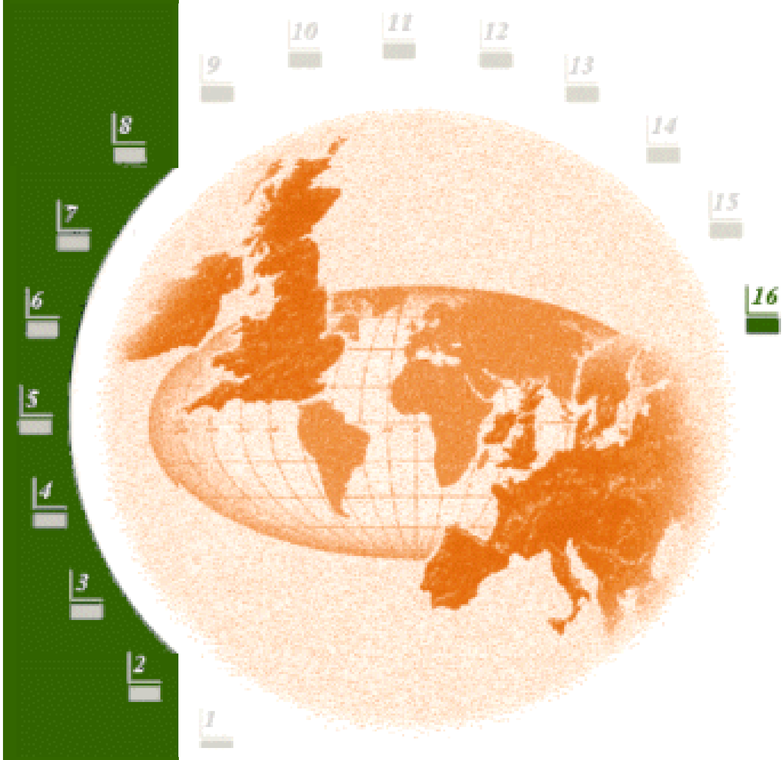
Foresight

PROGRESS THROUGH PARTNERSHIP

16



Office of Science and Technology

Foresight is a key policy initiative first announced in the White Paper on Science, Engineering and Technology. It embraces the dual themes of partnership and wealth creation. It brings together industrialists and scientists to identify opportunities in markets and technologies likely to emerge during the next 10-20 years, and the nwestments and actions which will be needed to exploit them.

The results of Foresight - drawing on contributions from a wide spectrum of skills and expertise - will inform decisions on spending, particularly by Government but also by industry.

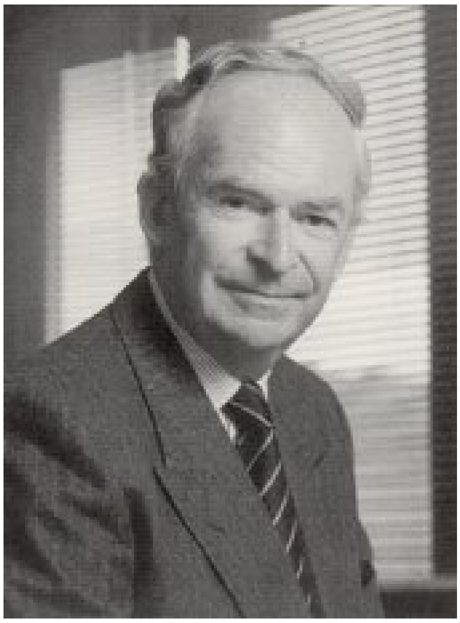
CONTENTS

MARINE FORESIGHT PANEL

This report was prepared by the Marine Foresight Panel. The views expressed are entirely those of the Panel. The membership of the Panel is shown below:

Mr David Goodrich	British Maritime Technology Ltd (Chairman)
Mr Tom Allan	Marine Safety Agency
Mr Kjell Avrin	Harland and Wolff
Prof Michael Baker	Aberdeen University
Mr Edmund Brookes	Chamber of Shipping
Mr David Clarke	Engineering and Physical Sciences Research Council
Mr Ray Coles	Ultra Electronics Ocean Systems
Dr Peter Dunn	AMEC Process and Energy
Prof Rodney Eatock Taylor	University of Oxford
Dr Chris Fleming	Sir William Halcrow & Partners Ltd
Mr Edmund Gmitrowicz	ACER Environmental
Dr Barry Hill	The Centre for Environment, Fisheries and Aquaculture Science
Mr Terence Lazenhy	BP International Ltd
Mr John Loughhead	GEC Alsthom Ltd.
Dr Brian McCartney	Proudman Oceanographic Laboratory
Mr David McKenzie	Marine Technology Directorate Ltd
Mr Bob Mulligan	Vosper Thornycroft (UK) Ltd
Dr Andy Norris	Kelvin Hughes Ltd
Mr Doug Pattison	Ministry of Defence
Prof Ron Roberts	University of Stirling
Mr Chris Stonehouse	Defence Research Agency Sea Systems
Dr Colin Summerhayes	Southampton Oceanography Centre
Mr Nigel Warren	FBM Marine Ltd
Dr Christopher West	Natural Environment Research Council
Mr Brian Wheeler	Brian Wheeler Associates
Mrs Arm Wilks	Department of Trade and Industry
Mr Michael Murphy	Office of Science and Technology (Technical Secretary)

FOREWORD



It was with pleasure and some trepidation that I undertook the task of chairing the Marine Foresight Panel. The inauguration of the Marine Panel was due to the recognition by the Office of Science and Technology of the marine sector's importance. We started our deliberations as a Panel some 12-18 months behind the original 15 Panels but, with the publication of this report, will have largely caught up with the main Foresight timetable.

The Panel's work has highlighted the importance of science and technology for the continuing health of the marine sector and, particularly, for the enabling skills and knowledge base necessary to exploit the many identified opportunities to expand the sector. Focusing on the right technologies will provide opportunities for commercial success, thus meeting the twin aims of Foresight - wealth creation and quality of life.

The first action agreed by the Panel was an independent economic appraisal of the UK marine sector. This confirmed how valuable the sector currently was in terms of GDP (4.8%) and employment (approximately 800,000 people).

The Office of Science and Technology [OST] and Government are invited to see the Panel's work during this phase as the first plank in developing a maritime technology strategy for the ongoing success of the marine sector.

