the fin-fish industry through the application of new marine ecosystem-based management techniques. These include the use of advanced ecosystem modeling, the development and management of marine protected areas, and broadly based restoration activities.

Significant systems engineering improvements are being made in aquaculture technology including cages, feeding systems, electronic monitoring, fish health, fish food and reducing the negative environmental impacts.

Ocean Technologies: Over the next ten years, Canada should maintain its international reputation in ice research, sensors, instrumentation, multimedia real-time technologies and ocean engineering in harsh environments. Ocean mapping technology has allowed us to definitively map underwater territories of nation states and with the aid of undersea devices can add bathymetric and biometric information to the charting of the ocean deep.

A Canadian research platform on an international research ship, similar to the *Canadarm* on the International Space Station, should prove to be a viable venue to demonstrate these new technologies.

TRM Opportunities

The following opportunities were brought forward with such frequency by workshop participants that they represent items worthy of early consideration:

- A series of made-in-Canada *Future Ship* designs and fabrications for various regions of the country based on a proper assessment of domestic and potential international demands;
- Sub-sea and deepwater smart well technologies and delivery systems;
- Sub-sea scientific observatory systems;
- Marine ecosystem modeling;
- Ship technologies for ice-breaking, ice management and ice secure propulsion systems;
- Cold water/harsh environment safety technology;
- Hydrate research and development;
- Aquaculture systems engineering, i.e., a multidisciplinary approach to cage design and integrated materials handling;
- Development of technologies geared toward sustainability, protection and preservation of traditional fish stocks;
- Fin-fish and shell fish, health, toxicity and ecology;
- Vessel traffic management and automated identification;
- Ocean mapping and electronic charting demonstration projects;
- Marine fibre optic design and fabrication;
- Autonomous Underwater Vehicle (AUV) research;
- Virtual prototyping and simulation; and,
- Defence and security emphasis on ports and harbours.

This list of opportunities is enriched by over 1200 other ideas brought to the table during the ten workshops. Many entrepreneurs and developers will undoubtedly find market opportunities in ideas beyond the short list presented above.

Photo credit: Industry Canada

1. INTRODUCTION

Canada is a maritime country. Eight provinces and three territories all border on salt water. Numerous pressures and demands are being placed on Canada's ocean and marine environment. Traditional sectors such as fishing, shipbuilding and water transportation are being joined by other uses including offshore oil and gas, aquaculture, recreational fishing and eco-tourism. The marine and ocean industries contribute $20 billion annually to the Canadian economy and add up to 350,000 part time and full time jobs, especially in coastal communities. [1]

About seven million Canadians live in coastal communities, where many depend on the coast and the sea to make a living.[2] *Canada has the world's longest coastline. The 1996 Canadian Encyclopedia gives the length as 243,797km, including major island coastlines ... Stretched out as a single continuous line, Canada's coastline would circle the Earth more than six times.*[3]

The dynamics of the ocean economy has been changing rapidly. The application of science and technology to increase the productivity and success of ocean-related industries impacts on both the ocean economy and the social fabric of coastal communities. Innovation and technology are an essential part of business success and lead to improved international competitiveness.

The oceans are becoming more important both economically and environmentally. A recent extension of national jurisdictions to Exclusive Economic Zones (EEZs) in coastal waters, the awareness of potential scientific and technological advances and the opportunity to commercialize on these ideas are giving rise to new marine economies, all of which make this roadmap necessary.

The marine and ocean innovation system is far more complex than found in a traditional single industry. It contains elements along industry sector or technology lines (shipbuilding, aquaculture, marine electronics) but it also includes environmental management, information handling, regulatory, and defence responsibilities with specific institutional and knowledge requirements. This innovation system requires a substantial flow of knowledge and information about the natural environment. It also involves the development of routines among economic actors, to enable them to learn from natural capital; the coordination of activities across a wide range of jurisdictions and industries, and, the establishment of governance mechanisms that are sensitive to the many non-commercial and commercial needs of humans who use the coastal and marine environment. The marine and ocean innovation system's institutions for research,

[1] *Canada's Ocean Strategy*, Fisheries and Oceans Canada, 2002 and Statistics Canada special tabulations.
[2] *Canada's Oceans Strategy*, Fisheries and Oceans Canada, 2002
[3] Ibid

education, extension, and concerted action also must reflect this diversity of relations and actors.

The marine technology sector is a key component of what is a dynamic and rapidly developing and evolving set of activities, united by the fact that they take place on or under the sea. The increasingly sophisticated technology developments involved in all sectors of the maritime economy have challenged the ability of operators, enterprises and administrations to cope with state-of-the-art technology

Future global trends in respect to climate change, energy demand, trade, food production and sustainability impact on marine technologies and drive industry demand and innovation in these areas. Competitiveness in these industries arises not only from research and technological innovation but also from factors as management skills, entrepreneurship, marketing and 'vision'. The increasing complexity of marine and ocean technology requires that individual operators, businesses, and governments cooperate with each other and engage in joint projects.

2. CONTEXT

Marine **technology** discussed herein refers to the **application of science, technology and innovation to enable the development of the industry and its supporting infrastructure associated directly or indirectly with Canada's salt or fresh-water resources**. This broad definition must be distinguished from other industry drivers, which involve those sectors of the economy that provide the capital and human resources and the primary wealth creation. Industry drivers utilize products and services associated with the marine and ocean economy. They identify the markets for the marine and ocean industry in Canada and abroad. Industry drivers are consistent throughout the world as well as in Canada.

The industry drivers of the marine and ocean economy include the shipbuilding and industrial marine sector, offshore oil and gas, marine transport, ports development, fishing and aquaculture, marine recreation, security, safety and defence and various other ocean services.

Marine and ocean technologies cover a wide range of disciplines including communications, navigation systems, sensors, underwater vehicles, acoustics, engineering, biotechnology, nanotechnology, meteorology, optics, radar, etc.

The successful exploitation of available and emerging opportunities in the marine technology sector requires a multi-disciplinary approach involving many different technologies in key areas.

Table 1 - Some Key Technology Areas, Technologies and their Marine Applications

TECHNOLOGY	SAMPLE MARINE PRODUCT / SERVICE APPLICATIONS	SAMPLE USES
Acoustics	Remote sensing; sub-sea communications; sonar (sounders, side-scan, multibeam); bottom and sub-bottom profilers	Navigation; fishing; fisheries management; oil and gas exploration, development and production; ice and iceberg management; naval warfare; coastal zone management; oceans research
Biotechnology	Sensors; aquaculture species development; aquaculture feedstock development; pharmaceutical, neutraceutical, chemical identification and extraction from marine species; biofouling control; invasive species control; remediation of polluted areas	Aquaculture; environmental management; coastal zone management
Environmental engineering	Aquaculture systems design; pollution prevention / control systems; risk management	Aquaculture; coastal zone management; environmental management
Information and communications technology	Instrumentation / controls signal processing; systems integration; data acquisition, processing, modeling, display, and storage / retrieval; operations simulation; operations management; intelligent systems; automated systems; software applications / information services	ECS; AIS; VDR; seabed / sub-sea survey; and mapping; control systems / robotics / AUVs / ROVs; ship / fleet management; ports management; integrated ship / shore management; oceans research; business and entertainment; training
Materials and adhesives	Offshore systems design; aquaculture systems design; instrumentation	Offshore oil and gas exploration, development, and production; marine transportation; oceans research
Nanotechnology	Sensors and instrumentation	Fisheries management; aquaculture; oceans research
Naval architecture	Ship, tug and barge design, offshore systems design / modeling; fish harvesting systems design; recreation boating	Great Lakes transportation, marine transportation; fishing and marine recreation
Ocean & other engineering	Offshore systems design / modeling; ice and iceberg management; fish harvesting and processing systems design; aquaculture systems design	Offshore oil and gas exploration, development, and production; fishing; aquaculture; coastal zone management
Oceanography / meteorology	Offshore systems design / modeling; risk management	Offshore oil and gas exploration, development, and production; marine transportation; oceans research
Optics	Sensors	Fish processing
Radar	Remote sensing; hazard and target detection	Navigation; surveillance; naval warfare; coastal zone management

a. Trends

The marine economy is international by nature. Most countries are coastal states and use the oceans as a source of food and other resources, as a transportation medium and as a venue for trade. The global marine economy has grown recently mostly due to increasing trade liberalization efforts.

The global marine economy is estimated to be $1,100 billion Canadian in 2000. [4] The majority of this amount is associated with offshore oil and gas, shipping and naval activities.

The global marine economy is predicted to grow at an average annual compound growth rate of approximately 3% over the next ten years. The key growth areas are shipping and ports, marine recreation and leisure, offshore oil and gas, submarine cables, marine security, marine biotechnology, underwater vehicles, marine IT, marine services, and renewable energy.

In Canada, the marine and ocean industries contribute $20 billion annually to the Canadian economy and an estimated 350,000 jobs, especially in coastal communities. The marine and ocean sector accounts for approximately 2 percent of total economic activity in Canada. In coastal provinces this share is much higher.[5] Canadian marine and ocean industries account for an estimated 1 percent of the global market.

While Canada's expertise is in specialized areas, the marine and ocean economy has been growing overall at a rate faster than the overall economy. From 1992 to 2000, the Canadian ocean and marine sector grew at an average annual rate of 5 percent in real terms, after netting out inflation.

b. Transformation

It is the changing circumstances and requirements of the primary wealth generating marine sectors that create the needs and opportunities, which, in turn, drive innovation in the marine technology sector and the development of new products and services. The primary wealth generating sectors, therefore, provide the markets for the marine technology sector. Technological innovation may also create new opportunities for primary wealth producers to become more competitive in their operations and/or in their product / service offerings. This relationship is graphically depicted in Chart 1.

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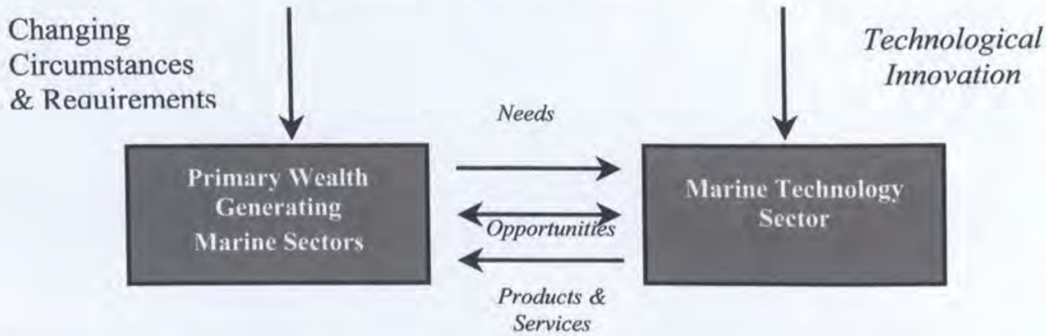
[4] Westwood, J., Parsons, B. & Rowley, W., (2002). *Global Ocean Markets*. The Hydrographic Journal, 103, 11-17.

[5] The statistical sources include Canada's *Ocean Strategy* and special tabulations by Statistics Canada.

Chart 1 – Modern Integrated Marine Economy



Marine and ocean industries, while distinct, are all part of a larger framework and are interdependent. Tied to Canada's oceans and connecting freshwater routes and especially dependent upon the St. Lawrence River and Seaway System, this interrelated set of economic and social institutions make up this industry. The TRM has endeavored to bring together this separate, yet integrated, community and to provide a **single voice** in order to address future technological challenges.

The TRM cuts across traditional sector boundaries. It embodies technologies that are key enablers in other industries including fuel cells, and nanotechnology. It also considers the work of the NRC's St. John's Ocean Technology Cluster development initiative.

Knowledge-based industrial clusters, similar to the St. John's Ocean Technology cluster potentially offer a high degree of synergy and cohesion amongst stakeholders working in a common industry or a set of industries that benefit from collaborative approaches between academia, scientists, government and business groups.

Successful clusters are based on the following factors:

- Access to, and usually interchanges with, university research, government research labs, non-government "think-tanks" and strong incubator initiatives;
- Strong social capital and collaborative networks where SME's, MNE's and industry champions can exchange "best practices" and collectively gain from practicing innovative management practices;
- Governments providing an investment and taxation environment suitable to generate growth;
- A strong post secondary education sector with an ability to grow skilled graduates and provide a research environment conducive to generate spin-off industries tied to university research and incubator initiatives;
- Well-developed municipal plans providing adequate hard and soft infrastructure for growth to occur; and

- Access to direct funded programs and other government support mechanisms and post secondary support from provincial government, federal granting councils and other initiatives.

c. Human Resources

The key HR challenges in the marine and ocean industry are to produce entry level workers that have the requisite skill sets to meet the requirements of knowledge-based industry; to produce sufficient numbers of managers that have the skills and experience to manage growth; to find incentives to attract managers and skilled workers to jobs in the coastal regions; and, to develop appropriate mechanisms to retain those workers who are contributing to the sector. [6]

Several marine industries and unions in Canada have flagged access to specialized human resources as a critical success factor. For example, the shipbuilding industry has called for HR policies and initiatives requiring collaboration between industry, unions, higher education, and government. Training is a critical issue for this industry to help workers learn how to operate new tools and equipment, to transfer existing knowledge from an aging labour force to younger unskilled workers and to introduce the latest information technologies to the work place. Training in many of these areas is already in place but there is an opportunity to better define the needs and review what is currently being offered to ensure that the needs of workers and industry are being met. [7] Some preliminary work in this area is being undertaken in relation to the TRM findings.

HR planning requires ongoing, close coordination between education and training institutions and industry. Aquaculture and shipbuilding are two industries that have recently diagnosed their HR and skills needs. The traditional concern in the shipbuilding and resource industries is with skills upgrading for ability to operate increasingly sophisticated equipment. To this concern now must be added an HR focus that ensures the development of business and management skills and the development of research and scientific skills to contribute to the marine and ocean sector's knowledge base.

d. Methodology

This *Special Report* has been prepared from the discussions and the research based on ideas taken from the regional workshops and information sessions. Over 1200 specific technologies relevant to the marine and ocean industries were discussed at these sessions. A relational database has been developed for these technologies and will be posted on the TRM website. A number of schematic

[6] See for example, Innova Quest (1999). Skills Needs in the Resource-based Sectors in Atlantic Canada. Report prepared for ACOA.
[7] Petroleum Industry Human Resource Commission (2001). Analysis of Gaps and Issues Related to Labour Supply and Demand in Offshore Exploration and Production in Canada.

charts representing specific opportunities spanning the next five to fifteen years have been prepared and included in this report. Other schematics will appear later on the website.

In addition to the TRM workshops and information sessions, a literature and Internet search has been carried out regarding specific technologies and all the market drivers of the marine and ocean industry. This research has led to a thematic discussion of the industry containing technology pathways and programmatic mission-oriented research proposals.

Finally, the paper presents a brief section on possible future opportunities that could be considered for development along actionable paths. These opportunities are congruent with the specific discussions from the workshops as well as the research. It is intended that specific opportunities for technology development in the marine and ocean industry will lead to direct action through government program support as well as direct investment and action by industry players.

3. VISION FOR THE MARINE AND OCEAN INDUSTRY

Canada is already recognized internationally as a strong niche player in marine industries, especially in some specialized areas such as cold-water technology. Strong communities of practice are taking shape in several coastal communities on the east and the west coasts. Synergies and strong social networks are necessary and will be evident between the private sector, academia and government research labs.

By the year 2012 Canada will become an internationally recognized center for marine and ocean industry technologies. This vision will be accomplished by building on current strengths, e.g., cold-water technologies, and by broadening these strengths, e.g., marine industrial supply to offshore oil and gas. A key part of this vision is to identify additional opportunities in niche technologies and services markets that can support the strategic use of Canada's oceans and make a significant contribution to Canada's economic and social objectives. These emerging and future technologies will find applications in the following market areas.

a. Shipbuilding and Industrial Marine

The Canadian Shipbuilding industry has a long and proud history that encompasses everything from the world's finest 19th century sailing schooners to modern world-class icebreakers. In between are a diverse group of vessels that have been designed and built in this country to serve our unique, expansive coastline and its network of coastal marine communities. This vessel history is primarily comprised of:

- *Canadian Patrol Frigate (CPF)*, which is a highly innovative ship on the leading edge of technology sponsored by the Canadian Navy in the 1980s and early 1990s, helped the shipbuilding industry in Canada to develop automation and systems integration skills that are world class.

- *Coastal transportation systems*; including tug and barge systems, self-propelled barges, ferries, and a limited number of coastal trading vessels

- *River transportation systems*; notably those on the Great lakes and St. Lawrence River which have high ice-going capability, and on the Mackenzie River system where extreme shallow draft capability is required

- *Icebreaker technology*; the development of oil and gas reserves in the Beaufort Sea in the 1970's led to the design and construction in Canada of the most advanced ice-breaking vessels of their type in the world

- *Great Lakes vessels*, the demands and constraints of the St. Lawrence Seaway creates a need for uniquely different vessel types

- *Special Service Craft*: The harsh and remote nature of the majority of Canada's coasts and marine environments creates a demand for patrol craft, search and rescue vessels, research vessels, supply vessels, Nav-Aids vessels and similar specialized workboats which are uniquely configured to Canadian operating conditions.

Photo credit, Industry Canada

The Canadian marine industry has for generations successfully provided the designs and built the ships which have ensured that our coastal communities and industries were provided with the supply lines necessary to continue their existence. In some instances the example of these vessels has led to demands for similar vessel types in other countries, although these opportunities have accrued more to the design community than to the shipbuilders.

It is important to note that in the past 30-40 years at least, many of these vessels were built under various programs of Government support and subsidy, including a National Shipbuilding Subsidy program that ran from the early '60's through the late '80's, and an Accelerated Capital Cost Allowance program which is still in effect. These programs resulted in major new-building initiatives, which effected the replacement of aging wooden vessel fleets in many arenas, and included the introduction of many new technologies in marine transportation. The net result was a renewed and more efficient fleet of vessels on all coasts of Canada, lower costs of transportation in many sectors of the industry, as well as a vigorous shipbuilding and marine equipment industry.

Despite periods of considerable domestic strength, since the Second World War the Canadian shipbuilding industry has never really been highly competitive on the international stage, especially for larger ships. Our labour costs are high relative to Asia, and the domestic market is not sufficiently large to sustain a level of production that could support the investment needed to compete internationally. As other countries with large skilled and low cost labour developed sophisticated methods and production technologies to improve productivity, many Canadian yards were left behind, building the few, usually one-off requirements of the domestic market.

Some Canadian firms however have invested in new production technologies and upgraded capital assets. Certain smaller shipyards, have managed to win competitive bids in selected international opportunities. Canadian yards contend that they are competitive with European and U.S. yards but face protectionism and foreign government incentives to support their industries. The major problem is market access.

Since about 1990, there has been an extremely low level of shipbuilding activity in this country. This is the consequence of the almost coincident occurrence of government spending cutbacks on new capital equipment, the end of the shipbuilding subsidy program, and the demise or major downturn of several marine-based industries, notably the east coast fishery, and the west coast forest industry. The result has been an all-time low in domestic demand, with the consequent loss of large numbers of the skilled workforce. More critically, there has been little incentive for new talent to enter this field.

The North American Free Trade Agreement (NAFTA) opened up duty-free access to the Canadian commercial shipbuilding market for all USA shipbuilders, without any reciprocity whatsoever. There are very limited opportunities for Canadian ship or boat builders to access that large neighboring market. Only the general lack of demand in Canada in the past decade and the low Canadian dollar have prevented a major influx of US built vessels into this country.

The completion of a number of shipbuilding programs in the late 1980s and early 1990s contributed to the reduced government expenditures. These capital programs including TRUMP, the Canadian Patrol Frigate Program and the Marine Coastal Defence Vessels Program (MCDV) provided $8.2 billion of government contract work in the 1980s and early 1990s. The completion of these major shipbuilding initiatives as well as reduced government contracts for refits and new construction of ships have had a major impact on the shipbuilding industry. As a consequence, the industry is restructuring, reducing net assets and rebounding to new markets such as oil and gas construction and repairing and refitting ships. However, the foreign competition is stiff and Canada provides a liberal foreign component environment, unlike a number of competitor countries.[8]

The 2001 federal government policy framework for the Canadian shipbuilding and marine industry is designed to increase business for Canadian shipyards.[9] One of the framework's initiatives is a Structured Financing Facility Program that provides interest rate buy-downs and/or credit insurance for domestic and foreign purchasers, lenders, lessees of Canadian built vessels and marine structures as well as for major vessel- refurbishment. Also, the policy framework will facilitate access by the shipbuilding and industrial marine industry to the Technology Partnerships Canada program. The latter enhanced access will evolve through the NRC/Industry Canada marine and ocean industry technology roadmap initiatives that will identify key marine technologies that may be eligible for TPC support. Shipbuilding utilizes considerable high technology applications and any substantial gain in Canadian production will provide substantial marine technology spin-offs. IRAP which complements the TPC program is a particular attractive option for smaller companies as it provides value-added advice and services including financial assistance, and access to publicly funded R&D which embrace the expertise of NRC scientists and engineers. The NRC expertise is available across the country.

The current situation therefore is one of a significant reduction in both plant and human resources in the industry, a limited source of demand for new construction, and an aging workforce with little incentive attracting new talented persons to the industry.

i. The Road Ahead

In spite of the generally grim current outlook, there are opportunities for optimism, and a potential resurrection for the industry. This is based on the real demands created by domestic fleet renewal requirements and the development of new market opportunities. These opportunities are discussed in more detail below.

[8] Based on discussions with Industry Canada.

[9] *A New Policy Framework for the Canadian Shipbuilding and Industrial Marine Industry, Focusing on Opportunities*, June 2001, Government of Canada.

Fleet Replacements

Since ships have a finite life, as long as any particular service has a continuing demand, then it is reasonable to expect that after about 30-35 years of continuous duty it will be more economic in the long term to replace a vessel than to repair it. Across the country there are entire fleets of vessels that ideally will fuel a demand for new construction over the next decade or so. These include:

B.C. Ferries

A significant portion of the BCFC fleet is over thirty years of age, and is in urgent need of replacement. BCFC have recently publicly announced their intention to build the following vessels within the next 10-12 years:

- Four 375-400 car new generation "C" Class ferries
- Three 110 car ferries
- Two 85 car ferries
- Five 60 car ferries

BC Coastal Towing Fleet

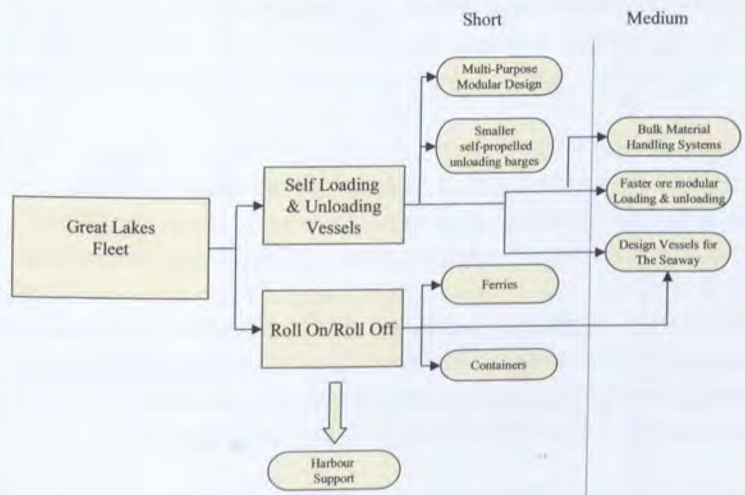
The west coast fleet of tugs and barges were predominantly built in the 1960's and 1970's, thus are largely over thirty years old. Demand for new vessels is much reduced at present due to the downturn of the forest industry, (the largest customer of the marine industry), but ultimately these vessels must be replaced, albeit in reduced numbers to the present day. However even a one-for-two or one-for three-replacement program would result in dozens of new vessels being built.

Great Lakes Fleet

The current fleet of "Lakers" is aging, and will likely be replaced by a new generation of vessels, the majority with self-unloading cargo-handling systems

Photo credit: St. Lawrence Seaway Authority

Chart 2: Great Lakes and Seaway Fleet



Arctic Fleet

The tug and barge fleet owned and operated by Northern Transportation Company Ltd. serves the entire Arctic coast. Many of these vessels were built in the 1960's and 1970's, and are due for upgrading or replacement to reflect either new route or service demands or simply to deal with the effects of age and damage.

Fishing Fleets

There has not been a major building program in the Canadian fishing fleet for many years, however the state of the fishery on both coasts is such that any significant number of new vessels is highly unlikely in the next decade at least.

DFO fleet

Government (non-military) vessels provide coastal patrol, search and rescue, fisheries and oceanographic research, fisheries patrol, ice-breaking, navigation aids maintenance and other related services in all territorial waters of the country. There was a hastily conceived program of accelerated vessel construction in the early 1980's, however many of the country's major service vessels were built in the 1960's and are due for replacement. In addition, many of the roles for which these vessels were built have changed, and new requirements such as domestic security have emerged as more critical. Certainly the need appears to exist for replacement and supplementary vessels, but funding has not recently been available.

Thus in total it can be seen that there is a significant opportunity for new vessel construction in the country. This fleet replacement should ideally be phased in strategically over a protracted period to ensure that there is a continuum of work for the existing yards, and that there is not a surge that simply drives up prices, thus enticing marginal service providers into the market.

Canadian Navy

The Canadian Navy has had a long and proud history contributing to Allied wartime forces and various peacemaking responsibilities over the past several decades. It has operated in most major theatres under all conditions.

The ability to maintain and repair naval vessels within Canada is considered to be vital elements to ensure the operational effectiveness and independence of the navy. Similarly, all Canadian vessels are to be procured, repaired and refitted in Canadian shipyards, providing a competitive process can be followed.

It is very expensive to design and build Canadian warships. There no longer exists the people or the infrastructure to do this work. It may be necessary for these ships to be common with and fully integrated with the United States fleet, or at the very least with other NATO vessels. In spite of past successes, there has never been a continuing demand to sustain a military shipbuilding industry in Canada. And there appears to be no expectation that there will be in the future.

Regarding its future requirements, the navy is developing an independent capacity to transport Canadian troops and equipment through building s multipurpose ship. This Afloat Logistics and Sealift Project (ALSC) will provide at-sea logistics support for naval ships and embarked helicopter detachments. This multipurpose ship will help the navy deliver military personal and equipment anywhere in the world accessible by sea. Other roles include aviation support, humanitarian crisis response and an at-sea headquarters command and control capability.

The ALSC ship is a one-off, probably billion-dollar ship. This same type of vessel already exists in the United States and it may be acquired there far more quickly than by building it in Canada, although our potential industrial and technological benefits associated with this initiative should not get overlooked.