Of the many recommendations which the Panel has made, probably the most important is that which seeks the appointment of a lead Government Department with ultimate responsibility for the coordination of issues affecting the marine sector. Because of its overall objective to promote industry, the Department of Trade and Industry [DTI] would be the most appropriate department to take responsibility for this role. Within DTI the Offshore Supplies Office [OSO] already carries out such a role for offshore oil and gas, and this might be a suitable model for the whole marine sector.

Finally, 1 would like to thank everyone who contributed so much to the work of the Panel: representatives from the research community, industry and government. It is a sign not only of their commitment but also of their belief in the future of the marine sector in the UK.

David Goodrich

David Goodrich
Chairman of Marine Foresight Panel
March 1997

BACK BACK TO INDEX FORWARD

MARINE FORESIGHT CHALLENGES

Offshore Energies
To achieve the capability for total subsea processing of hydrocarbons.
To improve the yield from existing hydrocarbon reservoirs by reducing proportions of residual hydrocarbons to at least half the current levels.

Maritime Transport and Construction
To develop efficient intermodal marine transport systems and to re-establish the UK as a major force in design, construction and operation of specialist ships, including high speed craft.

Marine Fisheries and Aquaculture
To improve aquaculture productivity world-wide through the application of UK biotechnology expertise.

Exploitation of non-living Marine Resources
To develop comprehensive operational oceanography to underpin marine environmental forecasting services.

Coastal Waters and Maritime Leisure
To increase exploitation of the coastal zone in proportion to population growth in a sustainable manner.

BACK BACK TO INDEX FORWARD

INTRODUCTION

The UK Foresight Programme is a systematic process for identifying market opportunities and related scientific and technological priorities looking up to 10 to 20 years ahead. The objective is to improve industrial competitiveness and quality of life. This information is used by Government and by the Research Councils in determining policy and allocating funds for research.

The programme began in 1993 when the Steering Group of Technology Foresight was established under the chairmanship of Sir William Stewart, the Chief Scientific Adviser to the Government. Sir Robert May took over the chairmanship when he became Chief Scientific Adviser to the Government in 1995. In Spring 1994, the Steering Group established 15 Sector Panels of experts to carry forward detailed technology foresight work on defined sectors covering the whole UK science base. The Panel on the Marine Sector was not one of these, on the basis that technology foresight for the marine industries would be accommodated within the other panels. However, as a result of representations by leading marine organisations and to ensure that marine technology priorities would be adequately reflected in the foresight process, a separate marine panel was formed a year later than the other panels.

The Marine Panel comprised 26 experts drawn from diverse fields, supplemented by five Focus Groups where additional expertise was represented. The five Focus Groups were: Exploitation of non-living Marine Resources, Offshore Energies, Marine Fisheries and Aquaculture, Maritime Transport and Construction, and Coastal Waters and Maritime Leisure. As some areas of relevance to the Marine Panel are also within the remit of other panels, the recommendations of these panels were taken into consideration.

The four collaborative research LINK programmes with marine interests were also taken into account, and these were:

- Advanced Sensors for Ocean Applications Programme (SEASENSE) sponsored by Natural Environment Research Council [NERC] and Department of Trade and Industry [DTI] with Government funding of up to £1.6m over five years.

- Aquaculture Programme funded by Ministry of Agriculture, Fisheries and Food [MAFF], Scottish Office Agriculture Environment Fisheries Department [SOAEFD] and NERC with funding up to £4.3m over five years.

- Hydrocarbon Reservoirs Programme jointly sponsored by DTI, Offshore Supplies Office [OSO] and NERC, with Government funding of £6m over five years.

- British National Space Centre [BNSC] Earth Observing Programme, funded by DTI, NERC, MAFF, as partners within the British National Space Centre, with Government funding of up to £2.5m over five years.

A number of consultation meetings were held during the course of the work, to augment the views of the Panel. In addition, a number of experts from industry, research institutions and academia were consulted. A number of written contributions were also received from individuals and organisations. All of these inputs contributed to the Panel's final recommendations. In considering the recommendations, priority was given mainly to technologies for wealth creation and quality of life in the next 5 - 20 years. Relevant environmental issues, sustainability, and the management of marine resources were also taken into account.

In conclusion the UK Marine Foresight Panel has confirmed the importance of marine related activities for the UK economy and it has identified technological challenges and opportunities for creating wealth, improving competitiveness, underpinning the development of marine policy and improving the quality of life. These have been reviewed carefully to formulate the recommendations in this report. The work of the Panel was carried out with limited resources over a period of thirteen months and the Panel's rernit covered the whole diverse marine sector.

Table 1 Turnover and Value Added by Marine Sector [Ref. 1]

Sector	Turnover	Value Added
	(£m)	(£m)
Oil and Gas	13300	10740
Leisure	8808	5964
Defence	5880	2350
Shipping invisibles	5580	956
Shipping	4354	2015
Shipbuilding	3480	1630
Equipment	3100	1250
Fisheries	2080	715
Environment	1200	400
Ports	1140	798
Construction	718	201
Research	561	269
Telecommunications	400	200
Safety	292	120

Crossings	155	87
Aggregates	146	76
Education	47	24
Totals	51241	27795

BACK BACK TO INDEX FORWARD

EXECUTIVE SUMMARY

Introduction

The UK is a maritime nation and most of its external trade is carried by ship. Marine activities make a very significant contribution to the UK's prosperity and quality of life. The added value of all marine related activities amounts conservatively to 4.8% of GDP, corresponding to a turnover of £51billion and an added value of £28 billion, with nearly 800,000 people employed. This may be compared with Defence and Aerospace: 3% of GDP, 250,000 people employed.

The UK marine industries comprise a variety of interdependent market segments providing products and services to global markets. These are listed with their component values in Table 1. All of the markets for the UK marine industries demand a wide range of key technologies, suitably qualified human capital and an understanding of the role of marine activities. These markets need to be supported by research and linked to other industries to underpin innovation and future competitiveness.

The UK has a strong academic and research culture, good links in Commonwealth and developing countries, a natural partnership with America, a small but technically advanced navy, a substantial offshore oil and gas and support industry and world leading information technology. These should be capitalised upon for wealth creation and improving the quality of life, enhancing the UK's competitiveness and underpinning the development of marine policy.

Drivers for Change

There are many and diverse drivers for change across the broad spectrum of the marine industries. The most significant of these drivers are listed below in priority order of value of the sectors given in Table 1.