Other navy priorities potentially impacting on the Canadian shipbuilding and repair industry include modernization of its Halifax class frigates and Victoria class submarines.[10]

[10] This discussion on the Canadian Navy is based on the report **Leadmark, the Navy's Strategy for 2020**, National Defence Canada, June 2001.

Other Opportunities

In addition to the demand for fleet replacements, there are some emerging new opportunities for the Canadian shipbuilding industry. These include requirements of the offshore oil industry in Atlantic Canada, namely offshore support and supply vessels, anchor-handling tugs, standby and rescue vessels, and crewboats.

Following the events of September 11, 2001 the notion of developing a small interceptor or protective/defense "class" or type of vessel similar to the old "Corvette Class" vessel has great appeal. Such a vessel could be "kit built" and could be of a totally Canadian "Future Ship" design. The vessel type could be designed for coastal defense, particularly in northern waters, and could be used to protect and police both the North American coastline, the Seaway and oil platforms on the continental shelf. The idea of developing this type of vessel has value in terms of immigration protection, search and rescue and counter terrorism measures reasoning.

The success of a "kit boat" depends largely on the availability of a successful and marketable design, which can be demonstrated to provide the end user with a cost advantage. The markets are usually third world countries that do not have the skills to do the designing and build planning that is offered through this approach. If this opportunity is to be effectively captured, it is important to identify what boats, what markets, and what Canadian industry bring to the table beyond just cutting the steel.

Some examples of "kit boating", also known as "collaborative production" or "work packaging" have been tested in the marine fishery production industry in Surabaya, Indonesia in conjunction with work done in British yards. This "soft technology" application benefits largely designers and naval architects and is prevalent particularly in Northern Europe, but there is no reason that a modified practice here could not be promoted here in Canada that would favour small yards prefabrication, as well as engage designers, and allow Canada to establish some sort of niche market. A Canadian experiment that did not realize completion, involving patrol boats and the Chilean Navy should perhaps be revisited so that we can learn and improve on our delivery success. The connection to the Chilean government remains intact and this side road still offers potential opportunities.

Environmental issues represent additional potential opportunities for the shipbuilding, shipping and related industries. For example, opening the Seaway to all season travel would expand the market for carriers and would also serve to reduce GHG emissions and contribute to Canada's Kyoto agreement commitments. Developing production for "green" marine propulsion systems (fuel cells or other energy-efficient means of energy) and moving more goods by improved water transport vehicles are also projects that could be brought forward.

At present, the industry is heavily engaged in Cruise Ship repair and, as a matter of fact, ship repair of all kinds. This effort is, in some corners, keeping the industry alive at the present moment. Because of our "cheaper dollar", the time availability in many of our shipyards and the proximity of many of our ports to major shipping lanes, we have had a comparative advantage in the repair work end of the industry. The advantage of engaging in repair and "topping off' work can be a lucrative, and even sustenance providing, shipbuilding activity and this niche should not be underestimated as a potential main highway or secondary path of action on the roadmap. It also serves as a ready and immediate stage for skills development. Cruise Ship repair, especially, can be seen as an alternative shipyard occupation... it is already being utilized as a support in some west coast yards. Building components such as industrial generators and generator barge production can also be a rewarding sideline for Canadian shipyards.

Research vessels will continue to be the backbone of marine science. However, interdisciplinary and international teamwork on board already requires a new generation of relatively large vessels with the capacity to accommodate more than twenty scientists at a time. These vessels should be equipped to handle heavy, yet delicate, tools. Smaller vessels will also be needed for work in coastal waters.[11]

Mission-specific research vessels are expensive, and the technologies incorporated in them change quickly. There is, therefore, a need for the development of a basic platform vessel that could be configured with modular mission-specific components to perform a variety of research tasks. This would indeed be a worthy Canadian "future ship" project with potentially strong market potential.

Other opportunities include:

Articulated Tug-Barge (ATB) systems; there is renewed interest in these specialized tug barge systems, particularly to replace bulk carriers on the Great Lakes.

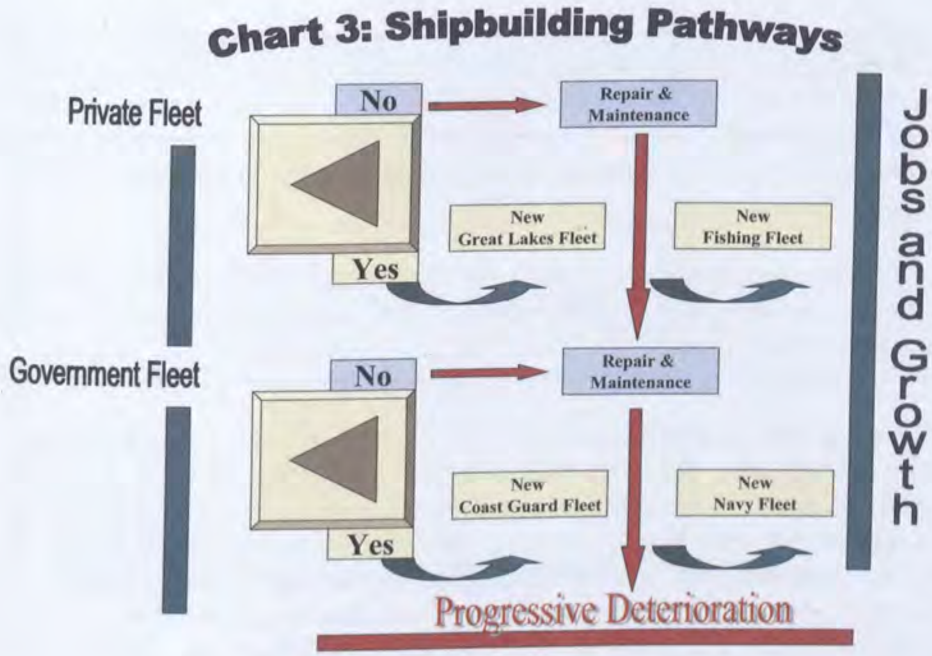
Patrol boats: Small craft such as these are almost the only vessel types which can be sold into the USA outside the "Jones Act", as these are not "engaged in maritime commerce". The Homeland Security thrust has created a huge near term demand for police and patrol vessels, and Canadian builders could be well placed to share in this market. In addition, there is likely to be a demand for similar vessels to patrol Canadian ports and waterways.

Ro-Ro Ferries: there has been some serious recent interest in developing medium to high-speed ferries for passenger/automobile service, or solely for commercial traffic across various routes on the Great Lakes. These would significantly reduce

[11] **Oceans 2020, Science, Trends and the Challenge of Sustainability**, Island Press, 2002

highway congestion in the adjacent highways systems in both Canada and the USA.

Tugs and similar workboats: this is the one area where Canadian shipyards have had some recent export success. Canadian shipyards have proven themselves competitive with yards in Europe and the USA in this currently busy market, with sales of at least 10 tugs in the past 6-7 years to Owners in Europe and Central America. There are indications that this market sector may continue strongly for at least a few years, but it is a highly competitive sector internationally.



Robert Allan Ltd. is an internationally renowned naval architectural firm based in Vancouver, British Columbia. The firm's experience includes designs for hundreds of vessels of almost all types, from small fishing vessels to ocean-going ferries. Robert Allan Ltd. is best known for its work in the fields of tug and barge transportation, ship-assist and escort tugs, fast patrol craft, fireboats and shallow water vessels.

ii. Future Technologies & Market Drivers

In order to establish a game plan for the Canadian Shipbuilding industry one must look realistically and pragmatically at what markets are reasonably accessible, at what potential those markets hold, and what will drive the buyers in those markets to purchase from a Canadian shipyard. It is also important to define what might be uniquely desirable about a Canadian-built vessel

Some smaller shipyards in this country have proven their capability to compete in both cost and quality on the international stage. Witness the recent sales of world-class tugs by the Irving Shipbuilding Group (East Isle Shipyard, P.E.I.) and Industries Ocean Inc. (Ile aux Coudres, Que.) to a variety of owners in Europe, Panama, and the Caribbean. These examples prove the potential for Canadian yards to compete in Europe and Central America with even the historically low cost builders of the U.S. Gulf Coast. The size of the Central American market however is not large, and competition into the European market is quite fierce. Any upward fluctuation from present exchange rates will likely impact our market access significantly.

> *East Isle Shipyards, Prince Edward Island's largest shipyard has recently been awarded a second contract for $15 million to build two more Canadian designed Tugs for the Panama Canal Authority. The contract was won over 18 competing countries. The shipyard has a strong reputation for state-of-the-art tug construction.*
>
> *The project has helped shape the skills of shipbuilders, electric crane operators, carpenters, electricians, engine fitters, machinists, maintenance workers, mobile equipment operators, pipe fitters, labourers and persons in other positions.*

There are many new technologies available to increase the productivity and profitability of shipyards. However by and large the investment in such things as robotics and advanced CAD/CAM systems demand large throughputs, and ideally repetitive runs of like vessels to produce a return on investment. These are not, in general, the characteristics of the Canadian shipbuilding industry, although shipyards will invest in new technology if they have market access. In spite of the limited opportunity to bid and win, some Canadian shipyards are investing in productivity enhancements.

Many countries with historically high skill levels in ship design and ship construction have high labour costs, and have consequently lost much of their building capability to low cost producers principally in the far east. Canada falls within this group of nations. However some companies, notably in Australia and in Europe have seen the potential to sell their design and planning skills by marketing "kit boats", which can then be assembled in locations of lower labour cost. This is most practical for small craft up to 25-30 metres in length. The components of the "kit" would at least include all the metal parts (steel or aluminum) for assembling the ship, and could also include all the machinery and outfitting components as well. Assembling the latter in Canada is not all that practical however as there is not a large base of marine industry manufacturers in this country. Nearly all engines, pumps etc are imported into Canada and resold through distributors, so there is little or no economic advantage in incurring these local markups for an offshore buyer.

Canadian firms offer considerable technical expertise in environmental monitoring, an issue which will be especially important to British Columbia, if their moratorium on offshore hydrocarbon exploration and development is lifted. Canadian shipyards are well positioned also to produce the components for offshore rigs and platforms that involve considerable Canadian value added and technical expertise. Normally the rig's shell will be produced in Korea or Japan and then floated to the site where the local country provides the critical components. It should be a challenge for Canadian yards to produce as much of the rig as possible here at home and Canadian firms to influence this process as much as possible.

Chart 4 discusses technologies used in the construction of ships and vessels over the short, medium and long-term time horizons.

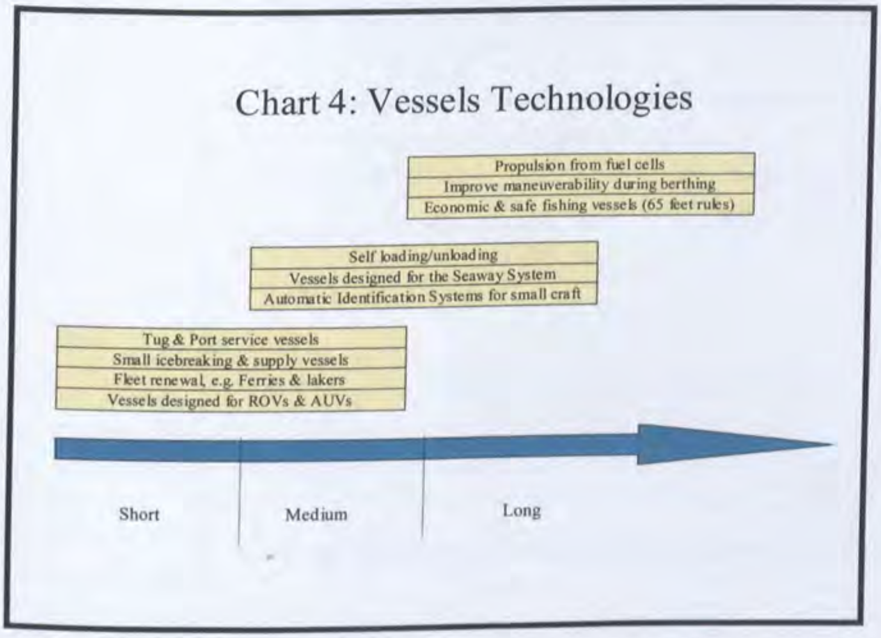


Table 2: Long term technologies used by the shipbuilding and industrial marine and industry

Shipbuilding and Industrial Marine
• CFER lab tested unique designs, e.g. honeycomb hull material cheaper than thick steel; other unique ideas, e.g. hull no stick coatings, water spray systems, bubble systems, etc. • Cost effective concrete/steel composite structures • Environmentally friendly anti-fouling paint • Vessels maneuverability improvement during berthing • New lighter, non-corrosive steel technologies • Propulsion opportunity for fuel cells in vessels and prime movers • Sensors for non-contact characterization of port bottoms or physical sampling:

Photo credit: Industry Canada

Chart 5 discusses the role of advanced materials and composites in shipbuilding and industrial marine.

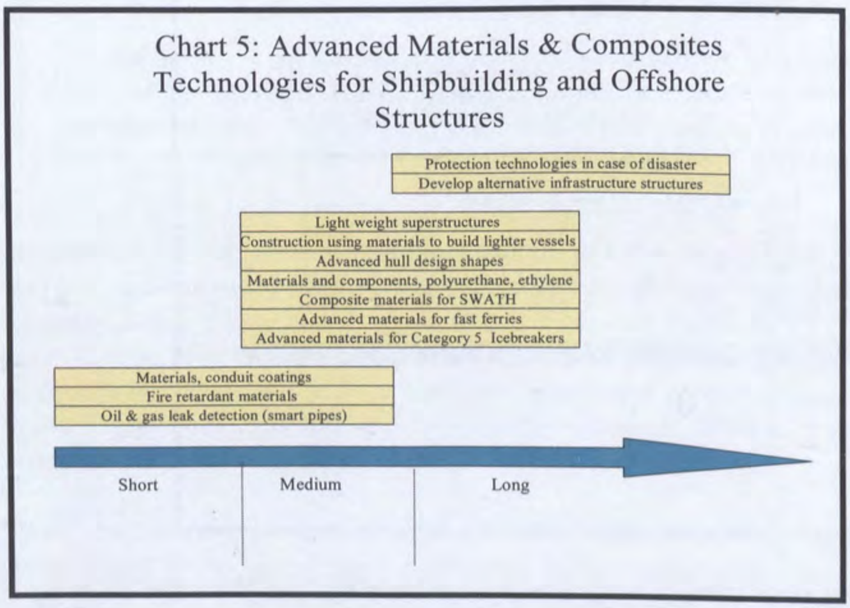
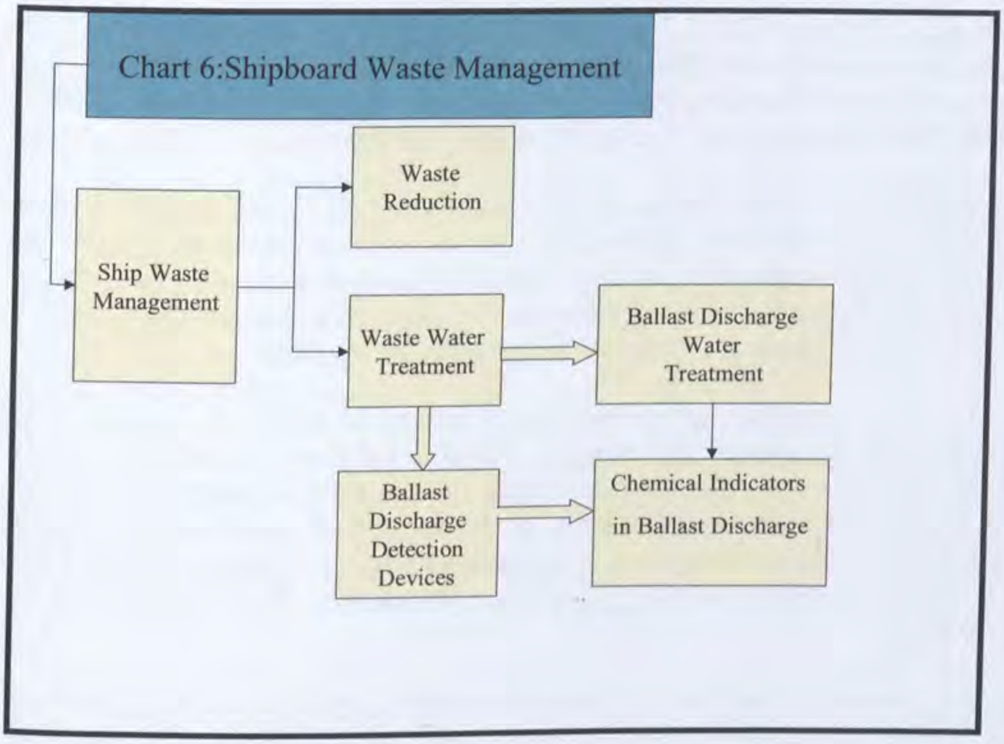


Chart 6 discusses specific technologies regarding shipboard waste management – part of an overall waste management initiative.



iii. Conclusion

An argument could, be made for a renewal of the Canadian Great Lakes Fleet, which would fix the Canadian vision on domestic improvement and have an immediate advantage. This activity would not necessarily be limited to Great Lakes yards, but could become a matter of national interest. Innovations in bulk carrier and tanker designs have largely centered on improved propulsion efficiency, safety, and protection of the environment, although new technologies have also emerged in cargo handling. In the latter field, one of the most interesting developments for bulkers is the self-discharging system, a concept developed on the Great Lakes decades ago and one, which is now being employed along the west coast of Canada. Elaborating on this theme could be a "Canada First" or "made-in-Canada" long-term goal/solution that would ensure the vibrancy of the industry for some time to come.

The objective here would be to develop and improve upon an already established technology advance, a self-discharger that incorporates hopper-shaped holds feeding into a sophisticated conveyor system that can lift and discharge dry bulks of all kinds over a slewing cargo boom. This could become a "Next Generation" Canadian vessel class over the next ten years. Developing its new and improved "systems" over the next three to five years could be both a design project and a research challenge. Fabrication techniques could be simultaneously developed, if not in hull production per se, then at least insofar as prefabrication of parts for a "kit" development process, Canadian developed modular assembly, and new systems development and systems integration. In the shorter term the industry could be kept vibrant through early work on prototypes demonstrated through design modeling and orchestrated repair and major retrofit work. Domestic and international work like this, which at present keeps the existing fleet afloat, could sustain the industry and add value to the technology process.

Similarly, the potential renewal of the Canadian Coast Guard and Navy fleets with modern ships designed and built in Canada would provide a strong stimulus to the Canadian shipbuilding industry. These alternative scenarios involving the renewal of both government and private sector fleets including ferries and fishing vessels would substantially benefit the Canadian shipbuilding industry.

The Canadian shipbuilding industry has a history of extensive capability and experience in the design and construction of specialized commercial vessels, generally smaller than 100metres in length. In this field our shipyards have for many years proven their capability to build world-class vessels, and have also recently proven their ability to compete on the international market for these types of vessels. *The industry should seek where best to market these same skills on the world stage.*

There is a latent demand for replacing large portions of the domestic fleet in the next decade or so. This represents a significant volume of work, and *it should be preserved exclusively for the Canadian industry, and phased in over a reasonable time period in order to sustain a sensible level of building competency on both coasts and in the Great Lakes.*

The greatest opportunity for export for Canadian shipyards lies in the market closest to us, namely the USA. At present this market is closed due to the "Jones Act", and the associated agreements included in NAFTA. This situation needs to be remedied. A dialogue between Canada and the United States on how to resolve this situation would be an important first step. These discussions should include both naval defence sharing arrangements and Canadian access to United States commercial markets.

A practical vision for the future of the Canadian Shipbuilding Industry would include a healthy, moderate-sized shipbuilding and repair industry, with capacity on both coasts and in the Great Lakes, all capable of supporting Canada's sovereignty claims to our coastlines, territorial waters and all maritime resources. This industry would have the capacity to provide all domestic commercial shipbuilding requirements, all military and commercial ship-repair capacity, and whatever additional export capacity the yards can garner through their own ingenuity and efforts.

Access to the USA commercial marine market would provide a far better opportunity for Canadian shipyards to sustain and to grow their capabilities than would be possible based on limited domestic demand alone.

A detailed future-oriented study of marine commerce in Canada would likely capture more precise information on the effect of the economy and economic choices on decision-making and technology development within the industry. Both shipbuilding and oil and gas futures are dependent upon "right choices" and an analysis of risk on the part of either industry or government. Studies such as these could add to, and continue, the dialogue initiated by the work done in this roadmap. This research could be undertaken as part the proposed Human Resources Sector Study. The transferability of skills, systems and technical ideas, processes and products across this sub-sector boundary are essential to the success of the industry as a whole over the next few years and will continue to be an important topic for discussion.

Even with continued facility modernization and improved labour force productivity, which are required for all nations to compete, our best option appears to be to seek out niche markets and to develop specialized techniques, processes and systems that can be sold both domestically and abroad, and to find ways to integrate Canada's shipbuilding strengths in these areas with those of the larger nation to our south.

The demands for services that can be provided by the shipbuilding and repair sector occur mainly in the development and early production phases. For example, production platforms, engineering and architectural design for development platforms and drilling rigs provides considerable opportunities for the Canadian shipbuilding industry. The Canadian industry, however, may wish to work collaboratively with others where the fabricated hulls or the raw platforms are concerned. There is considerable Canadian value added in providing components and high tech equipment and services to these development facilities. Major oil companies normally expect a large share of industrial benefits to come from local markets where offshore developments are occurring.

The refinement and reinforcement of this vision could be encouraged through a series of development projects which focus on existing strengths in the industry, and which provide opportunities to create new employment opportunities and growth in the industry. These include a "*future ship*" project in one or more geographic and technological sectors. Examples of such projects include:

- A modern self-unloading bulk carrier for the Great Lakes
- An ice-capable Offshore Supply Vessel (OSV) for east coast and Arctic oil exploration activities
- A new generation of energy efficient tug-barge systems for the west coast.

The present and future success of the shipbuilding industry is totally dependent upon having a long-term continuum of work. The new-building demands for replacement vessels in the Canadian marine industry are sufficient to ensure the health of the industry, provided any project which is supported in any way by Federal or Provincial monies or policies is required to be built in this country. If all these projects were built in Canadian Shipyards, then there is an ample supply of work to sustain a healthy and vigorous industry almost in perpetuity.

With a solid foundation of sustained domestic demand, the industry can invest in new plant and more cost-effective technologies, which will ultimately lead to an expansion of selective export opportunities.

With regard to this sub-sector, a second alternative suggested in a paper written for the TRM Steering Committee by one of its members, Robert Allan, should be fully discussed and considered as well by SIMAC.

> *The greatest potential market for Canadian shipyards remains the US domestic market, which has a very large demand for new workboats of all types, including tugs, towboats, barges, ferries and patrol craft. With Canadian labour rates at about 60% of their US counterparts, shipyards on both the east and west coasts could be extremely competitive. The problem at present is of course access to this market. As discussed previously, Canadian negotiators at NAFTA relinquished all rights to this potential market. What is needed is a viable strategy to gain access to this huge market, but it is obvious that something must be traded off for this access.*
>
> *The paper's recommended approach is to trade all future Canadian warship-building requirements to the USA, in exchange for a relaxation of the Jones Act for Canadian commercial shipbuilders.*
>
> *This would appear to be a win-win situation. At present Canada has no military shipbuilding capability. Further, our demand is so low as to make the periodic resurrection of this capability economically impractical. As our military capabilities and our total maritime defence are so intrinsically intertwined with those of the USA, it seems to make great sense in terms of commonality and compatibility to purchase all our* future warship requirements from US builders who have a very large maritime defense industry complex. In contrast, the small number and capacity of Canadian commercial shipyards represent a very limited threat to US commercial builders, but access to that market would provide significant opportunities for our shipyards.[12]

[12] Robert Allan, *A Personal Position Paper on the Draft Technology Roadmap Report, with a focus on the Shipbuilding Industry*, November 2002.

b. The Canadian Offshore Oil and Gas Industry

Except for the Persian Gulf, the world's oilfields are largely in the declining stage of their production cycle. Gross depletion levels or the annual decline in oil field output before being replenished by new discoveries, is declining globally by 10% annually. For oilfields outside the Persian Gulf, depletion levels are at least 20% a year. The International Energy Agency (IEA) forecast is that global production of crude oil must grow from 80 million barrels a day to 115 million barrels a day by 2020 if expected demand is to be met.[13]

In the continental United States, crude production has declined by about 35% since peaking in 1970. United States consumers are becoming more and more dependent on a handful of Persian Gulf producers.

There are perhaps two last frontiers in the search for giant oil fields: the Arctic and the continental slope at depths of 1000 to 3000m. ... But to find and extract hydrocarbons in these hostile environments requires extensive developments in both the supporting science and the operational technology, since many of the operations increasing take place on the seabed. Improved and more environmentally friendly exploration and drilling techniques are required, as are methods for decommissioning and disposing of old offshore platforms and facilities. Larger diameter and longer pipelines are needed, along with deep-water riser systems to circulate drilling mud from the drill platform to the borehole.[14]

Douglas Westwood Associates, a leading UK energy consultancy firm takes the view that growth in energy demand per capita will continue to outpace the oil industry's production capacity. It is argued that future oil demand will outpace population growth and that OPEC will be unable to produce sufficient quantities to keep up with demand, regardless of the price. The United States strategic reserves represents only one week of global consumption. Due to these considerable demand pressures, there is a lot of interest globally in new finds, non-conventional oil sources and renewable energy.

Recent technological changes in offshore oil exploration and production allows for drilling at previously unheard of depths. The offshore oilrig of the future will be able to reach 25,000 feet and can float safely over 4000 feet of treacherous waters. The future rig (as are many today) will be heavily instrumented and rely on computerized components, electronic chips safety and automation technologies. Currently, modern deep-water rigs are able to pump 115,000 barrels in a day and pay for themselves after three years. Deep water is the final frontier for the oil industry as essentially all of the large elephant discoveries on land have been made 20 years ago. The major oil companies believe that enormous amounts of oil are trapped under the ocean off Brazil, West Africa and in the Gulf of

[13] *World Marine Markets Developing a 25-Year View*, 2002 by Douglas Westwood Associates.
[14] **Oceans 2020, Science, Trends and the Challenge of Sustainability**, Island Press, 2002

Mexico. Deep water drilling and associated technological advances including subsea wellhead technologies and related opportunities therefore should be a major concern of the marine industry of the Canadian future.

Exploration and development of offshore oil and gas reserves off Newfoundland and Nova Scotia coasts has being going on for over thirty years. It is expected that this will continue for several decades to come, with half of Canada's oil supply likely to be coming from these fields by 2020. At present there are three east coast shallow water-operating fields and another two either under development or pending.

An estimated $55 billion is slated to be invested in offshore oil and gas exploration, development and operations over the next two decades. Even with oil and gas companies importing major components and systems, the spin-off benefits to the Canadian economy are substantial. Cold-water engineering, metal fabrication, transportation equipment, construction, third-party logistics providers, etc., benefit strongly from these offshore developments.[15]

While there are many areas which have yet to be fully explored and assessed on the Grand Banks, and other shallow waters generally less than 200 metres in deep such as the St. Pierre Bank, the industry is looking much further ahead to exploration and possible development in deeper waters over 1000 metres deep. Some of these areas such as the Cabot Strait and Canada's west coast oil reserves lie within Canada's Exclusive Economic Zone (EEZ) while other areas lie beyond the boundary of the EEZ but within the Continental Shelf (CS) region. There is pressure, therefore, for Canada to exercise its rights to the CS as provided under the Law of the Sea Convention so that there is a clear regulatory and cost-sharing regime in place.

[15] This figure of $55 billion may be conservative. It is based an the report prepared three years ago *Harnessing the Potential Atlantic Canada Oil and Gas Industry*, 1999 Sponsored by NOIA and OTANS. Strategic Concepts Inc prepared the report.

A list of current offshore oil and gas projects and milestones is identified in Table 2.

Table 2: East Coast Offshore Oil and Gas Projects[16]

Project	Start Up Date	Production	Corporate Ownership
Natural Gas			
Sable Offshore Energy Project	December, 1999	Tier I 510 million cubic feet per day natural gas NGLs: 22,000b/d Tier II 3 natural gas fields at 650mmcf/day; start up 2003-07	ExxonMobile Canada Shell Canada Imperial Oil Nova Scotia Resources Mosbacher Operating
Encana Corporation (DeepPanuke field off Nova Scotia)	2005	400 million cubic feet per day	Encana Corporation
Crude Oil			
Hibernia*	November 1997	200,000 b/d	ExxonMobile Canada Chevron Canada Resources Petro Canada Canada Hibernia Holding Murphy Oil Norsk Hydro
Terra Nova*	2002	135,000b/d	Petro Canada ExxonMobile Canada Husky Energy Murphy Oil Mosbacher Operating Chevron Canada Resources
White Rose*	2005	75-110,000 b/d	Husky Energy Petro-Canada
Hebron/BenNevis*	Not known		Chevron Canada Resources ExxonMobile Canada Petro-Canada Norsk Hydro
Petro-Canada		Exploration Activity: Flemish Pass, Salar Basin	
***Jeanne d'Arc Basin, Nfld.**			

16 Scotiabank Group, *Canada's New Energy Frontier – the East Coast Offshore*, March 1, 2001.

Photo credit: DFO

White Rose is located approximately 350 kilometres east of Newfoundland on the eastern edge of the Jeanne d'Arc Basin. The South White Rose oil pool covers approximately 40 square kilometres , with an estimated 230 million barrels of recoverable oil. The White Rose development is significantly smaller than the two previous oil and gas developments on the grand Banks – Hibernia and Terra Nova.

The South White Rose oil pool will require 19 to 21 wells and has a 15-year life. The production platform will be steel floating production, storage and offloading (FPSO) facility similar to what is being used for the Terra Nova Development. The subsea components for the floating platform consists of templates, manifold, flowlines, umbilicals and risers. Construction of the floating platform is being separated in two major components – the FPSO hull, being built in Asia and the topside equipment modules, likely to be mostly fabricated at the shipyard at Marystown, NF(Kiewit Offshore Services).

Natural gas will likely be Nova Scotia's largest export commodity surpassing forest products. With the development of the Deep Panuke field (400 mmcf1d) and the second tier of Sable Island (650 mmcf/d), exports will continue to grow especially to markets in New England. Technologies associated with this development such as the generation of electricity using natural gas powered turbines and all forms of related technologies will be of increasing interest in the near future.

On the Pacific west coast, industry awaits the outcome of the moratorium on offshore exploration.[17] The citizens and fishery of this region are very environmentally sensitive and vocal. Potential oil spills have a great and immediate impact, as they would be "pushed" to nearby shores by east traveling currents. Both the Federal and B.C. Governments are faced with striking "appropriate" balances between industrial development and the environment. Multi-jurisdictional concerns also exist between the Province, Canada and the United States including aboriginal land claims. Technologies in the environmental realm as well as processes and systems that address these social concerns need to be looked at by the industry.

Considerable gas exploration activity is taking place in the Yukon McKenzie Delta region and to a lesser extent in the Beaufort Sea. Exploration and development activity was in the $300 thousand range in 2001. Currently, the activity in the Delta occurs in the winter when the ground is frozen. Technical challenges on how to effectively operate large equipment in the muskeg during the summer months remains to be resolved.

Another area of opportunity in the Yukon pertains to large amounts of frozen gas hydrates that exist there in abundance. Challenges on how to effectively mine and work around these gas deposits, as well as package and transport the product once it is recovered, similarly remain to be resolved. Given the technical challenges to be surmounted over the next ten to fifteen years as well political instability in the Middle East, developing technologies to mine these gas deposits may prove to be the more expedient path down which to travel. It is believed that these solid forms of gas contain twice the amount of energy as is known to exist in all current fossil fuel finds.

ii. Future Technologies & Market Drivers

The extension of offshore exploration and development activities into such deep waters will require the adaptation of deep water technologies, procedures and support services used elsewhere in the world such as the Gulf of Mexico to North Atlantic conditions. These operations will also be much further offshore than present operations creating logistical challenges.

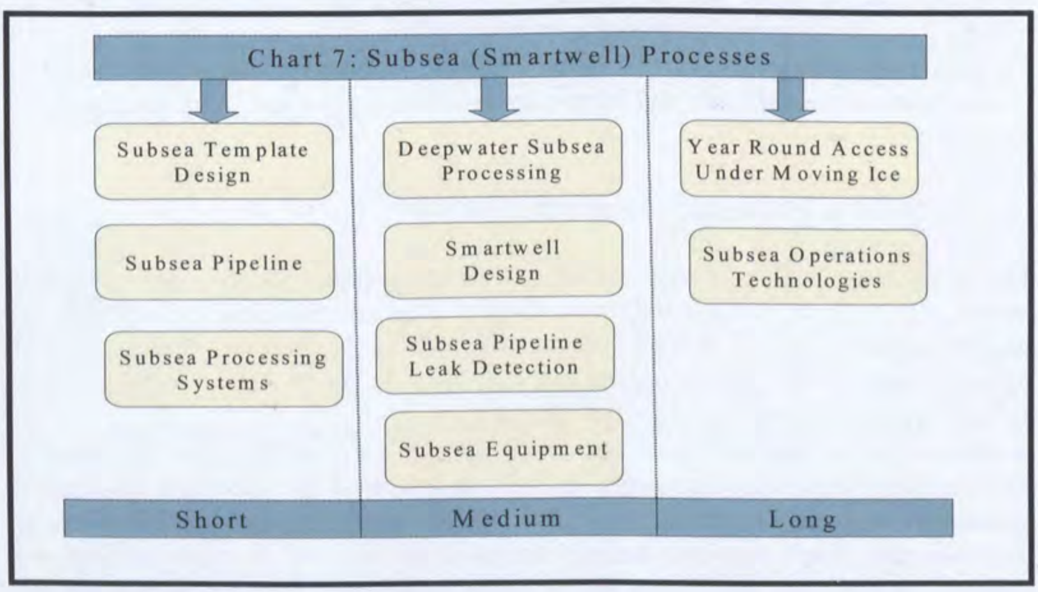
New technological developments in this sector will be required to support exploration and development in increasingly deeper water, marginal fields, and new frontiers, including the Arctic. Areas of focus will include drilling and production methods; anchoring and mooring systems; riser systems; large and longer multiphase sub-sea pipelines; remotely operated vehicle (ROV) and

[17] The moratorium is based on a policy and regulatory framework not to issue west coast exploration and drilling licenses and not by legislative governance or by a federal order in council.

autonomous underwater vehicle (AUV) design and operations; integrated onshore /offshore communications and control systems; maintenance and repair; decommissioning and disposal; down-hole and sub-sea processing; multi-branch well monitoring and control systems; extracting energy from gas hydrates; as well as improved environmental monitoring and modeling for design, operations and pollution mitigation.

White Rose Floating Production Platform
Photo credit: Husky Oil

Chart 7 discusses subsea technologies used in the offshore oil and gas industries.



Given the high value placed on marine and coastal ecosystems, and the sensitivity of the population to environmental issues, innovative approaches to pollution prevention and mitigation will likely be required before exploration and development can take place in earnest in British Columbia.

Global climate change can also be expected to have implications for exploration and development in the Arctic and elsewhere over the longer term. Thinning Arctic ice, rising sea levels, longer navigation seasons and milder weather can be expected to prompt renewed interest in finding and developing oil and gas reserves in the North and new navigation technologies elsewhere. This will present innovative challenges for the geomatics industry as discussed earlier but will also present new challenges for marine environmental protection. Arctic waters and coastal areas are extremely fragile and will likely become even more fragile with climate change impacts.

Robotics will play a much greater role in work in very deep water. Autonomous underwater vehicles (AUVs) are needed for deep-water site surveys for platforms and pipelines to cut costs and guarantee safe drilling. Remotely operated vehicles (ROVs) controlled via cables are similarly required to carry out complex tasks, such as rig testing in deep water.[18]

Table 4 below describes long-term technologies with a horizon beyond five years used in shipbuilding, industrial marine and the offshore oil and gas industries. All of these technologies are worth considering.

Table 4: Long term technologies used in offshore oil and gas industries

Offshore Oil and Gas
• Clean up & remediation; blowout management in broken ice: Oil containment needs modeling and test facility • Subsea technologies for operation • Prediction models/system integration • New technologies to reduce waste production • Harsh environment structures (big waves) • Transportation of hydrocarbons to market: Alternates to pipelines • Change form of energy • U/W transportation TM • Deepwater floating systems e.g. FPSOs, TLPs, SPAR, moorings • Construction new platform design • Adopt existing technologies for exploration in the Gulf of St. Lawrence • Oil spill & waster water prediction (AUV's, oil spill simulator/risk monitoring) • Availability of construction materials for support structures and roads: Develop alternate structures • Alternate exploration/detection technologies • Seismic on ice over water • Cost effective concrete/steel composite structures • Year round access/operation under moving ice: Subsea technologies for access • Deep water technology • Offshore support terminal (technology exists) • Requirements for relief wells: Develop alternate blowout prevention technology • Develop alternate control measures

[18] **Oceans 2020, Science, Trends and the Challenge of Sustainability**, Island Press, 2002

Offshore Oil and Gas
• New technologies to reduce requirements • Study of offshore permafrost • Offshore port infrastructure • Deepwater controls

Table 5 describes the specific commodities and services, many of them high tech, which are part and parcel of the offshore sector. For example, in the oil and gas offshore exploration stages, high tech services including geological expertise, geomatics and seismic surveys will be required. The demands for services that can be provided by the shipbuilding and repair sector occur mainly in the development and early production phases. For example, production platforms, engineering and architectural design for development platforms and drilling rigs provide considerable opportunity for the Canadian shipbuilding industry. Canadian industry, however, may plan to try to work collaboratively with major shipyards in other parts of the world where the hulls or the raw platforms are fabricated. There is considerable Canadian value added in providing components and high tech equipment and services to these development facilities. These activities, however, must be planned well in advance. Major oil companies normally expect a large share of industrial benefits to come from local markets where offshore developments are occurring. However, these same oil companies rely heavily on proven partners and their existing technology packages. Our job will be to try to convince them to deal with us or with us through their already tried and true partners.

Table 5: Technology, industrial benefits and offshore oil and gas activity

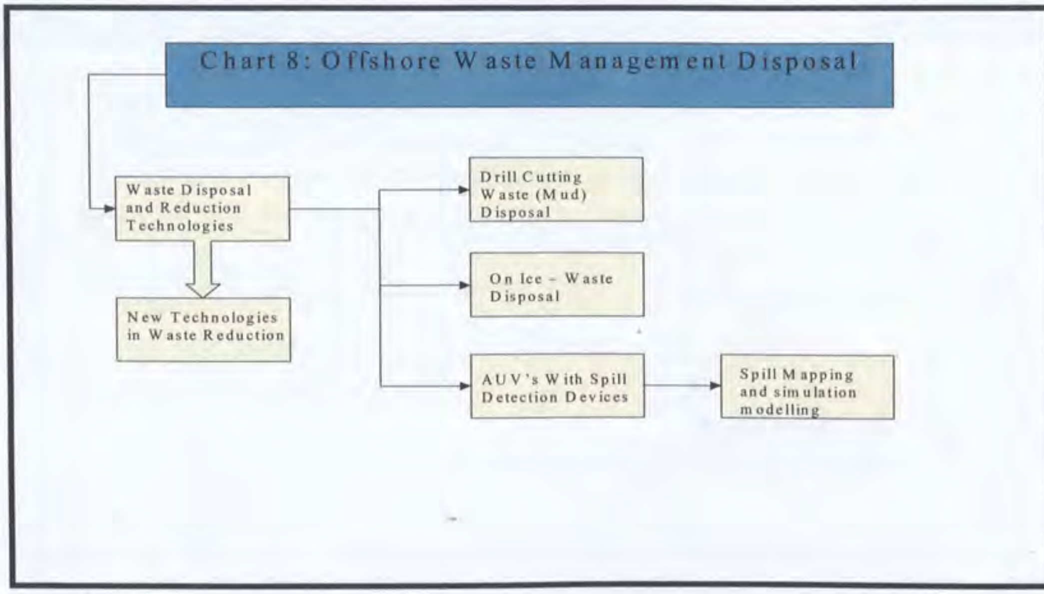
Exploration	*Development*	*Production*
• Geological & geophysical expertise • Drilling materials & services • Delineation drilling • Marine & air transportation services • Seismic surveys • Exploration drilling • Diving services • Drilling rig rentals	• Production platforms • Pipeline & flow lines • Subsea production facilities • Development drilling • Engineering & architectural design • Procurement • Construction & fabrication • Project management • Production & process equipment	• Offshore support vessels • Anchor handling tugs • Operations services • Crewboats • Tugs and barges • Engineering services • Helicopter services • Drilling services & supplies • Well completion services & supplies • Transportation & communications services • Shuttle tankers • Inspection, maintenance & repair services • Onshore supply services • Materials & supplies • Support services • Standby rescue vessels

The Marystown facility now owned by Kiewit Offshore Services is expected to play a major role in the White Rose project. Aker Maritime Kiewit Contractors (AMKC) was awarded the topsides fabrication contract for the White Rose floating production, storage and offloading vessel. They plan to build up to 60 per cent of the topsides modules in Marystown. This is part of a $400 million US contract. PKS is the majority partner. It is primarily responsible for fabrication and installation. And the Halifax Shipyard has also been busy with work on the Eirik Raude oil rig,, two new supply vessels, and ongoing repair and retrofit business.
The $400 million contract to construct the topsides for the White Rose offshore project will provide 2.7 million person hours of employment for local people in St. John's and Marystown.

Canada is engaged in research and development activities to enhance the safety and efficiency of offshore oil and gas operations off the east coast. This includes research on surface waves, winds, sea ice and icebergs, currents, ice structure interaction, seabed stability and basin assessment. These efforts have led to the development of novel instrumentation for sea ice observations; development observations; development of sea ice and iceberg forecast systems, and application of a model to assess the impact of drilling wastes on the marine environment.

In winter, sea ice that covers much of the continental shelf off the east coast poses a serious threat to safe navigation and offshore oil and gas development. Canada monitors sea ice drift and properties using global positioning system readings and in situ physical data from ice beacons to validate predictions from an ice-ocean forecast model. Measurements of ice thickness using a helicopter-borne electromagnetic system are also used to validate the interpretation of satellite imagery for the production of ice charts.

Chart 8 discusses specific technologies used in offshore waste management.



iii. Conclusion

The oil companies are well versed and comfortable with technical risks involved in offshore exploration and development. They prefer to use tried and true technologies and normally work with suppliers that are well known to them with long track records. The exploration and development process can involve considerable industrial benefits to both the local economies and firms in the more industrial provinces. As with most large energy projects, however, the industrial benefits are much greater during the development phase than when the production commences. Canadian firms as relative newcomers will have to prove their technological competencies early in the game.

Many larger oil companies are moving towards buying complete integrated packages where the design, procurement and build aspect of a project is completed as a system rather than purchasing isolated components. Canadian companies need to collaborate with larger players in order to be able to produce these integrated systems. The offshore oil and gas industry has been in business for over three decades. Major oil and gas companies have had considerable time to develop relationships with preferred suppliers. These suppliers are expected to be responsible for R&D related product development. A lot of the high technology developments in the offshore oil and gas sector have occurred in Europe by state oil companies. The challenges for Canadian firms to be able to realize the emerging opportunities are significant.[19]

[19] Douglas-Westwood Associates, UK *Marine Industries World Export Market Potential*, a report for the Foresight Marine Panel, October 2000.

c. Marine Operations

This section of the document discusses marine safety, communication, transport, recreation and port development.

Canada enjoys a reputation internationally as a stable country that has the capacity to deliver high quality marine products and services in certain niche markets. This reputation has been established based upon some world leading Canadian expertise in such technology areas as electronic charting, ocean mapping, satellite communications, ice forecasting, ice navigation, Arctic survival and simulation of special operations and training.

During the next ten years and beyond, our vision is that emphasis in marine safety, transportation and port operations will be on increased security and safety, reduction of environmental impact and improving efficiency. Vessels and shore-based infrastructure will increasingly use intelligent systems to contribute to these aspects. Technology will be developed and adopted to contribute to the ultimate goal of producing a marine transportation system that offers the mariner and those that use the sea, an environment that contributes to safe and efficient operations, as well as pollutant reductions. This technology will embody sensors, controls, information, interfaces, communications and software as well as new materials, designs and manufacturing processes.

The so-called future "Smart Ship" and "Intelligent Bridge" will mature. A smart ship must be able to access and provide the necessary information to support the decision-making of the ship's master. In addition, intelligence for owners and managers, and for shippers and port management, will be needed; all of which, will be interconnected. This will require systems that collect, transform, manage, communicate and integrate information where and when it is required.

i. The Road Ahead

In order to capture a significant portion of the international marine technology market, Canada must build upon its current expertise and continue to proactively develop the capability and capacity of the marine sector represented in industry, government and academia. This will require a commitment of both human and financial resources to the task of developing and maintaining Canada's role in marine technology development.

Canada however, needs to focus on the niche areas where it has specific leadership and expertise. It will not generally be able to compete in the broader arena against well-established global companies, with cost-effective manufacturing capacity.

Marine Transportation

Transportation of people and cargo by ferries, container ships, and bulk carriers is a mainstay of the shipping industry. Transportation of cargo by ship remains one of the most economical, energy efficient and pollution reduced means of transport over long hauls, and for certain cargoes it is the only practical method.

In 2001 there were in excess of 80,000 vessels over 99 tons operating in a transportation mode globally. Broken down this represents 18,473 Tankers (all types), 10,975 Bulk Carriers (all types) and 50,095 Dry Cargo / Passenger Vessels (all types).

While marine transportation is significant on a global scale, Canada's fleet is limited. The merchant flag fleet is defined as all self-propelled Canadian-flagged vessels of 1000 gross tons and over that carry cargo and passengers, excluding Canadian Coast Guard and Navy vessels. However, there are a very large number of smaller fishing vessels, auxiliary vessels and recreational craft operating in Canadian waters.

In 1957 the registered Canadian fleet numbered approximately 350 vessels. By 1998, the number had declined to 170 vessels. In addition, on average, the Canadian fleet is older than many of the world's other fleets. This limited domestic market means that Canadian suppliers and manufacturers must seek international markets and/or target the extensive recreational and fishing vessel markets and smaller vessels in general.

Canada's marine transportation environment comprises four unique operating areas each of which creates both problems and opportunities for development of improved systems:

- The east coast's ice covered and oil and gas filled oceans with access to Great Circle maritime routes to Europe;
- The west coast's resource-rich, eco-sensitive ocean playground with access to the Far East and natural North-South transits;
- The ice- covered Arctic with access to under sea and land based resources, polar routes and harsh environment; and,
- The Great Lakes - St. Lawrence Seaway System, which provides access from the heartland of North America to the world for ocean-going ships, as well as needed water resources for transportation, consumption, lock navigation, power generation, etc.

Canada has a very large RoRo passenger ferry fleet, an area where new regulations and technology are having an impact worldwide in the wake of major disasters. Most of Canada's fleet sail in domestic waters and this allows regulators to avoid international standards on occasion. Outside pressure, however, will likely result in Canada aligning itself with others in these areas.

The future will see black box voyage data recorders, improved life saving appliances, and enhanced training and certification requirements possibly making extended use of computer-based training and simulation absolutely necessary.

Marine Safety and Security

Globally, the prime consideration for the marine transportation sector is to deliver people and cargo from one location to another safely, efficiently, and on schedule. This sector is driven largely by commercial interests and therefore, any technology developed must demonstrate that it can significantly increase productivity, reduce cost, or improve safety before it can hope to be adopted. In addition to the commercial drivers, most of the vessels used there are also subject to mandated carriage requirements through international (SOLAS) or specific national regulations, and anticipating and addressing the needs of such regulations is key to the success of a commercially viable enterprise. Regulatory activity can also have a negative affect on technology development if not anticipated, as cited in many of the TRM workshops.

Canadian Coast Guard (CCG) vessels and crews regularly serve as a test base for Canadian marine products and research work. Examples include various shipboard information systems including Canadian ECS products, predictive maneuvering systems, and electronic communications. In many cases, CCG will also purchase and use Canadian products. This contribution is particularly important because of the limited opportunities to work with commercial fleets in Canada and the value placed by markets on such vetting.

Canadian Coast Guard Vessel
Photo credit: DFO Central & Arctic Region

Canada has an international reputation in marine safety issues as they relate to operation in ice-covered waters and is proactive in current update of international regulations for design, operations and certification of mariners involving operations in ice-covered and cold waters. Canadian opportunities that have resulted from this have included ice navigation simulators, iceberg detection radars and satellite imagery used for strategic and tactical navigation in ice and cold water rescue gear. The ARKTOS ice-capable evacuation system is now in use by several offshore development projects. Future initiatives in marine safety might include new evacuation and survival systems for ice-covered waters, improved high latitude communication systems, and the development of training courses for operators.

Having shown a lead in evacuation, escape and rescue the Canadian technology future may see the use of onboard simulations, and acoustic alarm systems for real time re-direction of passengers during emergencies as well as the emergence of improved life saving appliances. The integration of real-time weather information with operational decision-making for large and small vessels is another important trend where Canada has some leading-edge capability.

Each maritime nation has a responsibility to provide for safety, security, surveillance, and interdiction within the territory over which it expects to exercise sovereignty. The Navy and/or the Coast Guard of the respective countries jointly share this responsibility. Faced with dwindling budgets, governments seek ways to maintain levels of service with lower costs. Advanced satellite-based surveillance, autonomous (unmanned) interdiction vessels and Automatic Identification Systems (AIS) are emerging as potential technological advances in these markets.

In addition, navies and coast guards must also address quality of life issues as they attempt to attract appropriate personnel to a career that inherently requires long absences from home and family. This offers opportunities for improved communications (shipboard Internet and e-mail) products.

With marine safety comes the reduction in risk of polluting accidents. Canada has its share of eco-sensitive marine passages and harbours and there is a future in the development of the technology for improved vessel traffic management and control, as well as monitoring of discharges, treatment of ballast water, etc. Opportunities arise here in sensor development, data storage and analysis and in reporting.

Technology can be applied to improve the levels of service while reducing high fleet costs through improved communications, remote sensing, and appropriate, timely information. It can be used to reduce "down-time", improve port turn-around time and assist in the early identification of "problem ships" fostering their elimination from trading.

> *The Canadian Senate in September 2002 released a report on coastline security. The report concluded that Canada's coastlines are a terrorists dream, dotted with hundreds of tiny unpatrolled ports through which they could smuggle weapons of mass destruction.*
>
> *The Senate Panel recommended that the Canadian government should:*
>
> 1. *Adopt a timely warning system to notify authorities when vessels approach and leave Canadian waters;*
> 2. *Co-ordinate resources, including military, coast guard, intelligence and satellite to improve coastal monitoring; and*
> 3. *Co-ordinate efforts with US authorities, including establishments oj a joint planning group based with Norad in Colorado.*

Communications

Marine communications in its broadest sense covers all forms of information transfer, and related matters, and is a fundamental aspect of all of the marine sub-sectors discussed herein.

Currently, Inmarsat is the primary satellite communications carrier for vessels, largely due to its privileged position with respect to SOLAS convention regulations. Inmarsat will likely maintain a dominant role in marine satellite communications as it continues to expand its services and data rates including IP connectivity and packet switching rather than circuit switching. In fact Inmarsat is scheduled to launch a new set of I4 satellites in the near future that will provide data rates of 144kbps and integration with 3G cellular networks.

Inmarsat will not be without competition over the coming years. Other satellite systems have been proposed with global coverage and high data rates. To date, without exception, each system proposed and launched has been fraught with financial difficulties and has received less than projected uptake by the market, including Iridium and Globalstar. It is nonetheless possible that as technology improves, and the demand for high bandwidth applications at sea increases, another contender will provide satellite services for the marine market.

Recreational (Cruise and Pleasure) Craft

Canada's recreational marine market spans everything from sea kayaking to cruise ships. The market in small pleasure craft is very large domestically. The market for foreign flag cruise ships calling at Canadian ports and into the Great Lakes is expanding and forecasts after the event of September 11, 2001, are that it will increase. Many ports are expanding Cruise liner capacity and services.

Opportunities to develop products to address these markets exist. As an example, while many may view these craft as a new form of pollution, Bombardier's success with "Seadoos" is an example of our ability to address a particular niche in this market. The market forces drive the technology development here and there is little need for Government sponsored research except it may relate to regulation or control of emerging devices to ensure public safety and pollution control. Nevertheless, technology can be introduced at the recreational level to improve safety, navigation and communications. Technology employed in the recreational market ranges from the latest available equipment installed on cruise ships to a hand-held VHF radio or GPS that might be used by a kayaker.

Cruise ships operating in the pristine waters of the Queen Charlotte islands, the Arctic or the Great Lakes have to address the issues of pollution, in particular the requirements for handling ballast and other water discharges, and future "green ship" requirements that will be introduced by Canada. Opportunities exist for Canadian companies to develop water treatment systems, as well as monitoring systems for self and administration regulation of these discharges.