Offshore Energies
For the offshore UK provinces to remain important in world terms the cost of hydrocarbon recovery from (i) new fields in deeper water, (ii) marginal fields in conventional water depths and (iii) mature fields, has to be competitive. In addition there is substantial pressure to rationalise decommissioning and to reduce environmental impact. There is also a need to develop reliable and socially acceptable marine renewable energy.

Maritime Transport and Construction
The increasing trend towards global manufacturing with just-in-time delivery, and potential for large increase in trade, provides a requirement for faster, more cost-effective cargo transportation. Population migration - which is leading to an increase in coastal zone populations - together with a worldwide increase in leisure time, creates a need for more and
faster short-sea transportation without compromising safety, for both passengers and

vehicles, together with associated intermodal transport infrastructure. For construction there is a need for improved production methods and the use of new materials.

Marine Fisheries and Aquaculture
World population growth and increasing popularity of seafoods occurs at a time of widespread decline in natural marine fish stocks. Aquaculture offers the potential to contribute significantly to the needs of the global seafood market and to new medicines and biochemicals from marine organisms for biotechnology applications.

Environmental
A greater requirement for environmental research and related services is being forced in response to such factors as: Global climate change, the growth of coastal zone populations, increasing competition for the use of the coastal zone; marine industry requirements for greater accuracy in local weather forecasts, increasing awareness of the need to manage various types of marine environmental impacts; and demands for protection of the marine environment through greatly reduced pollution.

Opportunities

The marine Foresight challenges identified by the Panel arising from the drivers for change present many opportunities for wealth creation and for improving the quality of life. The future prosperity of the marine sector will first need to be underpinned by:

- A national commitment and vision for marine technology in the long term.
- Better coordination of Government Departments' strategies for marine technology, with the aim of improving wealth creation and quality of life.
- A national strategy for marine technology involving industry, Government and funding agencies.
- More investment by industry in research and technology for the longer term.
- A stream of high quality graduates qualified in the marine sector.

Recommendations

The Panel identified many opportunities to exploit the diverse marine technology activities where the UK has unique skills and capabilities. These opportunities were based on the findings of the Focus Groups for the five marine sectors within the Panel's remit: Offshore Energies, Maritime Transport and Construction, Marine Fisheries and Aquaculture, Coastal Waters and Maritime Leisure, Exploitation of non?living Marine Resources.

Recommendations arising from the Panel's work fall into three categories: specific objectives from each of the five marine sectors, generic research and development necessary to achieve the objectives and policy.

Sector Recommendations

Research and development aimed at achieving the following is necessary:

Offshore Energies
Novel methods for hydrocarbon extraction from seabeds at depths greater than 1,000m in exposed locations. Technologies for subsea operations including autonomous underwater vehicles for operation at these depths; decommissioning and disposal techniques; improved drilling techniques; downhole and subsea processing; large diameter seabed pipelines and risers; energy from gas hydrates.

Economic development of marine renewable energy technologies, and the establishment of a UK focus for marine energy technology.

Maritime Transport and Construction
Efficient intermodal and multimodal transport systems, including 50 knot passenger and freight ferries. Fast, high volume loading and off-loading facilities; system and design integration for ship construction to improve speed to market and cost reduction with a supply chain and life cycle approach; safer and environmentally cleaner ships; "all electric" ships.

Marine Fisheries and Aquaculture
A better understanding of the dynamics of ecosystems involved in marine fisheries, reducing waste in marine fisheries; new species, genetic improvement and disease control in aquaculture; alternative protein for fish feeds; novel medicines and biochemicals from marine organisms.

Coastal Waters and Maritime Leisure
Models of inderdisciplinary processes affecting the coastal environment; integrated information system for improved resource and coastal zone management; enhanced navigation safety measures for coastal and port areas.

Exploitation of non-living Marine Resources
Operational oceanography to satisfy the need for improved marine environmental management in support of offshore businesses; improved ocean models and ocean-atmospheric models for climate forecasting; sensors and communication links for data acquisition and dissemination; high resolution seabed maps. All of these will contribute to the proposed International Global Ocean Observing System (GOOS), from which the UK will benefit.

Generic Research and Technology Recommendation

Achievement of these objectives will require, inter alia, research and development in the following fifteen generic technologies in the marine sector which are vital for wealth creation and quality of life. These generic technologies are listed in alphabetical order below. Organisations which we ask to take forward our recommendations are given in brackets:

- **Acoustic, optical, chemical and biological sensors** for capturing information to enhance understanding of the behaviour, and to provide monitoring of the health, of the marine environment and seabed (Industry, Natural Environment Research Council [NERC]).

- **Biotechnology** for new products and processes, including aquaculture (Ministry of Agriculture, Fisheries and Food [MAFF], territorial Government Departments (for Scotland, Wales and Northern Ireland), Biotechnology and Biological Sciences Research Council [BBSRC] and NERC).

- **Design and system integration** with life cycle cost optimisation for ships and offshore construction (Industry, Department of Trade and Industry [DTI], Engineering and Physical Sciences Research Council [EPSRC]).

- **Digital information technology**, applied to the marine environment (Industry, DTI, NERC, EPSRC).

- **Dynamics of marine ecosystems**, including fisheries (MAFF, NERC).

- **Environmental and climate forecasting** (Department of Environment [DoE], MAFF, Ministry of Defence [MoD], Meteorological Office, NERC).

- **Environment impact assessment** (Industry, DoE).

- **Integrated electrical systems** for high efficiency of marine vehicles and lower pollution products and techniques for marine vehicles (Industry, DTI, EPSRC).

- **Intermodal marine transport systems** (Industry, Department of Transport [DOT], EPSRC).

- **Material properties and adhesives**, (high strength, corrosion and fire resistant, lightweight, low cost, smart materials, coatings), and construction technologies (DTI, EPSRC, NERC).

- **Miniaturisation and nanotechnology** (Industry, Particle Physics and Astronomy Research Council [PPARC], EPSKC).

- **Numerical modelling and simulation**, (Industry, DTI, DoE, NERC, EPSRC).

- **Safety management and risk assessment methodologies** for marine vehicles and transport infrastructure (DOT, EPSRC).

- **Subsea automation and robotics** (Industry, DTI, NERC, EPSRC).

- **Subsea communication** (Industry, DTI, EPSRC, NEKC).

Policy Recommendations

To enable the UK to regain a prominent position, it is necessary to secure a lead in many of the marine sectors within the Panel's remit. This will require the continuing development of the science and technology base in the UK to be underpinned by Government. In addition to the inter-departmental and agency funding of marine science and technology, particular
support should be given for the development of marine science and technology in the Higher Education Institutions (HEIs).