The future will also see improved cruise ship evacuation and people management systems, both shipboard and ashore, and Canadian simulation products are waiting to be developed to address these needs.

Ports and the St. Lawrence Seaway

The business of a port is to ensure that movement of goods and people on vessels is coordinated with other modes of transportation including trucks, trains, aircraft, and buses. There is a need to ensure that this is done so in a safe, environmentally friendly and efficient manner. Such coordination must be done efficiently to minimize the inter-modal transfer times and cost of the infrastructure. This cost is tied to the size and complexity of the process involved. Ports provide vessel traffic services to promote safe operations and must also respond to environmental conditions to prevent collisions and groundings.

Port-specific issues such as that of Placentia Bay, Newfoundland and Labrador, where tanker traffic has multiplied, can be addressed with existing tools and management processes, and risks can be reduced with improved traffic management systems, monitoring systems, etc. One of Canada's greatest shore-side marine infrastructures is the St. Lawrence Seaway.

Extended use of the Seaway through engineering for year- round operations is a goal to be sought after in order to reduce road-borne cargo particularly in the Montreal-Toronto Windsor corridor.

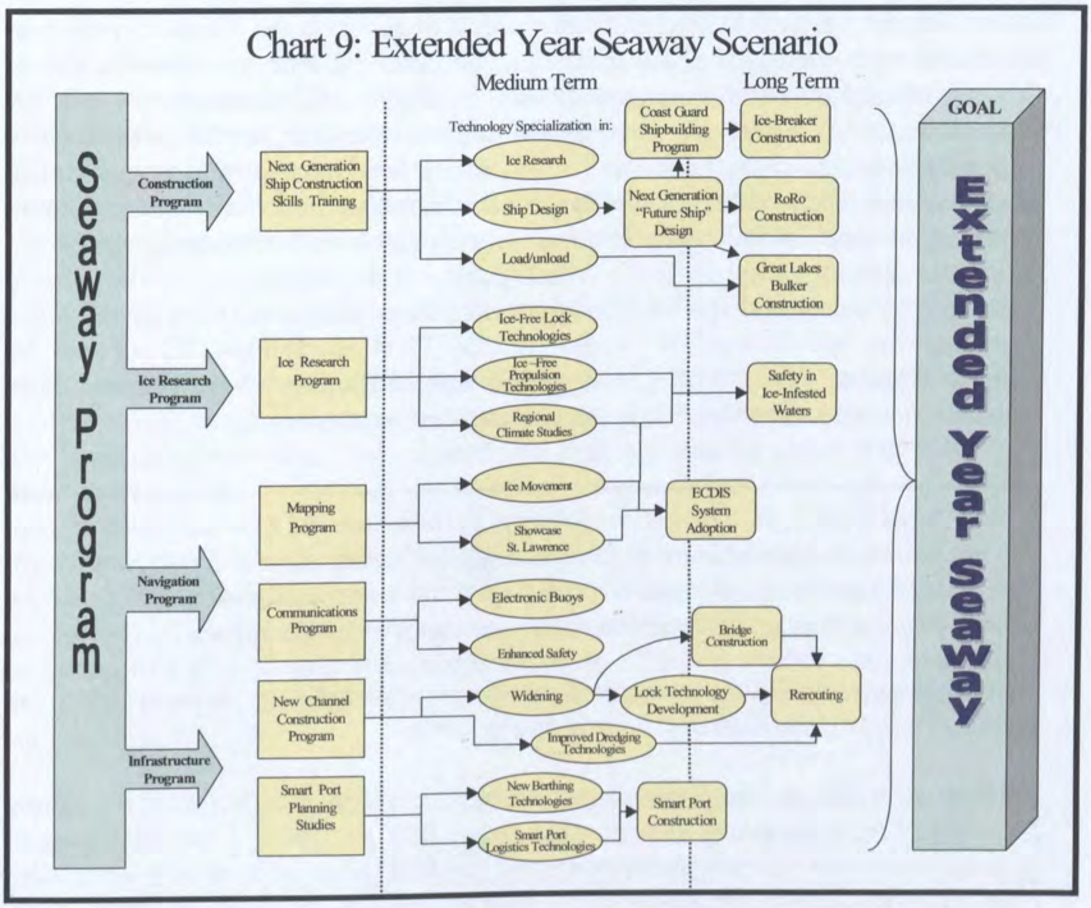


Photo credit: St. Lawrence Seaway Authority

The costs in terms of safety, road maintenance, energy use and pollution associated with increased truck traffic can be curtailed with an extended use of this marine transportation system that links the middle of Canada and US with the rest of the world. There are a number of relevant technologies for infrastructure design, vessel design and for navigation, water level control and vessel traffic management. Such areas as tug-barge combinations, improved efficiency and reliability at locks and alternate locking technologies can be explored. A proposal to initiate demonstration projects, which point out the advantages of navigation, water level control and traffic management systems for several navigable water systems, was put forward in several of the TRM workshops. "Showcase St. Lawrence and a "Placentia Bay Navigation and Traffic Study" are two examples of how roadmap workshops ideas have influenced industry interests.

The Great Lakes St. Lawrence Seaway System, since 1959 has been a vital waterborne transportation link for moving goods from central North America to and from international markets. The Seaway System extends 2,038 nautical miles encompassing the St. Lawrence River and five Great Lakes.

Every year, over 2000 commercial vessels move through the Seaway's locks to call on major Canadian and United States ports.

Maritime traffic on the Seaway uses much less energy and fuel than competing modes of transportation including railroads and trucking. Over one tonne of cargo can move over the Seaway system for 800 kilometres on only one gallon of fuel. The Seaway is highly cost-effective for moving mine products; steel, agricultural and heavy lift cargo to and from Europe.

Current efforts to quantify squat[20] and understand the effect of local weather on ice conditions or optimum routing in the St. Lawrence (Seaway and Gulf) could be combined to provide a real time rational speed limit regime that accounts for local water and weather conditions as well as specific ship attributes. With AIS in place, each ship could be given individual speed limits for sections of the waterway on a near real-time basis, and in many cases this might increase access speeds and allow faster passage. This idea combines a number of current technologies.

It has been shown, that improving infrastructure (such as roads) can reduce operating costs to private firms and make firms more productive. As Canada

[20] According to the Canadian Coast Guard, "squat refers to the increase of a ship's draught as a result of its motion through water. It is a hydraulic phenomenon whereby the water displaced creates an increase in current velocity past the moving hull causing a reduction in pressure resulting in a localized reduction of the water level and, consequently, in a settling of the vessel deeper in the water. For various reasons having to do with hull design, trim and other physical and operational factors, squat may be different at the fore and aft".

strives to increase productivity through innovation, infrastructure that allows for the efficient movement and transfer of cargo by marine transportation and is one area where government's leadership and authority can make a difference. Projects that take the form of public/private partnerships, private ownership or total public ownership need to be mounted in this area of technology development. The role of Government in the development of a suitable infrastructure is considered to be vital in this respect through leadership, regulatory activity and co-ordination.

ii. Future Technologies & Market Drivers

Information and communications technology will be a major part of Canada's marine sector development, contributing to all the developments that arise under the heading of marine safety, recreational boating, transportation and shore side infrastructure.

Communications is a fundamental element of infrastructure whether on shore or at sea. It improves efficiencies and is an essential element of safe operations. The safety and efficiency of operations at sea in the future will be realized through the enhancement of data communications services. Current marine communications technology is provided involving a range of radio services including HF, VHF, and satellite.

Looking to the future, only satellite communications can provide for the substantial increase in data throughput and coverage required to make giant strides in the business of operating a vessel at sea. Unfortunately, the high bandwidth and global coverage that satellite communications provides also carries with it a high and prohibitive cost. Nonetheless, the cost of satellite communications equipment can be seen to be dropping and it is possible that with continued competitive pressure, the connect charges also will drop to a point where this service will be more attractive as a communications option.

Communications and data transfer are a key part of port operations, designed to smooth the programming of vessels and their cargoes, ensure safety during maneuvering, etc. E-business has a major role to play in improving the efficiency of multi-modal and intra-modal operations through electronic logistics, and the automation of much of the current paper trail associated with shipping. International players are developing technology in this area, but Canada has the basis for some niche market products that specifically address Canadian shipping product patterns and infrastructure. The Port of Saint John with the New Brunswick E-Commerce Institute and a new e-business cluster is a perfect test-bed for such experimentation.

Breakthroughs in everything from automated docking systems, which "capture" the vessel and haul it safely to the dock and keep it there, have the potential to replace tugs and mooring lines in confined harbours and allow better usage of wharfage. These systems increase speed, safety, accuracy and reduce need for additional resources. Novel ship designs to assist with intermodal transfer of cargo can be developed. Also issues such as environmental, ballast water treatment and "green ships" impact on ports and their technology improvements.

Table 6: Some long-term technologies in the marine safety, communications, transport, recreation and port development industries are described below.

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	***Marine Transport***
• Oil spill containment or emulsion	• Non-toxic bottom paint
• Large load scanning	• AUV's long range
• Ocean surveillance technology (remote radar, underwater acoustics)	• St. Lawrence Seaway is open the entire year
• Sensors on cranes loading ships -	• Develop tools and equipment to reduce costs
• Side scanners, multi-beam – visualization	• Non-toxic bottom paint
• Bathymetric mapping and classification of St. Lawrence beds for submarine routes and for installation of mines	• Antifouling
• Oil spill containment or emulsion	• Discharges from ballast, bilges, waste water and organisms
• Specialized shipboard environmental protection technologies in case of disaster (oil, chemical, hazardous materials)	• Coherent radar for detection & tracking of small objects such as a person in water
• Review of regulations updated on the basis of new technology	• Remote operation (operational sensors, control technologies, communications)
• New technology for security standards	
• Renewal of coast guard/fleet solutions	
Port Development	***Marine Recreation***
• Harbour bottom clean-up	• Non-toxic bottom paint
• Improve docking and mooring facilities	• Marine parks, marinas, diving parks
• Improve the management of contaminated bottom sediment	• Non-toxic bottom paint
• Cost effective concrete/steel composite structures	• Electrical or environmental propulsion for small craft:
• Offshore support terminals (see oil & gas)	• Toys - the next seadoo, U/W gliders
• Floating offshore base	
• Cost effective concrete/steel composite structures	
• Saint John "Smart Port" development	

Chart 10 discusses automation technologies that are relevant over the short, medium and long-term horizon. Many of the automation technologies have relevance to this section of the document on Marine Operations. Others are more general and apply to the larger marine and ocean technology industry.

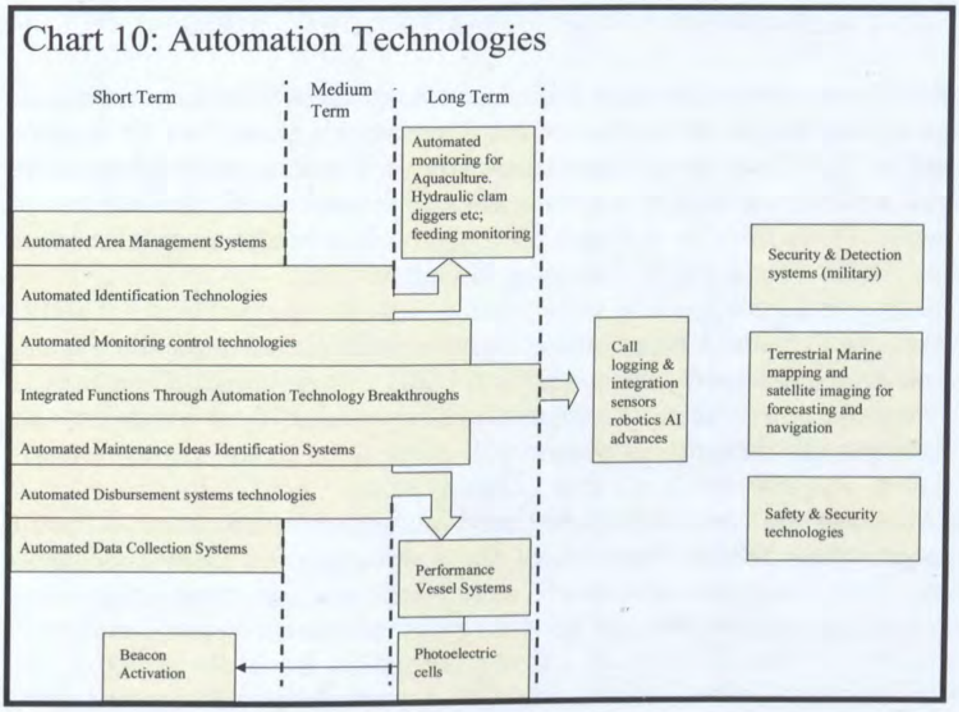
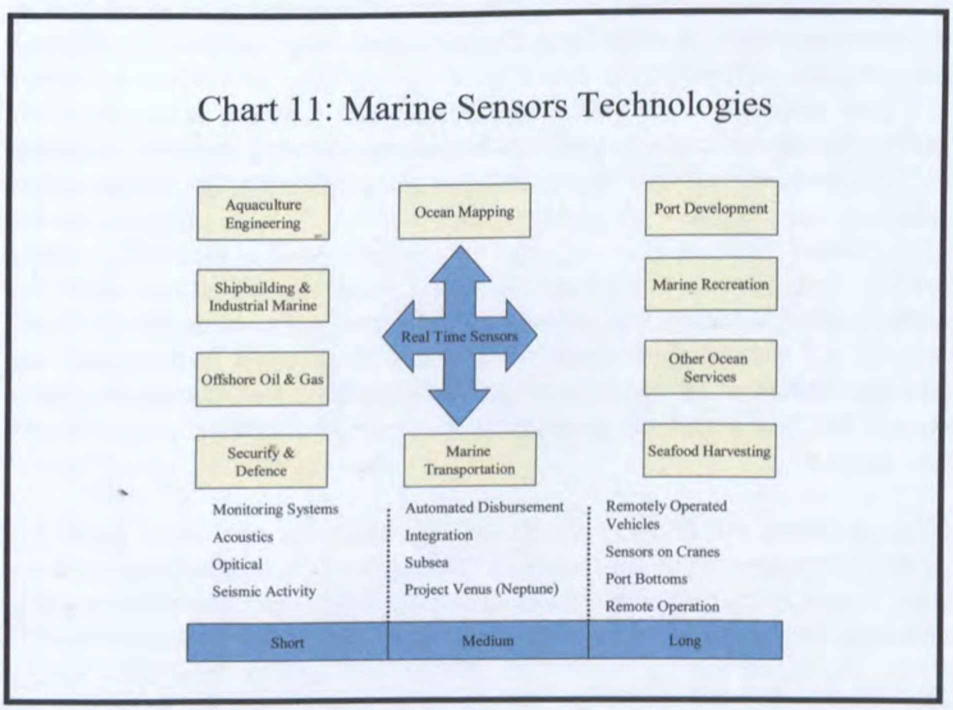


Chart 11 discusses marine sensor technology opportunities.



iii. Conclusion

The marine transport sector is much less of a driver of innovation than it once was due to an overall decline in the size of the Canadian merchant fleet. In fact, the small size of the Canadian merchant fleet acts as a serious impediment to the considerable number of marine technology Canadian companies focused on this global sector. These firms do not have a strong domestic market to provide initial sales and cash flow from which to develop foreign markets.

For progress to be made in this theme area, new initiatives and priorities must be focused on a few, potentially successful and highly rewarding technology areas, rather than proposing a "shotgun" approach of vague ideas from which it would be impossible to develop specific programs.

For the east coast the ideas might be focused on the marine transportation sector as it supports the offshore - particularly the deep water and ice-infested water scenarios. This might emphasize communications for forecasting, data transmission, telemedicine, etc, and harsh weather safety and rescue technology.

For the west coast, its market direction may be associated with technology to reduce environmental impact of cruise ships and recreational boating as well as toward safety in the fishing and small boat fleets.

For the ice-covered Arctic, a market niche is clearly the continued development of Canada's knowledge of safe operations in ice-covered waters including shipping, safety and survival.

Technological innovations of this kind can be viewed as being regional, however, those technologies associated with particular regions often apply equally across all regions.

In Canada, the progression of global warming should be studied carefully. We may see new opportunities as the nature of ice-covered water changes – offering the possibility of increased hazards on the east coast that will require our scientific attention, while providing an opportunity for extended season navigation in the North and the possibility of year-round navigation on the St. Lawrence Seaway.

For the Great Lakes and Seaway the issues are extended operations involving vessel size and season length. Intra-modal developments to attract goods off the roads and railways are also involved here. Pollution abatement principally required because of careless ballast water exchange must also be considered. In addition, an argument can be made that global warming is associated with a continuing trend to lower water levels which could have an impact on the volume and the profitability of shipping.

d. Fish Capture, Seafood Harvesting and Aquaculture

The global capture fishing effort has steadily grown over the past several decades in response to growing demand for fish both as a staple and, in some instances, as a high-value food source. There is increasing concern, however, that fish stocks may not be able to sustain this accelerated growth or even allow us to maintain current fishing levels.

While the world demand for fish is expected to increase for the foreseeable future due primarily to population growth and increasing per capita income, the potential for capture fisheries growth is finite. The FAO[21] reports that approximately 75 percent of the world's fishing areas are at their maximum potential for capture fisheries production or are to some degree overexploited or even depleted. There is an excess of fishing capacity globally and some technologies, which enable fishers to indiscriminately capture more fish, only exacerbate the situation. Most of the opportunities for growth are in under exploited or moderately exploited areas of the East Indian and West Central Pacific Oceans.

The FAO[22] predicts that total world demand for fish will grow by 9% to 20% by 2010 from its 1999 level of about 125 million tonnes driven mostly by increasing demand for food fish. Production from capture fisheries has been fairly constant at between 91 and 94 million tonnes over the period from 1994 to 1999 (except for a significant decline in 1998 due to El Ninõ). Aquaculture production over this period grew by about 58%, however, and continued high growth rates are anticipated, although perhaps not at this level. The ability of capture fisheries to contribute to anticipated growth in demand will, therefore, depend on further development of under exploited and moderately exploited areas and also on the effectiveness of fisheries management. Improved management of currently overfished stocks could provide an increase of between 5 and 10 million tonnes, whereas continued practices will likely lead to declining production. Most of the required increase in fish production is expected to come from aquaculture.[23]

Due to a dramatic decline in groundfish stocks, especially cod, the wild fishery on the east coast of Canada has changed radically over the past decade. The major decline in groundfish landings has been largely offset by increased landings of other species, particularly shellfish such as scallops, shrimp, crabs and lobster, which have a high market value.

[21] FAO (2000). *State of the World Fisheries and Aquaculture 2000*, Part 3 – Highlights of Special FAO Studies, The Economic Viability of Marine Capture Fisheries. Retrieved 29 May 2002 from *http://www.fao.org/DOCREP/003/X8002E/x8002e06.htm#P5*.

[22] Wikstrom, U. (2001). *Global perspective: Future Demand, Supply and Consumption of Fish and Shellfish*, FAO Rome. Presented at the ASEAN Millennium Conference on Sustainable Fisheries, Bangkok, November 2001.

[23] *FAO (2000). Projection of World Fishery Production in 2010.* Retrieved 29 May 2002 from *http://www.fao.org/fi/highligh/2010.asp*

Major fish harvesting companies in collaboration with government have put considerable effort into improving fishing techniques to reduce by-catch of threatened species. Fish processors have also focused on producing more and higher value-added products, frequently using imported fish where their own sources are no-longer adequate. These changes in the fishing industry have been accompanied by major upheavals in the socio-economic infrastructure in affected areas, which have strengthened some communities and led to the demise of others.

While there has been a ten-year moratorium on codfish harvesting, stocks have not rebuilt at the rate that was anticipated or to a level that would allow the moratorium to be lifted. Other groundfish fisheries have had various forms of restrictions placed upon them and in some instances there are significant positive signs of stock recovery. The impact on wild stocks from international fisheries just outside Canada's EEZ remains a strong concern for the future recovery of these fisheries. Overall, therefore, there is still a large degree of uncertainty about if, to what degree, and when groundfish stocks will recover which in turn is negatively impacting business decision making.

While the emphasis on shellfish harvesting is anticipated to continue into the foreseeable future, there is also some doubt about the long-term biological limits to such fisheries and their sustainability. There is some concern, for example, that the demise of cod and other groundfish stocks as well as the increase in some shellfish species are associated with lower water temperatures, which may revert over time.

There are strong drivers for innovation and adjustments that will mitigate the risks involved in the capture fishery and bring greater stability and growth to the fishing industry. The key players from the industry are already addressing this from a structural and innovation standpoint by trying to bring industry fishing capacity in balance with current resource carrying capacity. In addition, there is a need to better understand the underlying science behind variations in stock abundance from which better fisheries management and innovation practices can be developed resulting in more abundant and sustainable fisheries. While significant progress has been made, more research needs to be done utilizing new approaches and applying new technologies.

Other key drivers of change in the fisheries sector are marine pollution and global climate change. The correlation between these factors and the health of fish stocks are not fully understood, however, there is empirical evidence to suggest that both are having some degree of negative impact on world fish stocks. The changing ecosystem may affect the availability of food supplies and support the invasion of competitive species. In some cases, these impacts may even be positive.

Aquaculture, or the farming of aquatic species for food and other uses, has become increasingly important in many areas of the world including Canada in recent years. It is one of the fastest growing segments of the entire marine sector. The great attraction of the aquaculture industry is that it can provide high quality protein at much less cost, energy input, and generally less negative environmental impacts than other sources of protein such as beef and pork. Another reason for the growth of aquaculture is the increasing use of multiple aquatic species – both animals and plants – as a source of new pharmaceuticals, nutraceuticals, and other important biological materials. This aspect of aquaculture is much less developed as science has only begun to explore the different marine materials available, their nature, and potential uses.

To date, much of the technology development focus in this area has been on extraction of useful materials from wild stock or by-product as opposed to actually growing dedicated stocks for such purposes. This is, however, expected to change as more, and increasingly valuable applications, are discovered, especially those involving rare or difficult to obtain species. This changeover will occur when it becomes more economic to grow the source stock rather than harvest it from the wild. Aquaculture is also attractive because it is suited to, or adaptable to, a wide range of species in many different environments. It is, therefore, an area with very great growth potential from a market perspective.

In Canada, aquaculture activity is primarily focused at present on Pacific and Atlantic coasts with some modest freshwater aquaculture in other parts of the country. Aquaculture activities are generally distinguished on the basis of three categories:

- Fin fish e.g. salmon, trout, cod;
- Shellfish e.g. scallops, mussels, clams, oysters; and,
- Seaweed.

Heritage Salmon Company was created in 1991. Heritage is a wholly owned subsidiary of George Weston Limited, one of North America's largest food processing and distribution companies. Heritage currently successfully operates Canadian hatcheries, ocean pens and state of the art processing plants in the waters off Northern Vancouver Island in British Columbia and the Bay of Fundy in New Brunswick.

Heritage is involved in all aspects of salmon culture. Heritage Aquaculture, a related company, is an international group of business units focused on the production of aquaculture products for Heritage Salmon Inc. With over 50 fresh and saltwater production facilities on line, Heritage Aquaculture is involved in marine aquaculture feed supply, marine farming, broodstock production and salmon processing.

i. The Road Ahead

In aquaculture, a tremendous amount of innovation is required for a successful fish farming operation. The industry is attempting to accomplish in 30 to 40 years what it took the land-based agriculture sector some 300 to 400 years to accomplish. Each phase of the domestication and cultivation process presents numerous innovation opportunities and challenges. Aquaculture is part of the continuum that includes culture-based fisheries (enhancement and sea ranching), fisheries-based culture (live catch and grow out) and full-cycle culture.

There a need for much innovation on a number of fronts to widen the range of viable aquaculture species suited to Canadian waters. This would increase the long term growth potential for the industry, open whole new geographic areas to development, and create much needed jobs particularly in rural and Northern areas. Given the declining availability of wild fish stocks worldwide, the availability of fishmeals and oils potentially provides serious limitations, which may in time affect the growth of the industry, or its present-day economics. The need for alternative feed sources offers Canadians a multi-billion dollar opportunity. Some research and development work aimed at developing fish feed based on Canadian grain is already proceeding in British Columbia. Other approaches could involve harvesting baitfish for feed in the fish farms. Perhaps countries could enter into bilateral agreements on sustainable development of these fisheries using innovative management practices such as those offered through culture-based fisheries. This avenue of technology development is worthy of further exploration.

There are several areas of technological challenge and opportunity, which are key to the sustainability and enhancement of capture fisheries:

- More scientific research involving innovative approaches aimed at better assessing:
    - Fish stock levels need to be done in a timely and more reliable manner; and
    - The impact of external factors such as fishing, environment, climate change, disease, and predation on life cycles and habits needs to be studied.
- Innovative technologies are required that enable fishers to harvest fish "smarter" i.e. reducing or eliminating by-catch and spawning / immature stock rather than efficiency improvements such as increasing catch through indiscriminate harvesting.

Controlling the spread of disease has been and continues to be the key problem for commercial aquaculture operations due to the high density of fish in cages and the tendency to use purpose-bred stock, which are genetically uniform. When disease is introduced into such an environment, it tends to spread rapidly and with a devastating effect, often wiping out whole farms or at least whole breeding years.

Photo credit: Province of PEI

ii. Future Technologies & Market Drivers

The annual market for electronic products used by the fishing industry was estimated in the early 1990's to be in the range $1 billion to 2.5 billion (U.S.), of which fish-finding electronics accounted for $200 million to $600 million (U.S.).[24] Although the number of vessels, particularly in the developed fishing nations, is decreasing due to diminishing stocks and more rigorous conservation policies, the conclusion is that while overall demand for electronic products is static, there is a shift in demand to more sophisticated, discriminatory electronics.

An example of innovation in the capture fisheries industry has been the development by Clearwater Fine Foods of a new approach to managing and harvesting scallops which employs several technologies including multibeam sonar bathymetric charts and images, GPS, and an onboard computer logging of catch data. This technology has enabled the company to clearly visualize the seabed and to correlate catch data with bottom topography to identify prime scallop habitat as well as concentrations of scallops by size and age. This in turn facilitates more selective harvesting based on stock management criteria and market demands, and the use of harvesting techniques, which minimize effort and consequent habitat damage.

[24] A Marine Research, Technology, Development and Innovation Strategy for Ireland, Marine Institute 1998

Some Canadian fishing technologies involve mapping and inventory of known fishing grounds e.g., scallop fisheries, while others involve various ways of discriminating between types of fish e.g. groundfish. Ideally, fishing technologies would enable the industry to harvest on a highly selective and cost-effective basis using both sustainability and market criteria as guides.