To achieve these objectives in a cost effective and coordinated way the immediate steps recommended are:

- Appointment of a lead Government Department to act as the **UK authority for coordinating and sponsoring marine affairs with industry.** This recommendation was made by the industry and academic members of the Panel.

- Formulation of Government Departmental **strategies for marine technology** for the long term (10 to 20 years,).

- Effective **coordination of individual Government Departments' strategies for marine technology, together with those of Research Councils and other funding agencies,** in support of competitive development of the marine market sector (consistent with the individual requirements of Government Departments).

- Leading roles for Engineering and Physical Sciences Research Council **(EPSRC)**, the Natural Environment Research Council **(NERC)**, and the Biotechnology and Biological Sciences Research Council **(BBSRC)** to support strategic and targeted research in marine technology and for marine science in HEIs.

- Support for a national assessment of the requirements for **marine specialists** and for **marine education and training**.

- A **campaign to improve public awareness** of the importance of the marine sector to wealth creation and improving the quality of life in the UK.

- **National and international collaboration,** whenever opportunities arise, to enable UK to benefit from external sources of funding and to exploit overseas markets for UK research and technology:

  - Accession to the **Law of the Sea Convention**
  - Support for the **Global International Water Assessment** proposed by the World Bank through its Global Environmental Facility.
  - Support for the proposed ocean equivalent of the **Inter-Governmental Panel on Climate**

1 MARINE RELATED ACTIVITIES IN THE UK ECONOMY

1.1 The United Kingdom is a maritime nation. For many years skills in seamanship and marine technology have made a major contribution to the prosperity of the economy of these islands. Today, marine transport is the dominant method for importing and exporting goods; sea fish are a major food source; offshore oil and gas are the principal sources of energy; and marine activities are also vital for the implementation of our defence policies. Increased leisure means that the use of our coast and coastal seas for recreational activities will continue to expand and inevitably lead to conflicts of interest with other uses of coastal waters such as waste disposal.

1.2 On larger space and longer time scales, the United Kingdom's climate, unusually temperate for these latitudes, depends on patterns of ocean circulation. Understanding these patterns will help forecast any possible climate change and anticipate the consequences. The shipping and marine insurance sectors, which generate substantial invisible earnings, and which depend upon a knowledge of the frequently hostile marine environment, are among those which can gain international competitive advantage by exploiting the research and development knowledge base, which United Kingdom scientists and technologists are actively increasing.

1.3 This general awareness of the importance of marine-related activities for the United Kingdom economy can be expressed more exactly by analysis of the various marine sectors and their individual contributions. The work of the Marine Foresight Panel has been informed by recent analyses, and through the commissioning of a specific review of marine industries [1,2].The figures quoted below are for the financial year 1994-95, the latest for which information is available. Fuller details are available in the original publications.

1.4 The total annual turnover by the marine related sector estimated for 1994-95 is shown in Figure 1a and summarised in Table 1. This total marine-related turnover is estimated at £51.2 billion. The value added to the UK economy by each sector is estimated in Figure lb and Table 1, based on factor analysis and information from a wide range of sources. The total marine related value-added is £27.8 billion.

Figure 1a Percentage of Total Marine related Turnover by Sector, [Ref. 1]

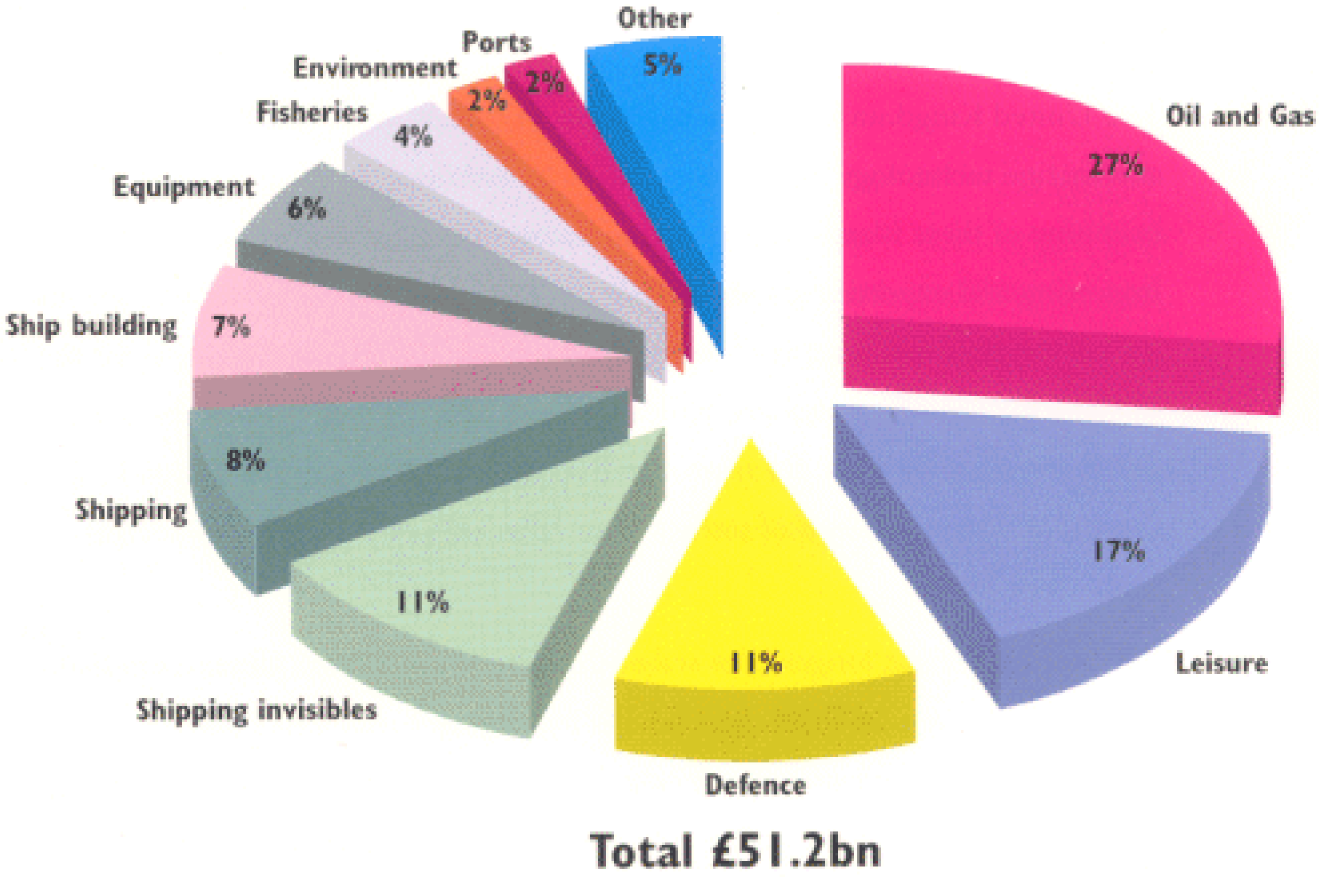
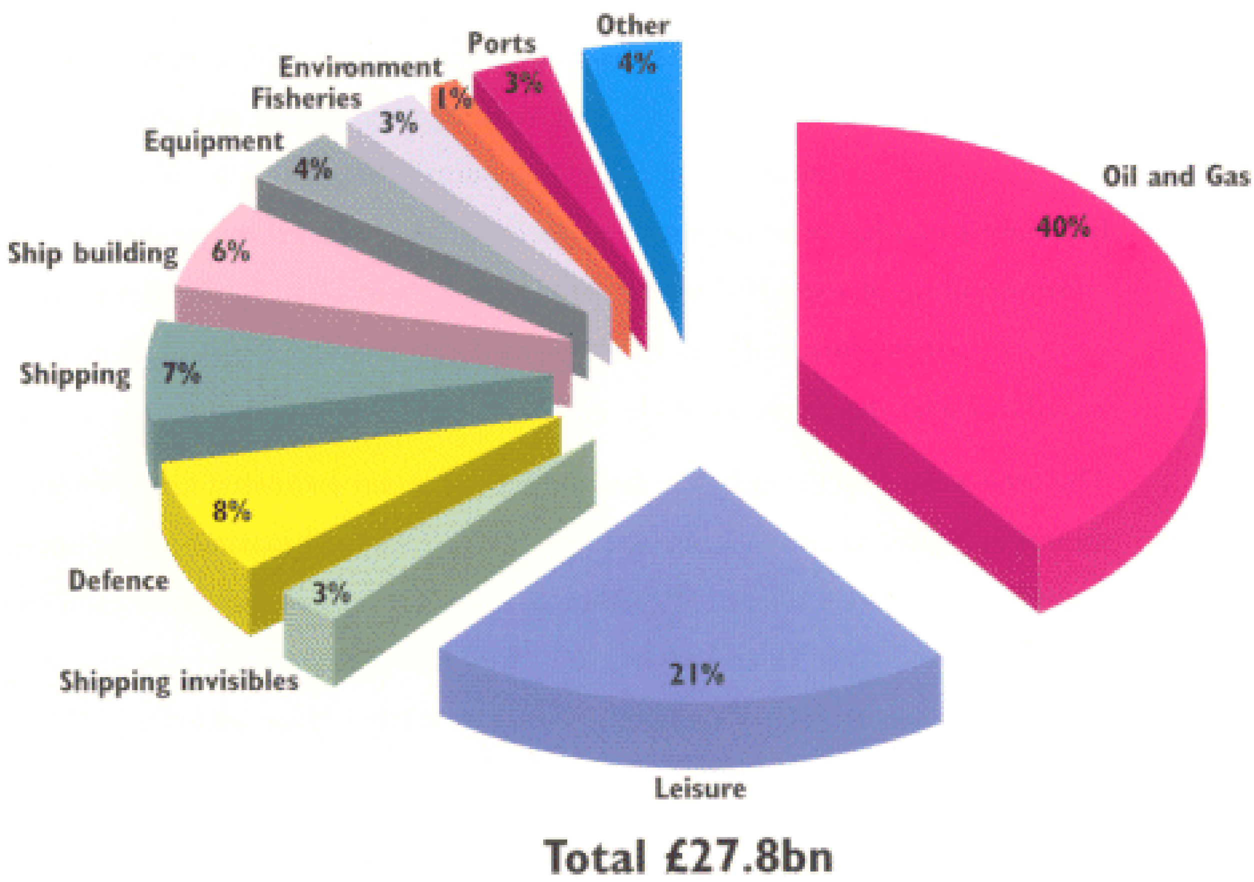


Figure 1b Percentage of Marine related Contribution to GDP by Sector, [Ref. 1]



1.5 In 1994-95 the CDP for the United Kingdom based on income analysis was £57.9 billion, giving a marine-related component of 4.80%. A value of 5% of the United Kingdom CDP for marine-related activities, estimated in an earlier analysis [3], centred on 1986, is not strictly comparable with these estimates because of different sources and procedures: however, if the 1986 survey had been made using the same procedures as the recent surveys, the value at that time would rise to around 6%, due to a much higher CDP contribution from the oil and gas sector at that time, although the level of production in that sector is now at a higher level than in 1986. The following additional comments on individual sectors are relevant.

1.6 Oil and gas is the most important marine-related sector of the UK economy. The contribution of the oil and gas sector to the UK CDP has varied considerably over the past 20 years, and as discussed this is often independent of the levels of production. CDP contribution depends on market prices and production costs, rather than directly upon production levels. The CDP contribution reached a peak of £19.6 billion nearly 7% of CDP, in 1984. By 1994 there had been some recovery from the very low world oil prices and CDP contribution of the late 1980s. In the mid-1990s the levels of production of both oil and gas continued to rise. Today emphasis is on the development of fields in deeper water, such as the Foinaven and Schiehallion fields west of the Shetlands, and on much shorter development times from field discovery to production. The CRANE initiative across the industry seeks to reduce the overall cost of production per barrel through a modular and standard approach to field development.

1.7 Leisure and recreation is a growing market sector with a strong marine component and high levels of employment. In addition to UK residents, overseas visitors totalled 9.1m, with an average spend of £54.8 per day, or £4bn in the year. The seaside element of this (43%) is therefore estimated as £1.7bn of overseas earnings. Holiday cruising is an area of strong market growth. Leisure craft comprise an expanding leisure activity which also involves boat and marine construction as well as the provision of a wide range of services. A recent analysis by the DTI estimates that some 4,000 companies supply equipment and services to the sector. The British Marine Industries Federation has estimated an annual turnover of £122m for retailers, and £424m for other services.

1.8 Naval operations provide a service to the nation, and are classed as a legitimate contribution to GDP. Although there have been significant reductions in defence expenditure in recent years, the Royal Navy remains a major employer, direct and indirect, of both service and civilian personnel, particularly in ship related design, manufacture and repair, where there is also a significant export contribution.