Technologies will be required to increase the value of fish products both in terms of quality and innovative uses. Technologies will also be needed to reduce the adverse impact on fish habitat from fishers bottom trawling as well as from other ocean users including offshore oil and gas operators, sub-sea pipelines, or sub-sea telecommunications cable.

Research into the domestication of aquatic wild species involves:

- Selecting organisms that grow well in captivity and are amenable to cultivation.
- Developing the technical knowledge and skills to control and manipulate the life cycle of organisms for:
  - Cultivation;
  - Hatchery technologies that ensure high survival rates;
  - Selective breeding and genetic engineering;
  - Improved brood stock and husbandry practice; and,
- Developing improved health characteristics, such as increased stress tolerance and disease resistance.

Table 7: Some long-term technologies for fish capture, seafood harvesting and aquaculture include:

Fish Capture, Seafood Harvesting and Aquaculture
Aquaculture Engineering
• An aquaculture and tidal power co-generation project fish-friendly turbines) • Biological: single-sex (non-reproductive) animals and genetically engineered for containment • Improving supply or organic feed ingredients (enzymatic modification of feed stock) • Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals) • Fish friendly turbines for tidal power generation • Bio-processing technology (i.e. enzymes) • Environmental marine mining technology • Genetic engineering GMOs (acceptability issues apply) study benefits and risks • Waste management • Fish "health" technology (e.g. vaccination technology) • Bio-engineer effects of domestic salmon on wild stocks to identify and prevent transfers
Seafood Harvesting
• Safety issues (fishing fleet renewal)
• Marine ecosystem modeling • Biological science and oceanography

Fish Capture, Seafood Harvesting and Aquaculture

Aquaculture Engineering

- Chemical science
- Habitat mapping
- Tools and signal processing for detecting species that are under farmed or not farmed.
- Identification (rapid screening techniques, monitoring path and environment). Could allow for OIE certification
- Humane non-stressful fish-killing devices, i.e. "stun and bleed" (perception and quality)
- Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals)
- Economic & safe fishing vessels (65, 45 ft. rules)
- Fuel efficient vessel design (fuel cells)

Ocean Nutrition Canada, launched by Clearwater Fine foods in 1996, has a team of 140 employees and 40 marine scientists who are dedicated to analyzing marine natural products in order to develop nutritional supplements. The company is a leading researcher, manufacturer and global marketer of natural marine products. Its two primary products are heart-healthy omega-3 fish oils, harvested from salmon, sardines and anchovies and the anti-arthritic compound glucosamine, which is an extract from crab and shrimp shells.

Ocean Nutrition Canada sells its marine compounds mostly to nutritional products companies and major food suppliers. While the company has competitors in the omega-3 and the anti-arthritic compound glucosamine business, no one else is developing nutritional supplements directly from ocean products.

Improved husbandry techniques involve containment practices, improved fish handling technologies (sorting, grading, etc.) and improved feedstocks.

Containment technologies involve:

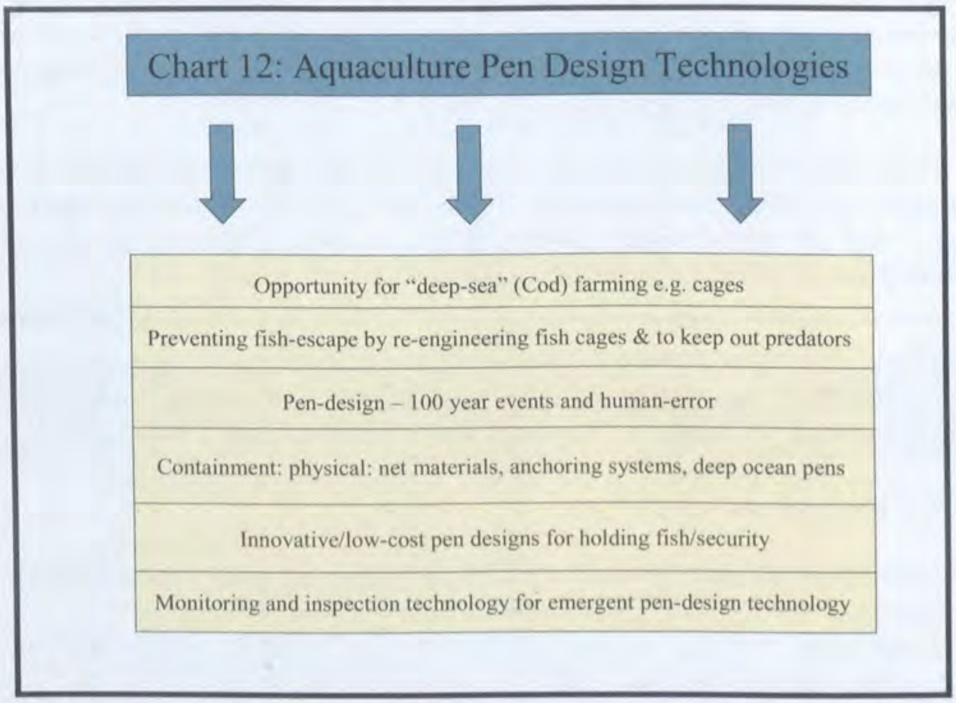
- Land-based culture systems, freshwater and saltwater re-circulation systems;
- Water-based culture systems or pens that facilitate waste product concentration and removal; and,
- Mobile pen systems for offshore aquaculture that float with the current and provide all required husbandry inputs such as feed, observations and monitoring.

Environmental technologies are also important for the aquaculture industry. These technologies include:

- Developing better environmental sensing and monitoring equipment to measure water quality throughout the growing cycle;
- Computer-based data gathering, storage and analysis;
- Use of satellite technology for remote sensing and communications across vast distances;
- Harvesting and processing;
- Innovative handling technologies to reduce handling time, maintain quality and improve food safety;
- Increased valorization and to utilize as much of the organism as possible (eliminate waste).

Aquaculture systems engineering involves a multidisciplinary approach to cage system design in order to minimize predator damage, fish escapes and exposure to toxic phytoplankton. Integrated materials handling approaches reduces labour costs and increases productivity in the shellfish industry.

Chart 12 discusses aquaculture pen development technologies..

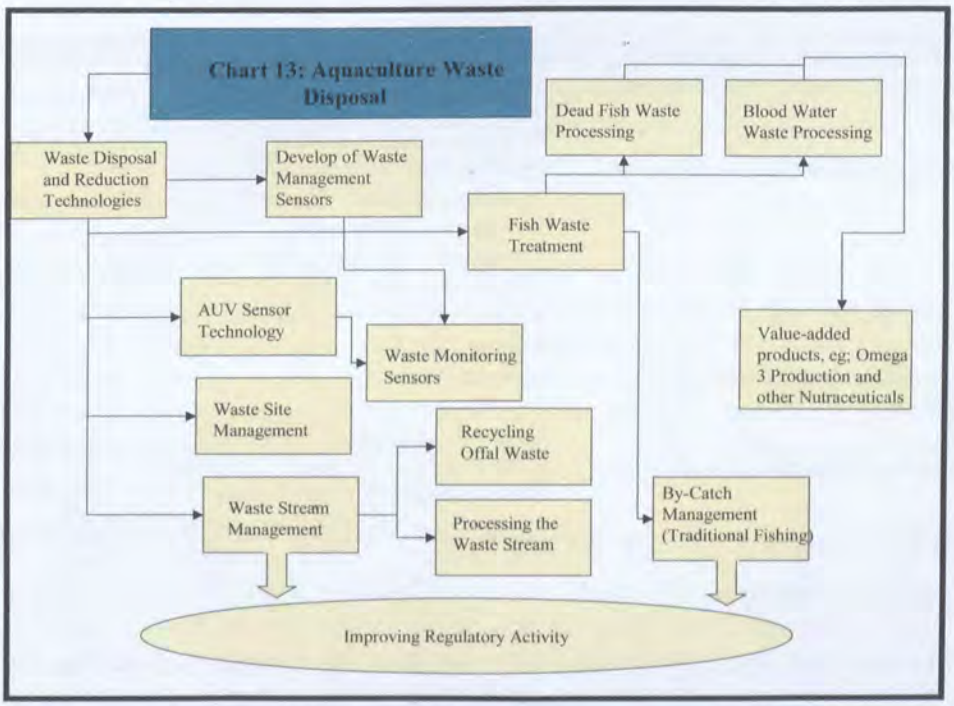


The pneumatic delivery of feeds in conjunction with camera monitoring has dramatically improved feed yields in salmon farming. System engineering approaches in the future will likely monitor fish behaviour, link it to feeder control and teach the fish to feed themselves.

Remote sensing plays an important role in the aquaculture industry. Just as the land farmer needs accurate site-specific weather forecasts, the aquaculture farmer needs data in real time to monitor critical conditions affecting the health of the finfish or shellfish. Shellfish farmers must monitor toxic and food phyto plankton and finfish farmers must be able to anticipate and protect their stock from harmful algae and low amounts of oxygen.

Continuous monitoring of biomass and net pen integrity is considered to be a future technology opportunity for the aquaculture industry. There will likely be a migration from relying on manpower for routine monitoring to greater use of electronics and robotics. In addition, methods to detect and monitor ecological impacts will be developed as well as new technological solutions and industrial operations to be incorporated into real-time coastal management procedures that enable long-term sustainability of the industry.

Chart 13 identifies specific technologies applicable to aquaculture waste disposal.



Transportation, storage and distribution technologies are also important to the aquaculture industry. These technologies include:

- Innovative shipping containers that maintain freshness and quality;
- Innovative packaging that is strong, light-weight, insulates well and is easily recycled;
- Retail innovative product handling and presentation that maintains quality, freshness (shelf-life) and food safety at the consumer level.

Increased use of technology is seen as necessary to remain competitive. Innovation will be needed to address challenges facing the industry. The British

Columbia Science Council in its paper entitled *BC Aquaculture R&D - A Proposed Organizational and Program Model* has identified five main themes for future R&D.

Photo credit: DFO

Table 8: Main themes and elements for BC Aquaculture R&D

Main theme	*Elements*
Health management of culture species	Disease prevention, diagnosis and treatment; Risks from culture to wild; Risks from wild to culture.
Technology improvement	Productivity; Product quality and diversity; Low impact technology; Reduction in escapes; Aquafeed development.
Operational improvements	Aquaculture/environment interaction; Logistics and Information Technology.
Commercialization of species new to aquaculture	Husbandry; Commercial production models.
Socio-economic impacts of aquaculture	Changing resource based communities; Valuing and conflict resolution; Integrating commercial and economic opportunity.

iii. Conclusion

There are numerous challenging areas of opportunity in the fisheries and marine sector related to aquaculture seafood harvesting and fish capture. These opportunities include: a growing demand for seafood; increasing awareness of the need for conservation practices and sustainable development; increasing demand for energy and fresh water; and, a growing recognition that fish are a healthy and excellent food source. Global over-fishing, greater utilization of underutilized species, science-related priorities to develop better bio-economic models and to better understand fish movements and behavior are key issues from both a conservation perspective and from the viewpoint of the fishers whose livelihood ultimately depends on this resource.

The long-term demand for fish products can only be met through a balanced combination of factors including: strong growth in aquaculture production;

greater consumption by humans of underutilized species; success in conservation practices; and, a commitment for the recovery of wild fish stocks. Technology and innovation play a strong role in achieving success in this regard not only by improving our knowledge base and capability, but by fishing smarter rather than the older approach of using technology solely to catch more fish. Technologies that are associated with marine geomatics and aquaculture are both important to realize success in this area.

The fisheries and the aquaculture industries are an important part of the Canadian marine and ocean economy and innovation plays a large role in the success of the sector. Much investment is needed here to continue to provide jobs and increase income in coastal communities. Balance and sustainability are the watchwords for this industry sub-sector.

e. Ocean Technology and Services

Human beings have the ability to peer into space, to reveal and study our moon, the planets, stars and even distant galaxies, yet we know relatively little about the oceans on our own planet. The oceans cover about 75 percent of the planet, but 95 percent of the oceans remain relatively unexplored. In other words, over 70 percent of the entire planet is unknown territory!

We remain ignorant about the significant impact that oceans have on our existence, and perhaps more importantly, about the impact that we are having on the oceans. By supporting extensive biomass and environmental problems, the oceans are directly responsible for the maintenance of life on our planet. Until we develop an understanding of the symbiotic relationship that exists between humans and oceans and appreciate the need to manage resources in a sustainable way, life on this planet will be severely compromised.

The oceans represent a vast, remote, complex and harsh environment and our understanding of them requires extensive data collection. The data sets that describe this environment can be very large, and combine aspects of both spatial and temporal variability. Phenomena in the water column, e.g., thermal gradients; variations in currents, wave formations, temperature and salinity; size and movement of fish stocks; etc., at and below the level of the seabed, and at the sea surface, are all important elements of this overall domain. Since ocean data are typically collected and used by different groups and for differing purposes including hydrography, oceanography, navigation, fishing, offshore hydrocarbon exploration, transportation, etc., these data tend to have differing structures, application environments and policies for distribution and use. While some data sets are relatively static, e.g. bathymetry, bottom type, others are dynamic, e.g., waves, surface currents, vessel location and are often required in "real time" to be of any value. Many users of ocean data operate at sea, from a moving platform or a subsea device in an environment that is for the most part remote by terrestrial standards.

The vision for ocean science and services in Canada is to develop, over the next several years, the necessary knowledge base for our oceans that will contribute to confident decision-making. This knowledge base should mirror in size and extent the database we have at our disposal for making such decisions on land.

Data gained in this process would be accessible through a marine geospatial data infrastructure (MGDI) that will enable access to information from multiple sources. The development of this marine information infrastructure will serve as a focus to support activities in ocean mapping, ocean science, fisheries, environmental monitoring, and non-renewable resource utilization. The infrastructure will be a model for other countries to follow as they move toward an understanding of their own oceans. This knowledge base can support the expansion of Canadian industry in terms its capacity and capability for ocean mapping and ocean science. It will also stimulate its own MGDI technology development that will be marketed internationally.

i. The Road Ahead

With three oceans bounding 244,000 km of coastline and approximately half of its sovereign lands under water, Canada is responsible for managing the second largest exclusive economic zone (EEZ) in the world, encompassing some 5 million square kilometers of Atlantic, Pacific and Arctic oceans. The Government of Canada with the adoption of the Canada's Oceans Act formalized Canada's claim to and responsibilities for these oceans. The Act gave Canada jurisdiction over exploration and exploitation, conservation and management of all the living and non-living resources of the waters, seabed and subsoil out to 200 nautical miles from the coast.

Only through bathymetric charting can we maintain our rights to resource ownership. Some mapping has not been updated since Capt. James Cook first did it in the 18^{th} Century. The work that has been done includes limited seismic exploration, mostly on the east coast. This area is relatively unexplored and unexploited. Its full potential remains a mystery. The market opportunity for ocean technology and other ocean services therefore abounds, and Canadians with their expertise in ocean mapping and other ocean technologies are well positioned to capitalize on this opportunity.

The requirement for up-to-date ocean data traverses a range of marine operations from improved navigation and safety to effective environmental protection and sustainable development of our marine resources and coastline. It includes all of the major issues we tend to package under 'sustainable resource development' including fisheries management; discovery and exploitation of hydrocarbon and mineral resources, the design and installation of oil and gas platforms, pipelines and telecommunication cables. It opens our eyes to new economic opportunities in the international provision of ocean mapping technologies and expertise and the development and sale of value-added data products and services. Finally the gathering and processing of ocean information is a fundamental requirement for issues associated with sovereignty, defence and national security.

Ocean Science

Canada's oceans offer some unique opportunities for scientific investigations that may not be found elsewhere. These range from fisheries science and habitat management, non-renewable resource exploration and extraction technology, ocean mapping, and climate studies. The combination of biomass, geological, and environmental features provides for interesting investigative opportunities.

To facilitate more accurate fisheries management, Canada has developed extensive expertise in the application of hydroacoustics technology and data processing and analysis techniques for the measurement of biomass, size, species and migration patterns. This expertise is shared among government departments, academic institutions and within industry. At present, for example, the Department of Fisheries and Oceans currently has at least some 38 projects using hydroacoustics for stock assessment and 51 for habitat and ocean sciences.[25] There has been some concern expressed, however, that the hydroacoustic methods in stock assessment, ocean sciences and habitat management are slowly being removed from many programs, due mostly to a lack of infrastructure support. A DFO Working Group on Hydroacoustics concludes that in these areas, infrastructure and expertise will ultimately be lost and the future for even a basic applied capacity is uncertain. A lack of financial resources to improve infrastructure and an inability to retain key departmental expertise are major reasons for this situation.

The use of hydroacoustics, however, will continue to play a major role in Canada's marine fisheries stock assessment, albeit at either a flat or somewhat reduced level over the next few years. Companies supplying this market with products and services are increasingly reliant on export markets where Canadian technologies and expertise is considered to be competitive internationally.

The proposed Neptune Project in British Columbia holds significant potential opportunity for Canadian industry as well as for the academic community. Neptune is a shared initiative between the United States and Canada to establish a long-term undersea monitoring network in the area of the Juan de Fuca plate just off the country's west coast. This area has long been recognized as seismically active and bio-diverse making it a prime location to increasing our understanding of geological and biological processes and their relationship to the ocean, its systems and our way of life. Neptune offers a variety of market opportunities in technology areas including data processing and management; design, construction and installation of network components and supply services including the

[25] The Application of Hydroacoustics in DFO Science: Current Status and Future Considerations, DFO Working Group on Hydroacoustics, January 2002, p.4.

operation of AUV and ROV systems. As a jointly funded project between Canada and the United States (30:70 ratio), companies will be vying for leverage opportunities. Thus, partnering with U.S. companies will be a logical approach for Canadian firms to maximize commercial opportunities.

As a forerunner to Neptune, the Canadian Foundation for Innovation recently announced funding approval of the Victoria Experimental Network Under Sea (VENUS). VENUS represents a scaled-down version of Neptune focusing on the Georgian Basin offshore British Columbia and involves scientists from approximately a dozen academic and research institutions across Canada and the United States. Commercial opportunities within Venus mirror those identified for Neptune. Beyond the monetary gain of winning project work and establishing a record of technological "know-how", the experience and skills gleaned through involvement in this project will be marketable elsewhere.

Ocean Mapping

Over the past decade the approach to ocean mapping has changed dramatically due primarily to mapping technology that now allows us to do for the oceans what aerial photography and satellite remote sensing has done for land. Technology such as multibeam sonar has now evolved to the point where it is globally accepted as one of the most effective ocean mapping tools and in its wake has created a new challenge; how to effectively manage and make readily available the huge amounts of data that it generates. Perhaps the most significant non-technical change is the recent unprecedented interest from coastal countries in mapping their underwater territories, which bring commercial opportunities in terms of applications and services.

The demand for better understanding of the marine environment is being driven on several fronts. Perhaps the most quoted reason for this demand is Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS). This article provides an opportunity for countries to claim territory beyond their current 200 nautical mile EEZ. The exact outer limit location of the extended shelf any nation may claim will depend on geophysical, hydrographic and geodetic factors such as the configuration of its shore, the limits of its continental shelf slope and the thickness of sediments at various points from its shore baselines. While this in itself is important, the benefits of understanding the marine environment are even more significant and far-reaching than just claiming new territory.

It has long been recognized that Canada's unique package of ocean mapping expertise, if appropriately supported and marketed, would be a valuable commodity on the global ocean-mapping scene. In fact, Canadian experts have been contracted to advise the governments of both New Zealand and Ireland on their national ocean mapping programs. These projects represent two of the world's largest ocean mapping initiatives.

The RADARSAT 2 program of MacDonald Dettwiler and Associates Ltd. (MDA) is a leading technology for commercial Earth observations. RADARSAT technology is especially useful for shoreline mapping, which requires the full integration of several scientific disciplines. The ocean wave dynamics and tidal action provide considerable challenges for mapping and monitoring coastal areas. In regions where the tidal action is mild the beach sedimentation is often quite different from a particular region where the tidal action is intense.

Photo credit: MDA

Over 80 Canadian companies are now working in the ocean mapping industry. These companies range from service and hardware providers to internationally recognized technology developers. Canada's capability in ocean mapping is broad-based, ranging from ship/surface-based data acquisition, remotely operated vehicles (ROVs), airborne and satellite based expertise. Most recently, mapping technology has been employed in the field of autonomous underwater vehicles (AUVs).

Private sector expertise is not limited to data acquisition but encompasses a wide range of ocean mapping technologies from technology development and supply to data processing, management and value added product development. Although ocean mapping expertise exists across Canada, it is most prominent on both coasts, with the highest concentration existing in Atlantic Canada.

Canadians were among the first to develop and implement electronic charts and electronic chart systems as a means to better manage shipping on the Great Lakes and St. Lawrence Seaway. DOLPHIN (an autonomous ocean survey vehicle) is a Canadian invention that was first introduced in 1990. Until quite recently, the US Navy used it extensively.

The most forward-looking ocean mapping opportunity to be considered by Canada has been the SeaMap initiative. SeaMap is an initiative of the Federal Departments of Fisheries and Oceans, National Defence, and Natural Resources Canada. SeaMap is a partnership among industry, universities and government with the focus on sea and lakebed mapping of Canada's offshore, coastal and aquatic lands utilizing leading Canadian technology. The aim of SeaMap is to provide the basic data and information needed for a variety of purposes including laying claim to the Continental Shelf (CS), resource management and development, ensuring sovereignty and security, and enhancing safety of navigation while providing a platform for developing and proving Canadian technologies and expertise that can be exported worldwide. Such an endeavor would put Canadian experience and expertise to work through government, industry and university partnerships, and ensure that the resulting data and information remains available to all potential users.

Efforts are also underway in British Columbia to rationalize the gathering of ocean information through the newly created BC cooperation Ocean Information network, or BC/COIN. This initiative is a cooperative effort by all players interested in the acquisition and use of data and information on BC's ocean resources: the water column, the seafloor and the sub-floor. It is based on the premise that through cooperation and sharing, more useful and useable data and information will be gained at lower cost. BC/COIN will also encourage and support cooperation in ocean technology developments, pursuit of related domestic and international project opportunities, and international marketing of joint capabilities.

The concept of a large-scale national ocean mapping program is not unique to Canada. New Zealand, Australia, Norway, Spain, United States and Ireland have already implemented ocean-mapping programs. These initiatives have been done in response to both UNCLOS requirements and a recognition that the importance of their underwater territory to their economic well-being has high value. Approximately 68 coastal nations are currently considered eligible to submit claims under the provisions of UNCLOS Article 76. Additional countries may be added following a successful submission of their proposals.

Recent studies demonstrate a global growth in marine surveying fueled by new challenges in deep water for oil and gas development. The contracting out of what was traditionally government research and/or hydrographic work is another market driver. A report for the UK Marine Foresight Panel valued the 1999 global survey market at $1.5 billion, growing by approximately 32 percent by 2004. [26]

While moderate, sustained growth is expected in the survey market, the oil and gas industry, EEZ mapping programs and coastal zone management initiatives worldwide will fuel this effort.

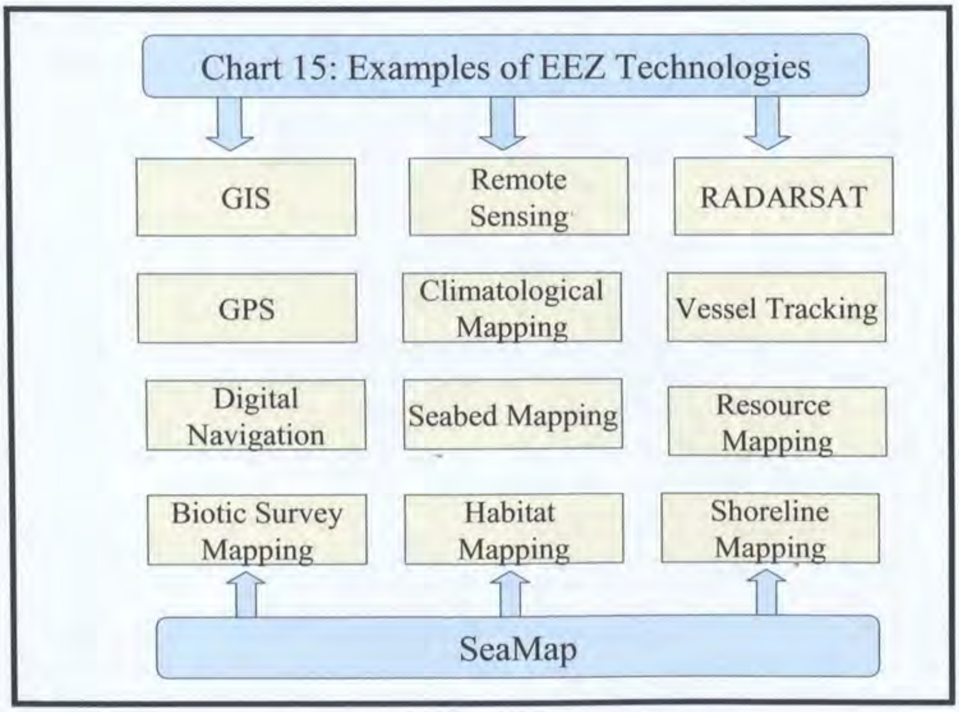
[26] UK Marine Industries World Export Market Potential – a report for the Foresight Marine Panel, October 2000.

Chart 14: Canada's Maritime Zones

ZONE	DEFINITION	RIGHTS & RESPONSIBILTIES
Territorial Sea (TS)	The TS extends 12 nautical miles from the baseline	Full rights & responsibilities
Contiguous Zone (CZ)	The CZ extends 12 miles from the outer edge of the TS	Customs, sanitary, fiscal & immigration
Exclusive Economic Zone (EEZ)	The EEZ extends 200 miles from Canada's baseline	Exploration, exploitation of living & non-living resources of waters, subsoil and seabed in the EEZ and scientific research
Continental Shelf (CS)	The CS includes up to the outer edge of the continental margin or 200 nautical miles, whichever is greater	Exploration & exploitation of mineral and non-living resources and sedentary living species

Coastal Zone Management, which is an element of the wider issue of EEZ management, presents a growing range of requirements with technology implications. Globally, coastal zones have high population densities and are characterized by a high concentration of industrial and economic activities. These include shipping, fishing and aquaculture, leisure and offshore activities. In addition to the fact that many of these activities degrade the coastal environment, it is also the recipient of all water-borne wastes. Monitoring the coastal zone and providing the tools for conflict resolution and rational management, requires the integration of recent tools such as GIS, Image Processing Systems and Remote Sensing with data management, analysis and modeling.[27]

[27] EEZ Technology, IGC Publishing 1998



Subsea telecommunications is an area where flat or negative growth is anticipated, with a static demand for bandwidth and telecommunications in general. It is evident that only a very small portion of subsea telecommunications infrastructure, particularly fibre-optic cable, is currently being used or in demand. However, we may expect to see some recovery over the next four to five years.