1.9 Invisible marine-related earnings by the City in 1994 have been estimated to make a GDP contribution of £956m. These earnings come from the operation of the Baltic Exchange, through various insurance activities, legal and financial services; and from Lloyds Register of Shipping. Year-on-year earnings are very variable because of major changes in insurance pay outs. Over the decade 1984-94 there has been a steady decline in earnings from financial sources such as ship mortgages, offset to some extent by substantial increases in insurance broking, P&I Clubs and legal services. Nevertheless, the decline over the period is about 37% in real terms.

1.10 Worldwide, shipbuilding remains active. There are expanding markets for cruise ships and ferries, with particular emphasis on multi-hull designs of smaller, faster craft for near shore and short passenger routes. Purchase of leisure craft is very sensitive to general economic factors and sonic UK boat builders reported reductions of turnover of more than 60% during the recession of the early 1990's, after sustained growth in the 1980's. Growth in 1993 and 1994 indicates that the decline has reversed; there are an estimated 200, predominantly small, UK companies constructing and repairing craft up to 60m overall length.

1.11 Marine equipment and materials is a difficult sector to estimate for many reasons. It includes a very diverse civil sector, partly covered by other sectors such as oil and gas production, ship and boat building and repairs, and fisheries. It also includes naval procurement, for which exact details are not available, a proportion of which are weapons to be operated at sea. Because of the diversity of the sector, any eventual marine application is not always explicit at the time of manufacture. For example, a winch or a pump may be used at sea or on land. Adding the procurement in the three fields of shipbuilding, naval activities and oil and gas sector investment, gives a total of £7.95bn. Without doubt there is double accounting in these figures, for example in the ship construction as a supplier, and naval activities as a purchaser. Faced with these uncertainties, rather than ignore the whole sector in the final analysis, a very cautious and probably conservative estimate has been made as the sum of the £825m from a DTI survey of equipment mainly for commercial shipbuilding, and specific construction for the oil and gas sector.

1.12 In the fisheries sector the UK fleet's UK landings consist of £292m of demersal fish, £34m of pelagic fish, and £1 28m of shell fish. There has been a gradual decline in the UK landings by UK vessels over the past decade and an increase in imported fish. Fish farming has been a growth industry world-wide over the past decade, and the UK industries have grown in parallel. For 1994, an estimated 20,751 fisherman (10,967 in England and Wales, 8555 in Scotland and 1229 in Northern Ireland) were involved in sea fishing in the UK. The direct port processing has been estimated at £1,263m providing 21,000 jobs. Average consumption of all fish in Great Britain was 71.54p per person per week, or £2.1bn per annum in total.

1.13 Expenditure on protecting the marine environment is very difficult to estimate, but is dominated by work to clean up waste water discharges to the sea. The sums of capital investment planned can be estimated from the k-factor embedded in the charging formulae approved by OFWAT, the Government regulatory body. From 1995 to 2000 an investment of £900m per annum is projected for construction. Additional operating costs of the plant are assessed at £300m per annum.

1.14 Civil engineering construction activities include estuary crossings, sea defences and harbour and marine construction. Dredging for port operations is also included. The level of these activities varies from year to year and can be dominated by a few major activities. The second Severn Crossing construction over a four year period cost £350m. MAFF estimate that £300m is spent each year on coastal defences around the UK. New orders for harbour construction placed in 1994 totalled £218m, a figure which has remained relatively constant over recent years. Dredging is a major expense in the maintenance of port operations: some dredging is routine and continual, but in some cases major capital investment is made to give new access facilities. For example, Associated British Ports have recently invested £28m in new channel construction by dredging in the approaches to Southampton.

1.15 Research and Development falls into three categories: University, Public Sector and Business Sector research. For Universities the estimated annual figure is £97m. Public sector research (£264m) is in support of Departmental policy objectives, to improve operational efficiency, or as a specific function (Research Councils). For the industrial sector, an approximate estimate of research and development expenditure based on typical spends and estimates from the companies involved is £200m per annum.

1.16 Telephone communication by cable is generally preferred by users to geostationary satellite links because there is less time delay. The market for submarine cables and submarine communication traffic has grown considerably in recent years, notably through the development and application of fibre-optic cables. The values given in Figure 1a and Table 1 exclude the telecommunication element (£1.6bn in call charges) as this is mainly related to land-based activities and may be compared with the value of goods carried at sea by ships, which is also excluded from the surveys.

1.17 Safety and salvage include a range of public and private sector activities. The activities of the Corporation of Trinity House, the Northern Lighthouse Board and the Commission of Irish Lights are funded by a levy on ships using ports in the UK and the Republic of Ireland (operating costs £65.7m).The Hydrographic Office (£33.36m), which operates within the Ministry of Defence, undertakes surveys and publishes nautical charts, timetables and other navigational information; a very high proportion of these are sold overseas. The Marine Safety Agency (£15.07m) operates on behalf of the Department of Transport to ensure high standards of marine safety and to minimise the risks of pollution from ships. The Coastguard Agency (£52.78m) also operates on behalf of the Department of Transport to minimise loss of life amongst seafarers and coastal users and to minimise pollution from ships to sea and coastline. The Health and Safety Executive (£30m) includes an Offshore Safety Division which operates an inspection team of about 450 people and its own research programme. The Royal National Lifeboat Institution (£64.7m) operates to save lives at sea around the United Kingdom and the Republic of Ireland. There are 214 lifeboat stations, each of which operates with some degree of autonomy and funding is through voluntary contributions. In addition commercial salvage activities were estimated at £30m.

1.18 Offshore aggregate extraction of sand and gravel in 1994 totalled 11.33m tonnes (11% of the total UK production). To some extent, the fall in UK demand during the construction industry recession in the late 1980's was compensated for by exports to Europe. Costs of transport are a high proportion of the final costs and so export to distant markets is unprofitable.

1.19 The reliability of these estimates varies considerably, in part because the marine related sectors are not separately identified in official statistics. However, some marine statistics are readily available from official sources. For example, in 1994, £114bn worth of goods were imported by sea, and £104bn were exported by sea. These constituted 78% and 77% respectively of the total value of exports and imports, equivalent to £1960 imported and £1775 exported for every member of the population.

1.20 Generally, however, statistics of marine related activities are much more difficult to synthesise. While there is no shortage of numbers, in the marine area there is no standard procedure for collecting them systematically. In choosing which activities are to be included as marine related, the surveys used a narrow definition: those activities which involve working on or in the sea, together with those activities that are involved in the production of goods or the provision of services that will themselves directly contribute to activities on or in the sea. Many activities are excluded. For example, in the cases of the fisheries sector and the oil and gas sector, only the landed value and the costs of initial processing are included. Consequently the figures produced are minimum estimates of the economic importance of marine resources and activities to the total United Kingdom economy.

1.21 There are also many examples of marine related activities which contribute to the quality of life of UK citizens, but which are not themselves classified as economic goods because no charge is made, and which do not appear in the figures quoted above. One example is the benefit of visits to the seaside. For 1994 the British Tourist Authority estimate 290 million total holiday nights of which 43% were seaside holidays. Surveys at 1988-89 prices suggested that people valued a beach visit at £7.65 per day, making an annual total of £2.22bn without adjustment for inflation. Another example is the money saved by discharging waste water with only primary treatment into the sea where there is high natural dispersion. Some 9% of the UK waste water is discharged in this way without the £160 per head additional costs which secondary treatment would require, at a total extra cost of £720 million.

1.22 The values for marine related activity can be expressed in more human terms. In 1994-95 the average value-added to the economy by each person in the United Kingdom was just under £10,000. For each person some £480 was marine related, and of this £9.60 was spent on research and development.

1.23 UK marine scientists and technologists in the academic institutions and research councils have an outstanding record and world reputation. They have excellent facilities and several have gained a top ranking in the Higher Education Funding Council for England [HEFCE] Research Assessment Exercise. This science and technology underpinning greatly strengthens the UK's ability to maintain and increase its world market share in marine business.

BACK BACK TO INDEX FORWARD

2 MAIN CHARACTERISTICS AND DRIVERS FOR CHANGE

2.1 This section reports the findings of the Panel's five Focus Groups. Some of the main issues that are common to more than one marine sector, such as environmental pollution, information technology and training and education, have been included in a separate section on cross cutting themes.

2.2 The Focus Groups formed to address the five marine sectors within the Panel's remit, have each produced a report viz.: Exploitation of non-living Marine Resources [4], Offshore Energies [5], Marine Fisheries and Aquaculture [6], Maritime Transport and Construction [7] and Coastal Waters and Maritime Leisure [8]. Summaries of the Focus Groups' reports are given in Annex 1.

Exploitation of non-living Marine Resources

2.3 With the growth in the world's population the coastal zone population is expected to increase by 10% by the year 2100, increasing waste supply, seaborne trade, coastal leisure, demand for resources (offshore mining of minerals and aggregates) and communication using seabed cables.

2.4 The increase in the volume of seaborne trade and in the number of passengers travelling by ship, especially high speed craft, will demand improved safety, environmental pollution prevention and control, as well as improved navigation, vessel traffic management and information services and surveying. Demands will also increase for a clean, green planet as embodied in the Earth Summit's Agenda 21, leading to monitoring of the oceans and regulatory enforcement by coastal states.

2.5 Technological advance and application will have a profound effect on almost every marine activity as a result of the growth in computer power, digital communication, information technology, miniaturisation, robotics and automation, and in the application of new materials.

Information Technology and Data Management

2.6 Information technology will grow in importance in addressing future market needs in the marine sector. There will be an increasing need for turnkey projects involving a complete package including data collection, assimilation of data into models, preparation of advice, and management of the resulting system.

2.7 In all data collection systems the trend is towards vastly increased rates of data capture from more and more observing systems. Adding value to this data by storing, retrieving, managing and manipulating it digitally to provide single factor products or to combine it in Geographical Information Systems (GIS) is increasingly demanded by customers, and holds out the promise of considerable business opportunities in the development of data processing services. There isgrowing evidence of an emerging global market for user-oriented information systems and for products designed to provide decision support for management, planning and operational activities in the coastal and offshore environment [9].

Offshore Energies

Future Energy Requirements

> Offshore oil and gas provide 25 per cent of the world's oil and gas production and account for about the same proportion of the world's known oil and gas reserves.

2.8 Some 75% of the surface of the globe is covered by sea and ocean, and today this environment supplies some 25% of the oil and gas produced, and accounts for about the same proportion of the world total of known oil and gas reserves. For the future the seas and oceans of the world represent a vast source of non-polluting and renewable energy, and it has been estimated that if less than 0.1% of the renewable energy available within the oceans could be converted into electricity, it would satisfy the present world demand for energy more than five times over.

2.9 The world-wide growth in energy demand over the next twenty-five years may be as much as 70% above today's levels, and while current thinking suggests that fossil fuel supplies will meet most of this increased demand, new fuel sources, will have to carry a progressively increasing share of the burden from about 2020 onwards. Any reduction in demand as a result of improved efficiency of energy utilisation in the developed economics is expected to be more than offset by the rise in demand from the developing countries.

Marine Energy Sources

2.10 The sources of energy from the marine environment divide into two distinct categories: the first is the existing international offshore oil and gas industry which can be expected to continue to make incremental advances within the Foresight timeframe. In the UK, this industry, together with its many supporting and service contractors, has undertaken a major assault on both its capital and operating cost over the last few years and is competitive at oil prices of US$15 a barrel or less. It is now embarking on developments in the deeper and more hostile waters west of the Shetland Islands and is positioning itself to continue production into the third decade of the next century.

2.11 The second category is the development of new sources of renewable energy from the marine environment, namely wind, wave, tidal and ocean thermal energy conversion. Here, there are several technologies, some of which are very new and some at more advanced stages of development. These new sources of energy may locally be economic oil small scales in today's energy market within the Foresight time-scale in the UK, and possibly on larger scales elsewhere. They represent possible future opportunities for UK industry if the technologies can be developed to be ready to meet the changing energy markets of the next century.

Offshore Oil and Gas

The offshore oil and gas industry accounted for some 17% of UK industrial investment in 1994 and contributed about 2% to the UK's GRP, and was also all important source of government tax revenues.

2.12 In recent years the offshore oil and gas industry has undergone major changes as it has sought to implement the lessons arising from the CRINE (Cost Reduction in a New Era) initiative and reduce its costs and establish new working practices. Much work has been done in identifying the requirements for research and development. A broad consensus exists on technology priorities and key areas for development, and these include increased reservoir yield, deep water developments, decommissioning and environmental protection, and the development opportunities offshore at Faroes and Falklands.