From an academic perspective, there are four Canadian universities with notable expertise in ocean mapping. These are University of Victoria, University of Quebec at Rimouski, University of New Brunswick and Memorial University of Newfoundland). A number of other schools offer some level of capability in this field.

> *"The ocean floor still is considered a vastly uncharted frontier. As the costs of operating in such an environment increase, innovative methods for exploration must be found. Quester Tangent Corp. of Sidney, British Columbia, Canada, in partnership with the Canadian Center for Marine Communications and the Canadian Space Agency, has developed QTC VIEW to support ocean exploration, providing scientists with remote control and monitoring capabilities for seabed mapping systems.*
>
> *Using QTC VIEW, scientists can log in via the Internet and receive status updates and data from a mapping device. Two-way communication links are available via INMARSAT, but the architecture will support any standard dial-up modem protocol."*
>
> *Source: GEO World, February 2002*

ii. Future Technologies & Market Drivers

The marine technology sector is a key component of what is a dynamic and rapidly developing and evolving set of activities, united principally by the fact that they take place on or under the sea. The increasingly sophisticated technology involved in all sectors of the maritime economy has challenged the ability of operators, enterprises and administrations to cope with state-of-the-art technology, and even to set the trends and guidelines for the application of new information and communication technology. Outsourcing of production and services, integration of applications and platforms, increasing automation, remote services and globalization are trends which challenge single operators, at all levels, in the maritime world. This whole new world mirrors all the land-based technology activities that have been in play for years. Increasing speed in technological development and high costs are forcing industry and administrations towards co-operation and concerted actions to keep market position and gain competitive advantages in the marine and ocean industry.

Future global trends in respect to climate change, energy demand, trade, food production and sustainability impact on marine technologies and industries and drive demand and innovation in these areas. Competitiveness in these industries arises not only from research and technological innovation but also from such factors as management skills, entrepreneurship, marketing and "vision".

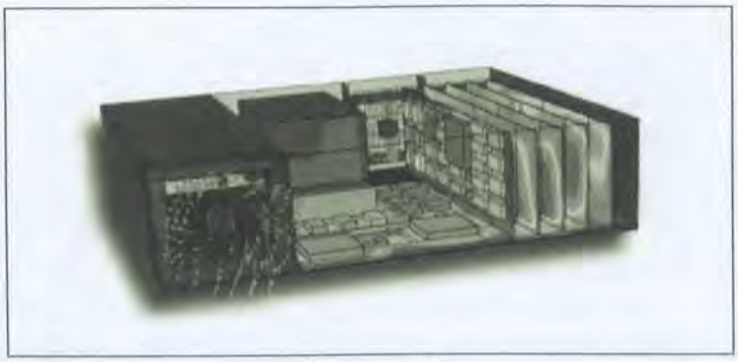
The challenge for the marine and ocean industry technology sector will be to enable a critical mass of expertise and companies to develop, servicing local, national and international markets; to facilitate increased sustainable development of Canadian marine resources; and, to ensure a good return on investment to both public and private investors. The sector faces the same circumstances as those, which exist in other parts of the world. Change is occurring at an often-bewildering pace. Concepts and techniques that underlie scientific and technological innovation in the marine and ocean industry sector arise from a wide array of disciplines and research areas – biotechnology, information and communication technology, acoustics, materials technology, nanotechnology etc. Bringing in the findings of these disciplines together and applying them in a focused and timely fashion is essential.

Simultaneously, our basic understanding of the role of, and processes in, the seas is advancing so that further new fields of research and development are emerging in e.g., the use of extremophile organisms in biotechnology and exploitation of renewable energies. These challenges also open new opportunities for the marine technology sector. Progress in areas such as robotics, miniaturized technology and communications offer new potential products to marine –based industries, and solutions to managers.

Guigné International is a Newfoundland and Labrador company specializing in applications of acoustics technology in the marine and space sectors. The company was spun-off from C-CORE, a Newfoundland research organization, by Dr. Jacques Guigne, based on his research and early work primarily for the offshore oil and gas sector.

Guigné International has developed a unique proprietary acoustic technology which it calls DRUMS (Dynamically Responding Ultrasonic Matrix Systems). This technology uses the physics of sound to create narrow acoustic beams, similar to a laser's use of light, which have unparalleled definition and interrogation capabilities. The company has developed a family of products around this technology with application to a broad range of industry sectors. These include defense, oil and gas, aquaculture, dredging, civil engineering, and environmental services.

Simulation-based design systems or virtual prototyping is an emerging technology that substantially lowers system life cycle costs for manufacturers. In fact, industry is now able to use computer simulation to design and test most of its products. This technology has considerable relevance to marine and ocean industries, especially shipbuilding, industrial marine and for offshore structures.

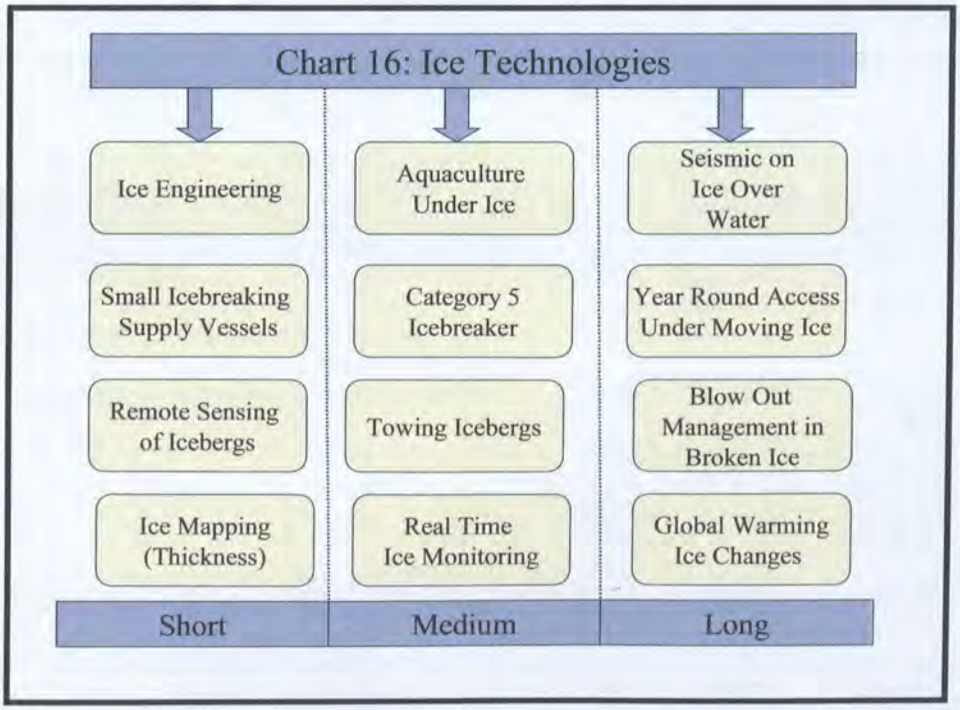


Black Box
Photo credit: CERCA

Miniaturization is ... an important trend that is already affecting marine science and technology. Between now and 2020, the first generation of micromachines (miniature sensors and motors about the size of dust particles) are expected to find widespread applications. [28]

Canada has considerable expertise in ice technologies.

[28] **Oceans 2020, Science, Trends and the Challenge of Sustainability**, Island Press, 2002



Canadian industry is a leader in airborne laser bathymeters (LIDAR). The world's first commercial lidar hydrography system, the Larsen 500, was built by Optech in the early 1980s and is still in operation. Optech subsequently developed more advanced equipment and has produced four of the six commercial systems in use today. The current system, called SHOALS, has been in operation since 1994 and the next generation of coastal mapping and charting systems, called CHARTS are now under development by Optech under a joint Canadian US program supported by Technology Partnerships Canada (TPC).[29] The resulting systems will be available in 2003-2004 and will produce seamless coastal surveys with soundings offshore and high-resolution elevations on shore. Combined with a digital imager this suite of sensors flown from a single platform will produce very powerful data to support everything from coastal management to military amphibious landings. Optech's main customers include DARPA (the United States Defence Advanced Research Projects Agency), USACE (United States Army Corps of Engineers), COMNAVMETOCCOM (US Naval Meteorology and Oceanographic Command), Royal Swedish Navy, Swedish Maritime Administration, and the Japanese Coast Guard. Development of future systems will centre on sensor fusion of complimentary systems, further miniaturizing of components, and increased automation enabling faster processing while reducing the level of expertise required for operating the equipment.

[29] Compact Hydrographic Airborne Rapid Total Survey, BATS (Bathymetric and Topographic Survey and Seafloor Mapping Feature Article, Sea Technology June 2002.

A summary of the long term technologies in ocean technologies and services industries that were discussed at the TRM workshops are identified in Table 9 below.

Table 9: Long term technologies in ocean technologies and services industries

Ocean Technology and Services	
Ocean Mapping Research	***Other Ocean Services***
• Climate change research, sea level rise impacts, prediction of rogue waves	• Sediment decontamination. Use of fill material. Habitat regeneration (organisms that remediate sediment contaminated by metals and chemicals)
• Exploiting data through visualization analysis, 4 dimensional modeling, ocean process simulation and data fusion	• Research and project on habitat zones regenerated using sediment
• 3D computational modeling of ocean systems with high energy flows (currents, tides, etc.)	• Develop methods for treating ballast waters
• Coastal erosion studies (Atlantic Coastal Action Program)	• Research to identify sources of pollution (industrial pollution found in sediment)
• Venus and Neptune; Identification of critical tech's over the next 5-10 years	• Underwater work and technological expertise in underwater projects (in cold and confined waters) Visibility in turbid waters
• Remote controlled sensors and control systems	• Tidal power renewed look, last done in '60s maybe small/medium scale development
• Deep water mapping including living resources	• Location of seals
• Carbon dioxide sensing	• Climate Change: Including; sea level; ice change; weather; use of TEK; instrumentation
• Fish counting (acoustically, optically)	• Ocean/wind power
• Power engineering	• Communications software technologies
• Coastal erosion studies (Atlantic Coastal Action Program)	• Develop new environmentally friendly paints (antifouling)
• Autonomous underwater vehicles (AUV) used as sensor platform navigated by GPS and fed information from shore	• Storage, conversion, switching of energy and change input to usable emerging technology
• Climate change research, sea level rise impacts, prediction of rogue waves	• Efficient turbines for tidal, field based generation and reverse generators
• Seabed resources map:	• Deep methane generation of U/W coal seams
	• Wave, tidal, thermal energy generation of U/W coal seams
	• Develop new environmentally friendly and economical dredging technologies
	• Environmental wave and tidal, power, ocean thermal energy conversion (OTEC)
	• Wind, wave, alternate energy sources devices design

A summary of some of the key requirements for marine development and management as outlined in foresight studies carried out in Europe, and examples of associated technology requirements, are identified in Table 10.

Table 10: Summary of key requirements for marine development and management

Activities	*Technologies*
Continuous monitoring of oceanic and atmospheric conditions.	Networks of land-based, sea-based and satellite observatories
Measuring and monitoring ocean currents	3D and 4D models and computer simulations
Monitoring the dynamics of deep-water masses.	Autonomous deep drifters
Map and survey the seafloor	High performance sub-bottom profilers, ultrasound spectroscopy and deepsea observatories.
Expand ocean drilling capabilities	Riser technology and down-hole logging tools.
Marine environmental monitoring	Autonomous data acquisition systems incorporating interdisciplinarity, energy supply and bi-directional data transfer over long distances.
Nutrient and pollution measurement, particularly biological and chemical parameters.	Sensors incorporating innovations in nanotechnology, medicine and molecular biotechnology.

New technological advances in our ability to collect and process ocean data have resulted in very rapid growth in the volume of data and information about this environment. As mentioned, efforts are now underway in many jurisdictions to implement the technical and policy framework required to facilitate access to geospatial data and information. In Canada, government and industry are collaborating to develop a Canadian Geospatial Data Infrastructure (CGDI) through a national program called GeoConnections. As partners in this initiative, the Canadian Centre for Marine Communications (CCMC) and the Department of Fisheries and Oceans (DFO) are leading the development and implementation of a Marine Geospatial Data Infrastructure (MGDI), mentioned above, that will facilitate access to coastal and ocean data and information by a broad range of users. This is having a major impact on the process of ocean mapping. Once the domain of specialized experts who acquired data and processed those data with the sole intent of producing a relatively fixed map product, ocean mapping is now trending towards a more dynamic process meant to be used by application experts. Users will access ocean data from a variety of online sources and combine these data using sophisticated software tools to create user defined views (maps) more or less unique to their particular information needs. As such, the technologies needed to process, manage and disseminate/access ocean data are now becoming part and parcel of the process of ocean mapping.

Table 11 illustrates key technologies and specific activities related to the marine sector. These technologies will increasingly become tied to offshore oil and gas developments, demand for seafood products and emerging defence needs.

Table 11: Marine Technologies and Activities

Marine Technology Function	*Specific Activity*
Marine communications, machinery and electronic industries	• Sensors and Robotics • Maneuvering and Propulsion Equipment • Hydraulics and Flow Equipment • Acoustics • Bathymetry • Aquaculture Equipment (cages, etc.) • Other Communications and Electronic Equipment • Industrial Marine • Navigation
Ocean services	• Offshore Platform Design • Rig supply, handling, repair and support • Materials and Structural Design • Systems Integration • Oceanography and Meteorology • Ocean Surveying and Mapping • Marine Communications • Navigation Systems • Naval Architecture • Environmental Engineering • Science Research (Iceberg Research, Ice Research, Oceanography, etc.) • Other Engineering and Professional Services • Diving and salvage.
Ocean science research	• Iceberg Research • Ice Research • Environmental Science • Aquaculture Science • Oceanography Science
Marine construction	• Shipbuilding technologies • Offshore oil and gas facility construction • Docks, Wharves, Piers and Terminals • Dredging and Pile Driving • Breakwaters • Canals and Waterways • Other Marine Construction

Chart 17 discusses specific opportunities in the Autonomous Underwater Vehicles, which is an area Canadian firms (see text below) have considerable expertise.

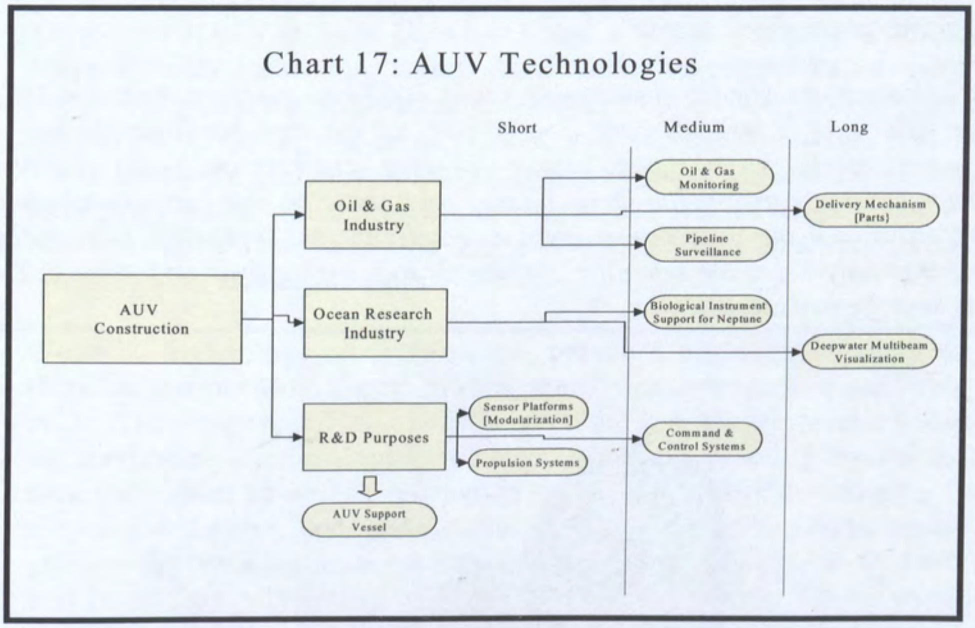


Photo credit: Nuytco Research Ltd.

Nuytco Research Ltd. is a world leader in the development and operation of undersea technology. Nuytco and its sister company, Can-Dive Construction Ltd. have over thirty years experience working around the world. Nuytco designs, builds, and operates atmospheric diving.

In 1997, Nuytco designed and manufactured a 2000-foot micro submersible Deep Worker, which is a revolutionary deep diving system that has been called an underwater sports car. Nuytco has a five-year contract with the National Geographic Society to provide Deep Worker and crews on sea expeditions where the Society is studying deep ocean environmental impacts. This micro submersible unit substantially helps the scientific community to increase their understanding of marine ecology and biodiversity.

Deep Worker
Photo credit: Nuytco Research Ltd.

iii. Conclusion

There are virtually no large Canadian based companies in the global marine and ocean industry technology sector. Most Canadian companies have learned to compete in global markets, and against large competitors, by focusing on diverse, specialized technology niches, product and services offerings, and markets. These niches are generally in areas where the companies have developed unique technology and/or where the market is small, not well developed, and with little competition. In most cases, the business may be based on a very limited set of product and/or service offerings.

While the technology niche focus has proven a successful strategy for many Canadian companies to get established, these companies subsequently find it very difficult to grow beyond their niche status if the opportunity develops. Growth of the companies is constrained by financial resources including limited cash flow, access to capital as well as production capabilities/capacity, marketing capacity, service and support, and management expertise. Canadian firms discover that growing opportunities attract more competition and they have to deal with many new issues from which they were spared as niche players. These issues include competitive pricing and the ability to provide wider, complementary product lines.

While Canada has a strong international reputation in select areas, overall its industrial capacity to innovate in the marine and ocean industry has not kept pace with competing countries. Private sector innovation markets are dominated by large, multinational companies based in Europe and the United States (and Asia for shipbuilding). In Canada, government support for innovation is largely based on developing public sector and institutional capacity rather than building private sector capacity. As a consequence, there are virtually no large Canadian companies in the global marine and ocean technology sector. Canadian companies focus on niche markets in areas where the market is small and there is little competition. This situation should probably continue to be the mode of operation over the near future. What this roadmap should do is help determine through dialogue those niche areas where it might prove valuable to invest in and to promote.

Synergies and cohesion between Canadian companies is based more upon knowledge exchanges and social networks than on value added chains. Many Canadian companies in this industry are geographically located far away from each other on both coasts. Quite often, their work is not even related, occurring in distinct niches, attracted only through reference to ocean science.

Sensor technology will be a key area of development and growth for the future, i.e. 3 to10 years. Challenges to be overcome in sensor technology include, the complex nature of the marine environment, insufficient sensitivity for low levels of trace chemical concentrations, fouling of sensors, selectivity limitations, limited stability of sensor chemistry and material, and insufficient resolution of pressure and depth sensors to allow *in situ* instruments to match satellite altimeter data. New product development in this field will occur in a variety of niche technology areas, including biosensors, sensor arrays, microsystems technology, coupled optical sensors, mass spectrometers and smart materials.

In marine geomatics, technological innovation is driven in large part by military needs. Their sponsorship has brought about huge advances in the technological capabilities for the industry. These advances include the development and widespread access to highly accurate global satellite positioning systems (GPS), the development of electronic charts systems (ECS) for navigation, access to a wide variety of satellite based remote sensors, multibeam (swath) and side scan sonars for bathymetry and imaging of the sea floor. These however have not allowed for the easy exchange of information concerning either data or technological advances.

The idea of a research platform on an international research ship, similar to what Canadarm on the International Space has done to demonstrate Canada's expertise in ocean technologies should be seriously considered as a project. Government programs in specific niche areas like GeoConnections would also encourage technological innovation.

4. TECHNOLOGY OPPORTUNITY AREAS

The following opportunity areas for future consideration and possible development are broadly categorized as follows:

- Shipbuilding and Industrial Marine
- Canadian Oil and Gas Offshore Industry
- Marine Operations
- Fish Capture, Seafood Harvesting and Aquaculture
- Ocean Technology and Services
- Areas Cutting Across Industry Boundaries

a. Shipbuilding and Industrial Marine

A key opportunity in shipbuilding involves a "made-in-Canada" ship design that will help develop and emphasize the importance of a "type" or "class" of vessel that can be largely fabricated and outfitted in Canadian yards.

b. Canadian Offshore Oil and Gas Industry

Potential opportunity areas include sub-sea and deepwater processing and operations technologies including smart well technologies and Arctic gas hydrate research and technology development.

c. Marine Operations

Opportunity areas for marine operations include ship technologies that involve ice breaking, ice management and ice secure propulsion systems and technologies that are applied in a cold water and harsh environment.

Concerning port operations, vessel traffic management systems and automatic identification systems are possible future areas for development.

d. Fish Capture, Seafood Harvesting and Aquaculture

Opportunity areas for future aquaculture development include systems engineering, i.e., a multidiscipline approach to cage design and integrated operations. Biotechnology research regarding the health of finfish and shellfish, toxicity and ecology are potential development areas.

Regarding seafood harvesting a key opportunity includes the development of technologies geared toward sustainability, protection and preservation of traditional fish stocks.

e. Ocean Technologies and Services

Opportunity areas for consideration in the marine geomatics field involve mapping and electronic charting in one or more Canadian oceans that focuses on navigation and marine transportation and safety.

Marine fibre optic system design and fabrication and an enhanced Autonomous Underwater Vehicle (AUV) research program, especially for longer range AUVs possibly powered by fuel cell are possible opportunity areas in the ocean technology area. Similarly virtual prototyping and simulation technologies provide a valuable tool for designers and manufacturers of marine and ocean industry products, especially large offshore structures and ships.

f. Areas Cutting Across Industry Boundaries

Possible opportunity areas that are not sector specific yet have tremendous application in a marine environment include biotechnology, real time technologies supporting Canada's Extended Economic Zones (EEZs) and the conveyance of social science to natural science

5 CONCLUSION

A number of generalized findings can be distilled from the ten national roadmap workshops and other meetings and interviews that have taken place over the past eighteen months. These findings set the context for the analysis that followed and which is presented in this *Special Report*.

The general findings conclude:

- The industry, which is diverse needs to pull together and speak to the world with one strong and consistent voice rather than with several independent voices;
- That this voice should carry forward a common message that stresses the importance of balance and sustainability in all aspects of technology development;
- That regulatory activity has both a positive and negative affect on technology development and that this needs to be taken into account in a any planning of technology programs of the future, so that the enabling qualities (rather than the disabling qualities) of the regulatory impact both technology and business development;
- That a focused approach needs to be mounted selectively choosing certain technology platforms at least initially, based on niche areas that we have already established leadership and expertise and where a probable market exists globally; and finally,
- That these choices be embraced wholeheartedly and in a programmatic fashion - not only by governments, but by industry and academic as well. These programs need to be spelled out as mission-oriented research projects and goal specific nodes on the roadmap pathway.

This Technology Roadmap does provide a single voice representing the marine and ocean industry community. The workshops and the research conducted for the roadmap has provided a wealth of information on marine and ocean technologies that are highly relevant in the present, medium term and longer term. A select number of technologies have been drawn out from the rather extensive data collected in workshops and elsewhere discussed in this report. Schematics that identify current and future research opportunities have been prepared for the following areas:

- Great Lakes Seaway Fleet
- Vessel Technologies
- Shipbuilding Pathways
- Extended Year Seaway Scenario
- Advance Material and Composite Technologies for Shipbuilding
- Shipboard Waste Management
- Subsea Smartwell Processes

- Offshore Waste Management Disposal
- Aquaculture Waste Disposal
- Aquaculture Pen Design Technologies
- EEZ Technologies
- Automation Technologies
- Marine Sensors Technologies
- Ice Technologies
- AUV Technologies

Additional schematics have been prepared for future revisions of this *Special Report* in order to present a more comprehensive picture of the industry technology opportunities. The next step in this process will be for the industry players to develop and discuss more detailed linked actionable paths like those illustrated in the schematic diagrams of this report. This dialogue can occur on the Marine and Ocean Industry TRM web site.

This roadmap is a continuing "living" process that allows industry players to design their own long-term plans. This report suggests some programmatic plans drawn up at one point on the road in a long and unfinished journey. New technologies relevant to the industry will evolve from ongoing discussions of the marine and ocean industry community, especially those people representing the private sector, especially those people that engage wholeheartedly in the dialogue.

The process is just beginning. The roadmap has brought together individuals from very different groups representing a wide range of marine and ocean interests. These range from traditional fish harvesting to high end ocean-related communications systems and fabricators of large industrial marine structures. The synergy developed by the roadmap through this community of practice needs to be continued and developed further through sustained interactions where such programs are discussed.

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ANNEX A: MARINE AND OCEAN INDUSTRY TECHNOLOGY ROADMAP STEERING COMMITTEE MEMBERS

NAME	ORGANIZATION	LOCATION
Robert Allan	Robert Allan Ltd.	Vancouver, BC
Gaétan Boivin	Institute Maritime du Québec	Rimouski, QC
Wayne Butler	Maritime Workers Union	Marystown, NL
Peter Cairns	Shipbuilding Association of Canada	Ottawa, ON
Chrystia Chudczak	Fisheries and Oceans Canada	Ottawa, ON
Linda Cooper	Environment Canada	Sackville, NB
Richard Domokos	Industry Canada	Ottawa, ON
Gilles Dupont	IRAP - National Research Council Canada	Sainte-Foy, QC
Terry Dooner	Technology Partnerships Canada	Toronto, ON
Michael Edwards	Natural Resources Canada	Rothesay, NB
Leslie Galway	Newfoundland Ocean Industries Association (NOIA)	St. John's, NL
Ian Glen	BMT Fleet Technology Ltd.	Kanata, ON
William J. Inwood	SeaState Capital, Inc.	Toronto, ON
Geoff Lewis	Industry Canada	Halifax, NS
Jacques Lyrette	ADGA Group Consultants, Inc.	Ottawa, ON
Captain David Marshall	B.C. Ferry Corporation	Victoria, BC
Doug Moody	InnovaQuest Inc.	St. John's, NL
Donald N. Morrison	Canadian Shipowners Association	Ottawa, ON
Ronald V. Newhook	Canadian Centre for Marine Communications (CCMC)	St. John's, NL
Thomas Paterson	FEDNAV Ltd.	Montreal, QC
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Ian Robertson	BC Cooperative Ocean Information Network	Vancouver, BC
Dr. Ross Graham	Atlantic - Defence Research and Development Canada	Dartmouth, NS

Jean-Jacques Rousseau	Centre de recherche en calcul appliqué	Montreal, QC
Victor M. Santos-Pedro	Transportation Canada	Ottawa, ON
Slawek Skorupinski	Skorupinski Enterprises	Nepean, ON
Barbara Stanley	Duo Holdings	Rothesay, NB
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Judith Whittick	C-CORE	St. John's, NL
Jim Wooder	Atlantic Canada Petroleum Institute	Halifax, NS

Annex B:

Marine and Ocean Industry Technology Roadmap

Technologies & Markets Discussed at Workshops

Photo credit: Chamber of Maritime Commerce

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Photo credit: Province of Prince Edward Island

Fish Capture, Seafood Harvesting and Aquaculture **Aquaculture Engineering**
• Tie in aquaculture and tidal power co-generation project
• Biological: single-sex (non-reproductive) animals and genetically engineered for containment
• Improving supply or organic feed ingredients (enzymatic modification of feed stock)
• Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals)
• Bio-processing technology (i.e. enzymes)
• Environmental marine mining technology
• Genetic engineering GMOs (acceptability issues apply) study benefits and risks
• Waste management
• Fish "health" technology (e.g. vaccination technology)
• Bio-engineer effects of domestic salmon on wild stocks to identify and prevent transfers
Seafood Harvesting
• Safety issues (fishing fleet renewal)
• Biological science and oceanography
• Chemical science
• Habitat mapping
• Tools and signal processing for detecting species that are under farmed or not farmed.
• Identification (rapid screening techniques, monitoring path and environment). Could allow for OIE certification
• Humane non-stressful fish-killing devices, i.e. "stun and bleed" (perception and quality)
• Applied aquaculture biotechnology (diagnostics, genetic trait tracking; immunology/nutraceuticals)
• Economic & safe fishing vessels (65, 45 ft. rules)
• Fuel efficient vessel design (fuel cells)

Shipbuilding, Industrial Marine and Offshore Oil and Gas Shipbuilding and Industrial Marine
• CFER lab tested unique designs, e.g. honeycomb hull material cheaper than thick steel; other unique ideas, e.g. hull no stick coatings, water spray systems, bubble systems, etc.
• Cost effective concrete/steel composite structures
• Environmentally friendly anti-fouling paint
• Improve vessels maneuverability during berthing
• New lighter, non-corrosive steel technologies
• Propulsion opportunity for fuel cells for vessels and prime movers
• Sensor for non-contact characterization of port bottoms or physical samples:
Offshore Oil and Gas
• Clean up & remediation; blowout management in broken ice: Oil containment needs modeling and test facility
• Subsea technologies for operation
• Prediction models/system integration
• New technologies to reduce waste production
• Harsh environment structures (big waves)
• Transportation of hydrocarbons to market: Alternates to pipelines
• Change form of energy
• Harsh environment structures (big waves)
• U/W transportation TM
• Deepwater floating systems e.g. FPSOs, TLPs, SPAR, moorings
• Construction new platform design
• Adopt existing technologies for exploration in the Gulf of St. Lawrence
• Oil spill & waster water prediction (AUV's, oil spill simulator/risk monitoring)
• Availability of construction materials for support structures and roads: Develop alternate structures
• Alternate exploration/detection technologies
• Seismic on ice over water
• Harsh environment structures (big waves)
• Cost effective concrete/steel composite structures
• Year round access/operation under moving ice: Subsea technologies for access
• Deep water technology
• Offshore support terminal (technology exists)
• Requirements for relief wells: Develop alternate blowout prevention technology
• Develop alternate control measures
• New technologies to reduce requirements
• Study of offshore permafrost
• Deepwater controls
• Offshore port
• Deepwater controls

Long Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
• Oil spill containment or emulsion	• Non-toxic bottom paint
• Large load scanning	• AUV's long range
• Ocean surveillance technology (remote radar, underwater acoustics)	• St. Lawrence Seaway is open the entire year
• Sensors on cranes loading ships	• Develop tools and equipment to reduce costs
• Side scanners, multi-beam – visualization	• Non-toxic bottom paint
• Bathymetric mapping and classification of St. Lawrence beds for submarine routes and for installation of mines	• Antifouling
• Oil spill containment or emulsion	• Discharges from ballast, bilges, waste water and organisms
• Specialized shipboard environmental protection technologies in case of disaster (oil, chemical, hazardous materials)	• Coherent radar for detection & tracking of small objects such as a person in water
• Review of regulations updated on the basis of new technology	• Remote operation (operational sensors, control technologies, communications)
• New technology for security standards	
• Renewal of coast guard/fleet solutions	
Port Development	**Marine Recreation**
• Harbour bottom clean-up	• Non-toxic bottom paint
• Improve docking and mooring facilities	• Marine parks, marinas, diving parks
• Improve the management of contaminated bottom sediment	• Non-toxic bottom paint
• Cost effective concrete/steel composite structures	• Electrical or environmental propulsion for small craft:
• Offshore support terminals (see oil & gas)	• Toys - the next seadoo, U/W gliders
• Floating offshore base	
• Cost effective concrete/steel composite structures	

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• Climate change research, sea level rise impacts, prediction of rogue waves	• Sediment decontamination. Use of fill material. Habitat regeneration (organisms that remediate sediment contaminated by metals and chemicals)
• Exploiting data through visualization analysis, 4 dimensional modeling, ocean process simulation and data fusion	• Research and project on habitat zones regenerated using sediment
• 3D computational modeling of ocean systems with high energy flows (currents, tides, etc.)	• Develop methods for treating ballast waters
• Coastal erosion studies (Atlantic Coastal Action Program)	• Research to identify sources of pollution (industrial pollution found in sediment)
• Venus and Neptune; Identification of critical tech's over the next 5-10 years	• Underwater work and technological expertise in underwater projects (in cold and confined waters) Visibility in turbid waters
• Remote controlled sensors and control systems	• Tidal power renewed look, last done in '60s maybe small/medium scale development
• Deep water mapping including living resources	• Location of seals
• Carbon dioxide sensing	• Climate Change: Including; sea level; ice change; weather; use of TEK; instrumentation
• Fish counting (acoustically, optically)	• Ocean/wind power
• Power engineering	• Communications software technologies
• Coastal erosion studies (Atlantic Coastal Action Program)	• Develop new environmentally friendly paints (antifouling)
• Autonomous underwater vehicles (AUV) used as sensor platform navigated by GPS and fed information from shore	• Storage, conversion, switching of energy and change input to usable emerging technology
• Climate change research, sea level rise impacts, prediction of rogue waves	• Efficient turbines for tidal, field based generation and reverse generators
• Seabed resources map:	• Deep methane generation of U/W coal seams
	• Wave, tidal, thermal energy generation of U/W coal seams
	• Develop new environmentally friendly and economical dredging technologies
	• Environmental wave and tidal, power, ocean thermal energy conversion (OTEC)
	• Wind, wave, alternate energy sources devices design

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
• Organic: Market research for management plan	• Data processing
• Animal species behavior	• Data management & collection forecasting systems to understand natural factors over long periods, the ecosystem, climate change data from past prediction
• Offshore production caging, holding, feeding, platforms	• More efficient regulatory instruments surrounding effective use of by-catch required.
• Adapt existing automated systems for maintenance and integration (sensors, robots, AI, etc.)	• Closed-loop farming adapted to northern climates
• In situ real time sensors for turbidity, chemical makeup of waste, monitoring, size counting, toxic alerts, and toxicology	• Net monitoring
• Adapt existing automated systems for automated disbursement and integration (sensors, robots, AI, etc.)	• How do fish think? Lotek-Net 5000 Y0Y
• Broodstock technology	• Adapt existing automated terrestrial/marine and satellite systems for forecasting and integration (sensors, robots, AI, etc.)
• Deeper water aquaculture	• Aquaculture synoptic & real-time oceanography for fin fish and shellfish
• Closed-looped farming	• Adapt existing automated systems for detection (military?) and integrations (sensors, robots, AI, etc.)
• OR-HAB: real-time and synoptic oceanography for prediction and optimizing growth parameters	• On growing wild fish in aquaculture technology, which includes fishery-based culture and culture-based fishery.
• Closed environment aquaculture techniques	• Inventory technology for benthic infauna (geoduck, clams)
• Offshore production aging, holding, feeding, platforms	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity
• Sea bed classification (tools, models for sitting design)	• ROV and AUV development and sensor integration
• Fish health	• Non-destructive survey tools for fish and habitat assessment:
• Traceability technology	• Mechanical systems
• Contamination of wild stocks	• Advanced cameras & advanced sonar
• Extract proteins from aquaculture waste e.g. For food supplements	• Flume tank testing
• Systems engineering and advanced materials	• Adapt existing automated systems for collection, logging and integration (sensors, robots, AI, etc.)
• Adapt existing automated systems for automated	• Data collection & forecasting systems for

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
disbursement and integration (sensors, robots, AI, etc.)	climate with remote operating bathymetry and surface sensors
• Water treatment re fish and effluent pollution from aquaculture-science	• Systems engineering and advanced materials
• Aquaculture site waste management	• Surveillance & management of wild species:
• Instruments to monitor environment and measure effects of aquaculture	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity.
• Environment/conservation technologies: Molecular Diagnostic tools (rapid tests)	• Bio-processing technology (i.e. enzymes)
• Telemetry	• Aquaculture synoptic & real-time oceanography for fin fish and shellfish
• Animal health (wild and domestic)	• Adapt existing automated systems for detection (military?) and integrations (sensors, robots, AI, etc.)
• Containment	• On growing wild fish in aquaculture technology, which includes fishery-based culture and culture-based fishery.
• Waste management	• Inventory technology for benthic infauna (geoduck, clams)
• Fish: Stress management and reduction	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity
• Tagging (biological and mechanical)	• ROV and AUV development and sensor integration
• Shorten time to market for aquaculture products	• Non-destructive survey tools for fish and habitat assessment:
• Tracking technology (laser)	• Mechanical systems
• Automated monitoring related to aquaculture	• Advanced cameras & advanced sonar
• Waste management: By-catch management. More efficient regulatory instruments surrounding effective use of by-catch required.	• Flume tank testing
• Biomonitoring	• Adapt existing automated systems for collection, logging and integration (sensors, robots, AI, etc.)
• Eco-system analysis	• Data collection & forecasting systems for climate with remote operating bathymetry and surface sensors
• Technologies to optimize farming in Quebec's climate (ice thickness and optimum farming)	• Systems engineering and advanced materials
• Winter solutions	• Surveillance & management of wild species:
• Robots	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity.

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
• Automated monitoring related to aquaculture	• Bio-processing technology (i.e. enzymes)
• Bio-med products to improve fish health	• Aquaculture synoptic & real-time oceanography for fin fish and shellfish
• Biomass detection systems	• Adapt existing automated systems for detection (military?) and integrations (sensors, robots, AI, etc.)
• Early warning toxic bloom systems	• On growing wild fish in aquaculture technology, which includes fishery-based culture and culture-based fishery.
• Baiting	• Inventory technology for benthic infauna (geoduck, clams)
• Trained predators	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity
• Market research for management plan	• ROV and AUV development and sensor integration
• Technology transfer	• Non-destructive survey tools for fish and habitat assessment:
• Rearing technologies	• Mechanical systems
• Containment: physical: net materials, anchoring systems, deep ocean pens	• Advanced cameras & advanced sonar
• Biotech advances and application	• Flume tank testing
• Biological advances	• Adapt existing automated systems for collection, logging and integration (sensors, robots, AI, etc.)
• Collection systems	• Data collection & forecasting systems for climate with remote operating bathymetry and surface sensors
• Waste Management: Processing waste stream (composting, stabilization of offal).	• Systems engineering and advanced materials
• Extend life cycle of parts and equipment: application of ceramic metal powder (protective enamel)	• Surveillance & management of wild species:
• Marine aquaculture, new solutions	• Remote sensing quality assurance, and advanced technology in processing to ensure product diversity.
• Develop technology for culture operations, management and development (e.g. systems for reading marine inventories)	• Bio-processing technology (i.e. enzymes)
• Environmental management of aquaculture sites	• Aquaculture synoptic & real-time oceanography for fin fish and shellfish
• Technology for "safe" large-scale aquaculture farming (e.g. shellfish)	• Adapt existing automated systems for detection (military?) and integrations (sensors, robots, AI, etc.)
• Rearing techniques	• On growing wild fish in aquaculture technology, which includes fishery-based

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
	culture and culture-based fishery.
• Alternative species	
• Cage design	
• Automated feeding	
• Ice & ice management	

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
• Advanced hull design shapes	• Exploration impact on lobster and other sensitive stocks
• Advanced materials for Category 5 Icebreakers	• Crew transportation
• Advanced materials for fast ferries	• Subsea service & maintenance
• Alternative fabrication techniques	• DP systems
• Alternative materials	• Deep sea calibration facilities
• Automatic identification system for vessels (affordable AIS for pleasure boats):	• Subsea equipment
• Ballast water treatment systems	• Year round reliable access for heavy equipment and supplies: Develop alternate transportation systems
• Ballast water treatment through UV, hydro cyclonic, nitrogen Y2/10Y	• Models incorporating arctic concerns
• Category 5 icebreaker	• Lack of understanding of the effect of development: Improved modeling techniques
• Coastal patrol vessel<100ft	• Feasibility: Logistics Studies; complex systems modeling: Software and modeling
• Composite materials for SWATH	• Project Definition: regulatory requirements; information support systems: Data mining
• Construction using materials and technology to build lighter vessels to increase payload capacity	• Deep water simulation
• Design of rapid ice-breakers for coastal shipping	• Crew evacuation systems, alternative safety
• Design techniques for Floating Production Storage and Offloading systems (FPSO) and topsides	• Evacuation and rescue in harsh environments
• Design vessels adapted to the context of the St. Lawrence to improve handling and transshipments	• Cold climate sewage handling
• Design vessels for the conditions of the St. Lawrence	• Disposal/containment
• Develop tools to improve naval construction management (time and task optimization,	• Environmental feasibility study

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
etc.)	
• Environmental technology for treatment and monitoring of ocean discharges, specifically oily water from ships	• Environment instrumentation to monitor chemicals, heavy metals, sewage
• Environmental U/W vehicles/monitoring payloads	• Pipelines with longs spans sub-sea
• Environmentally friendly anti-foulants	• Environment Technology to treat drill cuttings
• Extend the life cycle of composite materials	• Exploration impact on lobster and other sensitive stocks
• Fast ship technology & -propulsion systems	• Template design
• Faster, ore modular load and unloading systems	• Shore based control of offshore drilling
• Fibre optics training	• Robotic intervention
• High speed transport	• Diverless intervention
• Hull design	• Transporting gas by ships
• Increased productivity technologies	• Rig design
• Innovative construction, develop technologies and tools to improve productivity	• Sub-sea pipeline in-situ repair
• Materials and components, polyurethane, ethylene	• Deepwater AUVs
• Multiuse offshore diving support vessel	• Deepwater subsea processing Y3/5Y
• New ferries need modular designs	• Deepwater minimal platforms (automated)
• Next generation surface tolerant coatings (e.g. For ballast tanks where lot of corrosion	• Station keeping (DP) development
• On-board expert vessel operations management system (general maintenance ballast transfer)	• Deepwater down hole separation
• Outfitting tech for small vessels	• Smartwell technology
• Photometry to convert photos of ships for repair to digital 3D models for production of replacement plates	• Risers & moorings
• Pilot projects re adaptation to the marine field through technology aggregation	• Deepwater gas transportation
• Podded propulsion systems & other emerging technologies	• Deepwater pipelines
• Recycling single hull tankers	• Deep water APIs, ROVs
• ROVs and AUVs	• Deep water sub-sea processing
• Search for new equipment (NGV – regulation)	• Next generation autonomous underwater vehicles
• Shipbuilding processes & techniques to produce modular vessels and mass production techniques for "one offs"	• Train capable onshore companies for offshore diversification

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
• Simulation training for mine countermeasures	• Need to improve the current safety-system for evacuation of offshore platforms through development of mechanisms for deployment of chutes due to freeboard as well as technical issues (wind)
• Submarine AUV, ROV construction	• Tech Transfer; documentation of previous solutions through searchable data bases: Information & Multimedia
• Technology adapted to winter environments (construction, outdoor painting)	• Robotic systems; technology integration
• Training courses for all marine	• Extended horizontal drilling (10+km)
• Training techniques for FPSOs and topsides	• Feasibility; Seasonal Constraints; complex systems modeling: Financial modeling
• Treatment and filtration systems for ballast water	• Gas hydrates – drilling/drilling systems; insulation vs. refrigeration
• Vessels specifically designed/optimized for ROV/AUV operations	• Eliminate redundant equipment; well head systems; integration of current technology
• Voisey's Bay Shipping	• Synthetic drilling fluids
	• Composite risers
	• Piloting of ROVs
	• Data integration
	• Composites technologies e.g. light weight superstructures
	• Need to improve the current safety-system for evacuation of offshore platforms. Need for development of materials for this application that are fireproof. (New application of an existing system requires R&D)
	• Production: Testing protocols; testing demonstration facility broken ice vehicle; possible national facility
	• Protection/operation of people and equipment in cold climates: New Materials
	• Effects of Global Warming: More effective models
	• Wireless communication facilities
	• Deepwater oceanographic information (ice, etc)
	• Impact of hydrate on platforms/islands: Improved mapping techniques
	• High speed wide bandwidth system
	• Improved monitoring technology (wildlife, plants)
	• Icebreaking towing
	• Spill detection

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
	• Seismic streamers
	• Environmentally friendly seismic sounds
	• Innovative seismic tools
	• Wearable computers
	• Deepwater flow assurance (hydrate migration, etc.)
	• Deepwater down hold sensing
	• Remote sensing and surveillance (water temp, current, etc)
	• Multiphase metering
	• Deep water modeling technology development
	• Subsea pipeline leak detection, inspection
	• Ice scour mapping by seabed modeling
	• Topsides fabrication
	• Harsh ocean production technology
	• Spill detection
	• Deepwater flow assurance (hydrate migration, etc.)
	• Deepwater down hold sensing
	• Remote sensing and surveillance (water temp, current, etc)
	• Subsea pipeline leak detection, inspection
	• Improved data visualization
	• Ice scour mapping by seabed modeling
	• Topsides fabrication
	• Harsh ocean production technology
	• Environmental simulation training
	• Desalination technology
	• Deep water training
	• Information gathering, physical oceanographic data technology
	• Deep-water construction

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
• Acoustic array transducer design	• Development of maintenance-free independently powered aids to navigation
• Acoustic array handling system design	• Barge-tub linkage systems to increase flexibility and expand load capacity
• Remotely piloted vehicles for surveillance in 200 mile zone	• Self unloading vessels
• AUV technology	• Well vessels
• Submarine rescue technology	• Aquaculture utility vessels
• Design and development of multi role, high speed coastal patrol vessel	• Treatment of ballast waters
• Marine data networks – integration of existing systems	• Modeling channel sedimentation
• Development of standards	• Simulation training for sub-sea rescue
• AUV to monitor pipeline activity need development of propulsion system	• Various electronic and communications, safety
• Demand for maintenance of underwater facilities, communication lines, etc. requires underwater hard suits currently made of metal to be made of composites to reduce corrosion, cost and fragility. Need more structural integrity.	• Cruise and tourism management
• Remote sensing	• Positioning systems for confined waters
• Emergency communication	• Free flow of transshipments of goods
• Deepwater surveys with better and cheaper bathymetry	• Insitu and remote sensors
• AUV's to monitor pipeline activity need command control for multiple AUV operation s	• System for monitoring illegal discharges
• Underwater communication (digital, secure & convert); ship to sub, sub to sub and sub to shore	• Permanent navigation buoys in the Great Lakes
• Container scanning	• Need ability to function in high electromagnetic interference and without solar power
• Under-sea port defense	• Integration of communications technologies
• Acoustic arrays	• Weather conditions
• Intrusion detection for nuclear power plants	• Improve communications coverage
• Screen ships further away from port	• Tie marine information to vessel management
• Container scanning for contraband, nuclear, human smuggling	• Precise bathymetry on vessels of opportunity
• Mine countermeasures sensors & vehicles	• Navigation in confined waters and voyage optimization on the St. Lawrence/Great Lakes
• Improve detection and control systems (stowaways, drugs, explosives, firearms,	• Technological development for real-time monitoring of ice thickness in the channel

Medium Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
cargo, crew, etc.)	
• Coherent radar for low cost coverage of small areas	• Anode, batteries
• Over the horizon radar development	• Electronic charts AIR VTS
• Surveillance equipment for containers including radioactive detection	• Winter navigation and night navigation in winter
• Container screening systems needed for; navy screening machine	• Transshipment technologies
• Database info system needed for container screening	• Environmental fuel consumption
• Need ID screening mechanism	• Environmental Ship emissions of air & water
• Need better information on sub seawater column and surface through a combination of sensors, video, acoustic and signal analysis	• Lock operations & navigation technology to extend shipping season
• Long-range coastal detection system (200 nautical miles) including a data integration system:	• Ship transponders for fleet mgmt
• Submarine rescue techniques	
• Marine data networks – integration of existing systems	
• Development of security and defence standards	
• System Integration for naval and commercial applications across the board	
• Long-range coastal detection system (200 nautical miles) including a data integration system.	
• Submarine rescue training	
• Mine hunting training	
• Cargo inspection (national security)	
• Need to improve the current safety-system for evacuation of offshore platforms through development of mechanisms for deployment of chutes due to freeboard as well as technical issues (wind)	
• Environmental, safety insurance, liability, security, structural integrity of monitoring platform require Sensor integration for global view of entire structure rather than specific view	
• Acoustic array signal processing	
• Need better information on sub seawater column and surface through a combination of sensors, video. Acoustic and signal analysis	

Marine Safety, Communications, Transport, Recreation & Port Development	
Port Development	**Marine Recreation**
• Harbour clean-up	• Numerical modeling
• Engineering and marine and harbour environment	• Sea tourism for the aging baby boomers
• Integrate road, barge & ocean shipping	• Integrated coastal zone management
• Transportation hub will also require a year round link to South	• Vessel construction techniques
• Integrated coastal zone management maps (GIS)	• Low cost Auto Information System (AIS) equipment
• Global vessel tracking database	• Hull inspection technology
• Wharf protection (ice)	• Resins and more environmentally friendly materials
• Harbour modernization	• Three Way Catalytic Converter (TWCC):
• Improve handling methods	• Friendly & smart navigation tools for recreational boaters
• Vessel technology coastal/transponder	• Automated data collection for area management
• Technology to identify persons or other contraband (drugs, explosives, etc.) hidden in containers	• Close piloting navigation system to supplement radar
• Degaussing range	• Lighting for salt water aquariums for the hobbyist investigate spectro-characteristics
• Sensors for harbours	• Smart navigation systems (see safety mechanism systems under security and defense)
• Technologies to lower building cost, e.g. insulation to cover permafrost	• Expert systems for the engine room
• Alternative materials	• Technology to replace 2-stroke marine engines with 4-stroke (driven by environmental effects)
• Navigational aids	• Development of new types of excursion vessels
• Vessel traffic management systems	• Live rock and live sand technologies for reef restoration
• Large ship bulk material handling systems	• Green motorization
• Global vessel tracking database	
• Harbour at Tuk is too exposed, too shallow, too prone to silting	
• Information integration	

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• New technologies to collect seabed data	• Virtual reality based (marine) training
• Bottom penetrating sensing software	• Web based (marine) training
• SEAMAP national program	• Improve ship waste management
• Accurate seabed mapping: new technology to interpret existing data	• Environmental cleanup & treatment technologies
• Smart maps and charts (multi data/information; multi media	• Mitigation of environmental impacts e.g. Thermal phase separation Y5Y
• Large dataset manipulation in real time	• Improve environmental response times
• Data warehousing techniques for massive data sets	• Effectiveness & risk management of training methods (insurance companies will reward proven effectiveness)
• Data management and interpretation Interdisciplinary nature of the applications of this data	• Develop new techniques for minimizing the impacts of dredging
• High-volume, multi-dimension data management tool	• Identification of under exploited marine resources such as various species and pharmaceuticals
• New sensors (improved penetration) particles in the water column	• Tidal electric generation
• Send video through water at 4 or 5 megabytes/hr with and without cable	• Environmental wind power
• Data fusion	• Tidal and wave power
• Real time data for safety and marine activities (weather, sea state, sea bed, water column date	• Improve environmental response technology
• Coastal and sea level monitoring systems Y2/5Y	• Semi permeable membrane monitors
• Neptune Project support with instruments, AUVs, ROVs, sensors, communications and mapping	• Identification of under exploited marine resources such as various species and pharmaceuticals
• Sea bed classification tools	
• Shallow water and beach mapping systems and tools	
• Coastal and sea level monitoring systems	
• Integrated coastal zone management sensors	
• Bottom penetrating sensing hardware	
• Leveraging, positioning and multi sensor fusion	
• Underwater sensors	
• Water Column – direct density measurement	
• Smart molecular sensors to sense specific compounds for offshore/pipeline contamination using: lasers, video, DNA chips like land based explosive detectors	

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• Sub-bottom – pathogens monitoring	
• Submerged sensors or sensors on buoys:	
• Oxygen sensors, long term, low cost fast	
• Pathogens e-coli sensing	
• Forecasting ocean environments	
• Radarsat/R.S. coastal management	
• Data inter ret storage through 'self describing structure' comprising signal processing, data cleanup, event detection	
• Real time data for safety and marine activities (weather, sea state, sea bed, water column data	
• Integrated coastal zone management software	
• High speed continuous transmission through water calibration, laser, acoustic, RF	
• Develop mapping technologies for dredging operations	
• Large dataset visualization	
• Reservoir visualization	
• Oil spill detection and mgmt remediation	

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
• Value-added processed foods:	• Design innovative fishing vessels (beat 65' rule) catamaran design
• Monitor in situ fish inventory (weight, health, activity, numbers).	• Shrimp trawl beam (buoyant) 40'x 2 ½ "d AL2 to keep mouth of net open (increased catch)
• Technology transfer	• Vessel hull technology; bulbous bow; multihull; podded propulsion; motion control
• Cage-culture deployment	• Gear, e.g. trawl doors & other boards & beam trawls TM (the science, design, fabrication and business)
• Optimization of feeding (training/technology)	• Trawl door design
• Monitoring and inspection technology for emergent pen-design technology	• Trawl performance for drag efficiency
• Value-added processed foods: Infrastructure (processing technology for regulatory approval; and monitoring technology)	• Smart trawl design
• Predator Management	• Trawl doors affect fuel consumption
• Value added products from waste stream (e.g. Oils, vitamins, minerals)	• New methods of extracting compounds (e.g. molecules) from the resource
• Algae cultivation	• Equipment suitable for directed fishery (emerging species)
• Poly-culture technology	• Processing waste stream; (composting, stabilization of offal, value-adding).
• Flow efficiencies	• Humane slaughter methods (physical, stress management and improved techniques):
• Mort retrieval	• Electrical shock
• Market development of feed and feeding systems	• Mechanical slaughter
• Blood water disposal (big load on municipal waste system)	• Application of currently developing AIS to meet scientific needs in the collection of data and integration of sensor information
• Waste and by-product management (green)	• Environmental instrumentation for fisheries monitoring
• Aquaculture disease control vaccinations	• Fish grading image capture
• Shark and jellyfish protection	• Non-destructive survey tools for fish and habitat assessment:
• Bandwidth and integrated data management	• Gear, e.g. trawl doors & other boards & beam trawls TM (the fabrication)
• Alternative species research eg. Salmon, urchins, etc.	• Shucking
• Offshore production cost efficiency and cost control (related to aquaculture)	• Automated hydraulic clam digger
• Food production	• Data management & collection forecasting systems to understand, natural factors over long periods, the ecosystem, climate change data from past prediction, interrelations between fisheries

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
• Cage manufacturing design	• Bandwidth and integrated data management
• Marine recirculation technology	• Harvesting technology quality control
• Automated controls	• Harvesting & processing
• Development of robotic growing/harvesting technology (hardware)	• Reducing by catch technology
• Size and number discrimination	• Market development for underutilized species
• Adapt existing automated systems for identification, collection and integration (sensors, robots, etc)	• Gear, e.g. trawl doors & other boards & beam trawl TM (the business) Y2Y
• Fish counter	• Fish grading image capture and analysis
• Red-tide: real-time sensing; also telling the good from bad toxins to avoid benign blanket closings	• Lotek, tagged fish
• Measure health of fish	• Resource management technology
• Need for accurate fish-count: acoustic based technology (biomass)	• Need to deal with by-catch technologies for selective harvesting (catch what you can, not what you can't) Y2Y
• Open ocean container systems	• Aquaculture nutrition for new and existing species to lower cost. Development of fishmeal substitutes such as fish oil and canola plant protein.
• Blood water disposal system (big load on municipal waste)	• Live transport from production to point-of-sale (biology and handling)
• Automated controls	• Under utilized species (krill harvest):
• Coastal zone management requires GIS, mapping, etc.	• Aquaculture disinfectants for reduced environmental impact and increased effectiveness:
• Size and number discrimination	• Waste management
• Acoustic tracking	• Ballast water treatment
• Site selection for aquaculture, for other industries	• Spill dispersal & cleanup
• Shellfish: real-time data on water environment required to gauge effect of environment on product	• Marine emissions
• Remote monitoring systems, rather than divers checking nets	• Safety issues stemming from DFO regulations
• U/W control & communications	• Selectivity
• Remote monitoring	• Harvesting equipment
• Marine transportation logistics for live transport to markets	
• Coastal Zone Management Planning	
• Innovative/low-cost pen designs for holding fish/security	
• Kinds of fish – Atlantic Salmon, Black Cod (new technology required for bottom-dwelling fish)	

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
• Monitor in situ fish inventory (weight, health, activity, numbers).	
• In situ net inspection, testing and repair	
• In situ net cleaning (labour	
• Understanding the issues and develop appropriate technologies for fish-farming	
• Adapt existing automated systems for monitoring and integration (sensors,	
• Predation control	
• Prairie farm FEEDSTOCK sources	
• Monitor in situ fish inventory (weight, health, activity, numbers)	
• More efficient pumps	
• Pro-biotics	
• Organic certification technology	
• Recirculation Systems improving technologies; ongoing development by industry	
• Advanced net design	
• Advanced diving methods	
• Fish feed technology: soy and other different kinds of feed	
• Economics of land-based vs. coastal-based	
• Pen design – preventing fish-escape by re-engineering fish cages, also to keep out predators	
• Health of humans – how consumable is farmed fish	
• Genetic engineering of species	
• GMOs and genetic selection	
• Culture of different species using new technologies	
• Intelligent systems re: fish behaviour and water temperature	
• Physical feed development	
• Increasing demand for fish as food drives need for fish farms	
• Grow out tanks	
• Containment reduction	
• Opportunity for "deep-sea" (Cod) farming e.g. cages	
• Tank design	
• Cage design	
• Alternative species research eg. Salmon, urchins, etc.	
• Mooring systems for high energy	

Fish Capture, Seafood Harvesting and Aquaculture	
Aquaculture Engineering	**Seafood Harvesting**
environments	
• Alternative energy	
• Surrogate cages (rhedundant tankers) Y2Y	
• Integrated management of the use of water bodies	
• Feeding Systems	
• Geomatics applied to aquaculture	
• Waste Management: Mortality recovery	

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
• Abrasive resistant and low coefficient of friction coatings for tanks in self-unloader vessels	• Offshore refuge/refueling services (e.g. In the Virgin Rocks)
• Adaptation of Canadian shipyards to modern construction and management methods	• Underwater pipeline (Gaz Metropolitain) multi-beam mapping of routes
• Advanced (lean) manufacturing techniques	• Operations: Leak detection: Smart pipes; advanced materials
• Application of data to management for border crossings	• Risk assessment
• Automated info systems to track performance of key vessel systems	• Operational logistics (helicopter visibility, distance)
• Ballast water treatment	• Outfitting & completion
• Bandwidth and integrated data management	• Permafrost mapping by radar and remote sensing
• Bulk carriers, lakers (design, system, construction)	• Monitoring ability for Arctic Pipelines:
• Cable-laying vessels – modification of vessels for installation; prevent future repairs	• Ice mapping (thickness) by radar and remote sensing
• Cheaper ship based units	• Design of New Structures: e.g. Bottom
• CNG technology for ships (HDPE liner)	• One person felt that development of higher-pressure pipe was required whereas others believe that technology for this is available now, issue is that investment at mills is not categorized
• Coherent policy of ship components & competition for international advantage	• Oil & gas fisheries interaction
• Conveyor system for self-unloading vessels.	• Facilities that are compatible with fishing gear
• Design double hulls without altering the structural integrity of the vessel	• Infrastructure; environmental heating impact: Permafrost mapping by radar and remote sensing
• Development of technology clusters related to shipbuilding	• Access to historical data: improved distribution

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
• Double hulling technology	• Ice mapping (thickness) by radar and remote sensing
• Emergency response vessels	• Cultural issues, e.g., aboriginal
• Exportable Technologies/Designs. <<Best Arctic naval architects in world reside in Calgary	• Automation
• Fabrication training simulators	• Distance learning
• Fire retardant materials	• Facilities that are compatible with fishing gear
• Fleet renewal and search for the best vessels for Canadian Markets and existing	• Move to deepwater teleoperation, robotics, intelligent pigs
• Fleet renewal and search for the best vessels for Canadian markets and existing infrastructures (e.g. waterway) e.g. ferries or lakers-	• Riser moorings
• Fuel cell propulsion	• Outfitting & completion
• Gauging environmental effect of ships on marine mammals requires acoustic sensors	• Infrastructure; environmental heating impact:
• High value added vessels and systems	• U/W support, eg. U/W vehicles for exploration & survey, environmental monitoring
• LNG carrier	• Facilities that are compatible with fishing gear
• Low noise propellers	• Environmental. Analysis and impact studies
• Marketing international business technology	• Need monitoring systems for environmental weather forecast
• Materials, conduit coatings	• Predicting seismic activity requires remote sensors
• Merging data for goods tracking	• Wearable computers
• Monitoring of oil slicks	• Products for Permafrost: New cements for anchoring casing
• Multi purpose modular design for Great Lakes vessels	• Production: Emergency safety systems: Mechanical Design
• Need to specialize for exports	• Rescue in harsh environment
• New ferries design for robotic assembly	• Availability of construction materials for support structures and roads:
• Newdock Xmas trees	• Find alternate energy sources
• Pipe corrosion control (all leaks) on board vessels	• Availability of construction materials for support structures and roads:
• Procedural	• Predicting seismic activity requires remote sensors
• Propulsion systems	• Transportation – needs to be secure
• Quality control systems & monitoring	• Newer: Seabed Classification; applies to oil and gas industry
• Recycling ships and old platforms	• Seismic issues become important with pipelines
• Reducing crew costs with evacuation &	• Possible use of AUVs as delivery system

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
safety systems like high-capacity chutes and rafts requires refinement and further development of existing design and components for cost reduction	
• Regulations for carrying sour gas	• Pollution monitoring and accountability (oil spills)
• Seabed resources mapping	• Air Quality Problem: New sensors or other measuring methods required as well as baseline data
• Ship design packages to market to foreign shipbuilders	• Technology for acquiring shallow geophysical data
• Ship design; patrol vessels; tugs, barges, ferries, design tools	• Transfer technology from Alaska
• Ship designs for export	• Refrigerated mud techniques so as to not degrade frost
• Ship dismantling and recycling	• Non-corrosive steel and materials coatings
• Ship repair technology	• Seismic impact/seismic transmitters; transceivers
• Shipbuilding innovation (value added construction)	• Advanced material technology in light/strong alloys
• Shipbuilding process; materials handling (cutting, vending, fabrication); robot assisted assembly; modular outfitting	• Harsh ocean composite material
• Shipyard blasting systems to deal with problem of water freezing	• Methane release
• Small icebreaking and supply vessels design and outfitting	• Research on Gas Hydrates in Permafrost (not same as land based permafrost):
• Small Water Area Twin Hull	• Need media products through multimedia research
• Smaller self-propelled unloading barges <5000 tonnes	• Underwater drilling systems (not surface based)
• Special ships & support vessels	• Deep water drilling
• Specialized vessels for export markets	• Oil & gas rigs and components, crew boats, supplies
• Surface preparation (sandblasting, paint) gas emissions, harmful products	• Undersea pipelines
• Systems that would allow ships to eliminate double ballast pumping by doing it when they offload	• Sub-sea platforms (Gulf of Mexico, south-seas) transport compressed gas by pipeline
• Thin steel technologies	• Dynamic Position Rigs predicated on real-time control systems
• Training in upstream capabilities	• Deep water construction techniques
• Transferring intuitive skills people I.P. development (capture worthwhile experience)	• Mooring systems
• Transferring intuitive skills technologies (new market opportunity)	• Distance learning &/or portable simulators
• Transport by barge modern schooners	• General skill upgrading

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
• Tugs & barges; operations design and build	• Training: Require some system we can take to North
• Tugs & port service vessels (inspired by CPF)	• Deep sea templates
• Tugs & port service vessels (inspired by CPF)	• Ship-based (CNG) gas transportation
• Ultra-light structure (honeycomb)	• Innovative (hybrid) structures
• Upstream design of offshore rigs and subsea templates	• U/W vehicle retrieval system
• Vessel design	• Portable drilling
• Vessel outfitting and completion Y0Y	• Subsea processing systems
• Waste reduction and management (air and water)	• Oil & gas fisheries interaction
• Waste water treatment (land/ship based or mobile). Note: four streams of water treatment (bilge, gray, black, ballast)	• LNG/CNG vessel design
• Water treatment systems	• Harsh ocean (deep, extreme weather specialty vessel design
• High-speed vessel monitoring and control technology (i.e. black box that includes engine, propulsion, hull & ship system monitoring)	• Subsea pipeline
	• Drill cutting disposal/waste mgmt
	• Environment instrumentation re: dissolved gases, oil spill detection
	• Isotopes in oil to trace after oil spills etc.
	• Conventional techniques won't work on oil in broken ice and tests/demo projects required, but cannot get permission to do as disposal; of waste products (garbage, drill cuttings, etc.)
	• Recycling technology
	• CNG/LNG facility
	• Specialty material handling
	• Protection/operation of people in cold climates: Protective clothing
	• Insulation
	• Shelters
	• Survey services
	• Simulators (ROV's, etc.)
	• Deep Water opportunities require remote Environment Sensors (acoustic v. optical) to measure currents etc. 1000m+
	• CNG technology
	• Ice technology
	• Bandwidth and integrated data management
	• Environmental Sensing

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Shipbuilding, Industrial Marine and Offshore Oil and Gas	
Shipbuilding and Industrial Marine	**Offshore Oil and Gas**
	• Clean Up & Remediation; Blowout management in broken ice: Oil degradation; needs chemistry research

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
• Deep water dynamics	• Fast coastal vessels
• Replacement vessels for DND	• Bridge automation
• Encryption and interception	• Self-loading and unloading
• Anti-piracy measures technology	• Medium speed urban passenger vehicle
• Bandwidth and integrated data management	• Double offloading speed
• Night vision equipment	• Innovative supply vessels/low operating Y cost models (design)
• Personnel & equipment scanning technology integration	• Handling and supplies
• Fabrication of fast ships featuring, water jets, marine turbines, surface piercing propellers	• Satellite communications
• Coastal surveillance remote sensing	• Telemedicine
• VTS: transponder technology	• Safety-related communication and tracking system
• Disaster recovery system, power, communications and shelter	• Traffic management
• VTS: Problem: impeded by global standardization, regulations	• Integration of all technological tools and additional technological development
• Risk management	• Integrated Marine Information Infrastructure
• Develop systems and taining for shipboard fire fighting, spills, sea rescues, etc.	• Integrated management of on-board marine information
• Submarine rescue	• Determine ice position and movement to facilitate winter navigation
• Personnel & equipment scanning technology integration	• Develop expertise in technology integration Y ongoing
• Personnel & equipment retina & fingerprint (biometric) scanning	• Pursue development and integration of electronic navigation tools ECDIS
• Enforcement systems	• Electronic navigation charts
• Remote monitoring of bilge-water for environment protection	• AIS
• Buoy power-management	• Currents
• Port/container security – container inspection, surveillance (visual, artificial nose) & tracking	• Remote community access
• VTS: Systems Integration	• Navigation Aids: (Conventional/shore based, versus new technology)
• Acoustics: Technology Transfer: Military to Commercial	• Real time, online monitoring of fluid performance (e.g. oil, coolants, lubricants)

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
• VTS: Mapping	• Voyage data recorders
• Vessel Traffic Management Systems (also Automatic Identification Systems); Incremental development and adaptation	• Night vision equipment
• Humanitarian de-mining (GIL land antipersonnel mines underwater)	• Lower N. Shore and N. Canada Development of special vessels (12 months) Y2Y (profitability, operation, applied research)
• Linear infrastructure for pipelines, ice management, ice engineering	• Bandwidth and integrated data management
• Iceberg management	• Legislative/government regulation
• Civilian platforms…such as fishing fleets as platforms for tech payloads and for e.g. Bathymetry, nautical data, etc.	• Placentia Bay trials gas ECS/AIS/VTS
• Port management technology after Sept. 11/01	• Data management in marine transportation
• Maritime security fleet/system (smooth)	• Demo opportunity through field trial of risk mgmt in marine transportation
• Disaster management	• Fleet renewal and search for new marine links (coastal and intermodal shipping)
• Port security	• Use new tools to reduce the number of pilots on board
• Mine and marine countermeasures	• Study to develop technology to keep the St. Lawrence Seaway open year round
• Sensor/probe for detecting presence of vessels or pollution technologies - intelligent dust-electrochemical or acoustic sensors, electrodynamic or thermodynamic sensors	• Shift from VTS to AIS; also involves Ports; also Ships and Industrial marine, Security and Defence
• Cargo inspection/control for detect weapons and drugs as well as stowaways	• International standards more of an impediment than technology
• Fisheries interdiction e-plates and SAR	• NW passage shipping operations
• Automated nocturnal scanning of lakes and rivers (beacon activation systems):	• Barge/container local transport
• Remote Security – surveillance buoys, coastline video	• Navigation Systems/adopt existing technology
• Technology to detect unexploded ordinance (UXO) in shallow water	• Integrated supply chain mgmt software
• Electronic noses	• Integrated electronic navigation system that would be used to identify obstacles or fishing gear.
• Detection Systems	• Integration of transportation systems (intermodality)
• Remote sensing of icebergs	• Transportation management system allowing monitoring from the point of origin to the final destination
• Ship black-boxes (similar to flight recorders)	• Reusable (and recoverable) non-leaching absorbent:
• Instantaneous language translation	• Ocean safety training

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Marine Safety, Communications, Transport, Recreation & Port Development	
Security and Defence	**Marine Transport**
• Anti-piracy technology for commercial and recreational vessels	• Need to train marine managers. Develop training tools.
• Ocean surveillance technology re: human traffic, drugs interdiction	• Chair in marine transport. Increase management support and training
• Surveillance systems (ID systems, digital radar, Internet, electronic charts, electronic bridge)	• Training simulators; virtual design
• Air-born sensors	• Floating booms available at high-risk sites:
• Personnel & equipment retina & fingerprint (biometric) scanning	• Life saving
• Winter and night navigation	• Egress & evacuation regulations
• Integrated logistics	• Icebreaking technologies
• Buoys: low bandwidth video from remote sources like buoys	• Cold water survival
• VTS: reduced cost of RF technology	• Profitability vs. technological development with implications for vessels
• Design of fast ships featuring water jets, marine turbines, surface piercing propellers	• Seaway open for 10 months of the year (ice thickness – Technology to be developed
•	• AUV's short range mechanical or biological

Marine Safety, Communications, Transport, Recreation & Port Development	
Port Development	**Marine Recreation**
• Structures for high currents environments	• Small boats sewage systems
• CNG/LNG facility design	• Large recreational boat building
• Permanent port at sea for emergency and refueling	• Development of large recreational boat building
• Ramp fitted to accommodate/transfer rail cars	• Marine archaeology submersibles
• Improve pier de-icing systems	• High quality yachts
• Automated dredging/water depth	• Quiet sea doors
• Structures for high currents environments	• Recreational submarines
• Deepwater AUVs multibeam visualization	• New underwater tourism sites
• Web-based ports information (see security needs) real time cargo tracking	• New pack-ice platforms for eco-tourism excursion
• Cargo tracking registration system (by radio frequency)	• Hulls
• Docking facilities	• Winter recreational navigation
• Economic modeling for ports	• Extend the length of the season
• Bandwidth and integrated data management	• Environmentally friendly outboard motor technology. For example, a four stroke engine
• Small craft berths (yacht-friendly) in working ports	• VTS: Commercial – making this affordable for yachting
• Remote (piggy-back) customs clearance	• Mini cruiser design for eco-tourism
• Find innovative solutions for responding to	• Soft shell life ring

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Marine Safety, Communications, Transport, Recreation & Port Development	
Port Development	**Marine Recreation**
drop in water level	
• Increase speeds of cargo transshipments	• Non-cumbersome life jacket:
• Onshore transport to move cargo quickly from ports	• Integrated life jacket attachment system with high-performance fibres (Kevlar)
• Marine data networks for data fusion	• Non-cumbersome life jacket:
• Municipal Infrastructure	• Integration and addition of information on navigation systems (multimedia electronic maps)
• Dredging & port protection techniques require development	• Fusion of sensors (consolidation) for the mass market
• Piloting & safety technology for all ships	• Hand held sonars for divers
• Habitat transformation and protection during infrastructure construction.	• Observation of marine wildlife U/W camera
• Need for R&D and training in harbour construction.	• Automated safety monitoring in swimming pools
• Harbour architecture and engineering in Quebec.	• Bending metal into complex shapes for 50-60 foot hulls
• Harbour defence environmental monitoring	• Advanced fabrication for yachts, boats, kayaks
• Use of dredged material	• Submarine tours
• Monitoring	• Salvage tours
• CNG/LNG facility	• Bandwidth and integrated data management
• Specialty material handling	• Adventure tourism…coastal Labrador, Newfoundland, Greenland, Eastern Arctic
• Using simulator for port development planning	• Inventory and thematic mapping of eco-tourism areas accessible by sea
• Titanic VR simulator	• Wreck diving
• Multi-modal container movement	• Small boats sewerage systems
•	• Reclamation methods for fiberglass and disposal technologies
•	• Acoustic exhaust system:

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• Batteries safer and longer life	• Desalination by positive displacement and reverse osmosis
• AUVs Y2Y	• Moorable, maintainable turbines for smaller creeks
• Fibre optic cable design	• Tidal flow power generation
• More robust sensors (longevity) required for arctic use	• Offshore wind farms
• Acoustic sensors design	• Transponders for fishing boats
• Station-keeping buoys for platforms	• Instrumentation sensing integration
• Artificial intelligence for autonomous vehicles	• Detection of invasive species

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• Autonomous underwater vehicle-fuel cells	• Further development of Doppler technology
• Power management cable and fibre	• Air quality problem: new sensors or other measuring methods
• Technology for transportation of samples	• Bandwidth and integrated data management
• Pharmaceutical and biological extraction	• Iceberg harvesting and market expansion
• Power engineering components	• Skills shortage technologies
• Materials and manufacturing for hostile environments	• Technology oriented skills transition from manual to semi-automatic
• ROV position feedback	• Skills marketing (export)
• ROV visualization	• NSERC should have Ocean Engineering Committee (with them just civil/mech) to facilitate ocean technology
• Expendable instruments that are cheaper, smaller, better, faster	• Development of a contaminated sediment management framework
• New tools for processing, displaying and interacting with data	• Instrumentation systems (oceanography and metrology)
• Management of dense information (multi-dimensional databank)	• Weather prediction: El Nina, etc.
• Biological indicators using animal species that are sensitive to contaminants in drinking water sources:	• Requires a great deal of data gathering, remote sensing, communication, etc.. Not achievable without method
• Tools for gathering data at sea with real-time transmission by means other than satellites	• Ocean resources for human foodstuffs, pharmaceuticals and nutritives
• Satellite environmental monitoring of oil spills, oil slicks	• Energy: alternate sources – driven by demand, capacity and environmental issues
• Consolidation of land and marine data (coastal geobase)	• Wave, wind, solar-pilots projects with BC Hydro
• Multibeams and visualization	• Photo-volatic collaboration with universities, institutions & corporations
• Marine data networks for scientific data projects	• Impact of Kyoto Accord – as a driver of environmental technologies?
• ROV pilot training	• Wildlife monitoring in Arctic: Marine Mammals (whales are key concern, e.g. more difficult to tag than bears)
• Environment change – communication and bandwidth + cost (access)	• Training technology (virtual software)
• ROV Mission planning rehearsal	• Biology (e.g. Ballast water)

Short Term Technologies Relevant to the Marine and Ocean Industry Technology Roadmap

Ocean Technology and Services	
Ocean Mapping Research	**Other Ocean Services**
• Sea-bed mapping: multi-beam techniques under ice	• Find an ecological cycle for sediment
• Hydrographic survey in turbid warm water layered over Arctic cold water	• Micro-hydro plants; less environmental damage
• Remote sensing technology	• Environmental training
• Fibre optic cable fabrication	• Tidal power – environmental. damage is a problem for commercialization
• Shark and jellyfish protection	• Disaster recovery system, power, communications, shelter
• Seabed classification	• Logistics…identification and management of information on trade
• Desalination: Land and Marine	• Data Assimilation through numerical modeling
• Emerging surveying techniques	• Newer: further development of Sonar Correlations
• Long-term maintenance; materials and anti-fouling	• Gauging Environmental Effect on marine mammals requires Acoustic modeling
• Disposable buoys for remote sensing	
• Environment instrumentation for oceanographic monitoring	
• Bandwidth and integrated data management	
• Network technology	
• Systems integration	
• Methane gas hydrates identification by acoustic mapping techniques; software to analyze signals; hardware for acoustic profiling, magnetic profiling, gravity meters, transient Electromagnetic equipment, sensor technology and interface	
• Surveying in a cost effective way	
• Expendable turbulence, tem & velocity sensors	
• In situ nutrient sensors	
• Remote measurement of ocean currents in deep water (3000m+)	
• IT, DIS issues for data management	
• Power management of sensors	
• Chemicals for deep water application	
• Identify resources and technologies for systems integration: collaborative development	
• Environmental Change requires scientific monitoring to detect/predict change; (ice and sea levels)	
• National sea boundaries	
• Ocean mapping applied to ocean sciences and to the management of coastal and ocean areas	
• New layers of graphic information (value-added) for related users (e.g. fisheries, sciences, defense)	

ANNEX C

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July 10, 2002

Mr. George Emery
Strategic Planning Officer
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National Research Council Ottawa, ON K1A OR6

Dear George.

First of all, 1 have to apologize for the lateness in my response to the discussions held in Moncton on February 8, 2002 between the MWF executive and yourself.

During that meeting, we were given the opportunity to express our concerns and viewpoints as to what we felt is necessary to protect the future of the Shipbuilding Industry. Specifically, what direction must be taken to map out and ensure a viable future for all shipyards in this country.

I will try and summarize in point form the position of our Federation regarding the future direction your committee must recommend to ensure the survival of our industry.

I. We have a real concern that the Advisory Committee as recommended in Brian Tobin's report, **A New Policy Framework for the Canadian Shipbuilding and Industrial Marine Industry,** has not been appointed. We feel this committee is a priority and should be appointed immediately.

2. We recommend that the final report of the Technology Road Map Steering Committee be reviewed and approved by the Advisory Committee prior to being presented to Government.

3. With the requirements of ship replacement needed for the Great Lakes Fleet, it is imperative that the federal government does whatever is necessary to ensure this work is done in Canadian yards. i.e., Saint John Davies, Port Weller etc. This will secure work in these yards for years to come and prevent any closures.

4. Federal procurement needs are at an all time high whether it is the Department of National Defence. Department of Fisheries, Department of Transportation, etc. It is essential that these procurement needs be carried out in Canadian yards.

5. Canada should learn from the example provided by the George Town Shipyard in P.E.I. where they have developed and are exporting harbor tugs to world markets. It would be a good idea to develop a prototype ship that could be specifically designed, developed and built in this country for export to world markets.

6. It is also very important that we design and develop a made-in-Canada solution to the developing offshore oil and gas resources of the East Coast and soon the West Coast of Canada. The opportunities for shipyards in this county are unlimited provided government takes the initiatives to ensure this work is done in shipyards in this country. The design and development of deep-water technology is a must to capture a large portion of this market share.

7. There has to be more money allocated to research and development (R&D) to enable companies to design and develop prototypes and new technologies that put this county on the leading edge of new products designed toward building our industry for the future.

It was decided that the MWF executive support the efforts of you and your committee to try and develop a clear direction as to the future of our industry. We feel, however, it is essential that our recommendations must provide an integral part of the Technology Road Map Committee's report.

I thank you for the work you have done on this issue and your anticipated corporation in the future.

Yours truly

Bern Harty

President

WB/BH/palmwfcawl

cc: Bob Chernecki, Assistant to CAW President Hargrove
Les Holloway. CAW National Rep.
*MWF/CA*W Executive