2.13 UK companies and research organisations are acknowledged world leaders in seismic, drilling and completion technologies, because of their experience in the North Sea. These technologies were underpinned by extensive technological and scientific research and development in the UK. Sub-sea developments in deep water are now of world-wide significance and present different challenges to those of the North Sea. Development and the application of innovative technologies and execution strategies are seen as essential elements in optimising the industry's capabilities for future challenges, both for the North Sea and for world markets.

2.14 The Energy Panel gave priority recommendations to two specific aspects of the oil and gas industry:- *high hit rate exploration techniques* (to increase the accuracy of field identification through improved acquisition, integration, analysis and interpretation of geophysical data) and - *increased yields from existing hydrocarbon reservoirs* (by more accurate characterisation and improved simulation, better drive and production technologies). It also identified "drilling for oil and gas" and "low cost oil/gas production including platform and pipeline construction/maintenance" as being important targets, but of lower priority.

2.15 The Agriculture, Natural Resources and Environment (ANPLE) Panel pointed out that new technologies had been an integral part of the success in the North Sea and that the UK needed to maintain its leading position in hydrocarbon technologies through continued research, technological development and demonstration. In the marine area, the ANRE panel particularly identified remote and subsea technologies as key areas for development, with very deep water fields, far from land, as being one of the prime targets.

Marine Fisheries and Aquaculture

Fisheries

2.16 In 1993 world food fish supplies were 72.3 million tonnes. Of these, 56.5 million tonnes came from marine fisheries and 15.8 million tonnes from aquaculture. Using the 1993 estimated world level of per capita fish consumption of 13.0 kg/year (in liveweight equivalent), the increase in world population, forecasted to reach 7 billion by the year 2010, would require total food fish supplies of 91 million tonnes per annum, [10].

2.17 Maintaining present per capita consumption levels in the year 2010 would therefore require an additional 19 million tonnes of food fish. Such ail increase in the production of food fish is considered feasible if aquaculture production can be doubled in the next 15 years, and if significant improvements can be achieved in the conservation and management of capture fisheries, through stock rebuilding and more rational harvesting practices, and with application of food technology to improve utilisation of by-catches and small pelagic fish yields for direct human consumption.

2.18 The quantity of fish landed by UK vessels amounts to around 755,000 tonnes per annum, but home supplies do not meet demand and the UK is a net importer of fish. Major changes have taken place in the UK fishing industry over the past 20 years which have affected the composition of landings and the structure of the fleet. Catches by UK vessels fell in the late 1970's, due principally to the loss of access to traditional distant water fishing grounds, and since the 1980's have been held in check by a combination of policy instruments aimed at controlling the pressure of fishing on the main stocks. These measures have had only limited success, however, as evidenced by the failure to achieve fleet reductions in line with multi-annual guidance programme (MAGP) targets laid down by the EU.

2.19 Without sustainable management, the future of marine fisheries is bleak. World population growth and increasing popularity of fish products associated with increased income imply a major increase in demand for fish which cannot be met by conventional resources. This will put further economic pressure on management. Improved management requires emphasis on: the control of fishing effort and the reduction of industry's over-capacity; resource allocation decisions; the establishment of more effective users' rights; greater participation in decision making on resource use; and the adoption of precautionary approaches to fishery conservation and management.

2.20 The principal management problems are found primarily within waters under national jurisdiction. The important fisheries of the high seas make up only 10 per cent of overall fish production. Even when allowance is made for the important straddling stocks, the overall catch of marine living resources outside of national jurisdiction is relatively small. It is therefore reasonable to focus on the problems faced by national authorities in regulating fisheries within EEZs.

Sustainable management can be improved by the adoption of a precautionary approach to fisheries management and through support for further research and information-gathering to reduce the range of scientific uncertainty in factors affecting productivity.

Aquaculture

2.21 The anticipated increase of 19 million tonnes in the supplies of food fish required globally by the year 2010 is likely to have to come mainly from aquaculture. To produce 35 million tonnes from aquaculture by the year 2010 will require an overall average annual increase of just over 1 million tonnes a year above the total of 15.8 million tonnes in 1993. This seems feasible considering recent annual rates of expansion, the potential for increased farmed fish production in Africa and Latin America, the available scientific and technical know-how, and the interest of the private sector, governments and financing institutions. Nevertheless, the challenge is formidable.

2.22 In Europe, over the next 10 years a 10% (conservative) to 40% (optimistic) increase by volume in aquaculture production is expected, increasing total production to between 1.1 and 1.4 million tonnes per year. Aquaculture production in 1993 is estimated to have represented 12.4% by volume and 25% byvalue of all EU fish production, providing significant employment, particularly in economically fragile rural and coastal regions [11].

2.23 In the UK it is widely predicted that over the next 10 years major changes will take place in the aquaculture industry. There is likely to be a wider range of farmed species, stricter quality standards, innovative product and market development, more stringent environmental control, larger and more influential companies and producer groups, and reduction in production costs. Production is expected to increase by approximately 10% per year in the next 3 or 4 years and salmon supply is expected to exceed 100,000 tonnes within the next 5 years. Though potential for some expansion of mussel and scallop production exists, other shellfish production is likely to remain relatively static. Development of farming of "new" finfish species such as halibut, Dover sole and cod may be of greater significance.

Maritime Transport and Construction

Maritime Transport

2.24 Ninety five percent of intercoastal trade is carried by ships and one third enters and leaves Europe by sea. With the globalisation of industry, door-to-door transport networks and just-in-time deliveries will become more and more important for manufacturers and shippers. This underlines the need for efficient intermodal transport systems and presents new trade opportunities as well as export potential for specialised ships and equipment. Overall speed of transportation requires a systems approach to the logistics network, with optimisation of multimodal routes. As far as ships are concerned, the major challenge is the safe and efficient transfer of cargo/ passengers between ships and adjacent modes. Innovation in this area could transform port operations and also stimulate interest in alternative vessel configurations capable of operating safely at speeds up to 50 knots and above.

2.25 As far as intra-EU trade is concerned studies suggest that over the next ten years the trade in bulk goods will double. With road systems becoming congested, and rail systems difficult to expand due to investment and planning constraints, waterborne transport is now recognised as the only under utilised transport resource in Europe. Specifically, short sea crossings, coastal and inland waterways are capable of handling a much greater volume of trade. Waterborne transport has the advantage of being the most environmentally friendly of all. It is also the safest and most economical mode of transport.

Shipbuilding

2.26 At some time in the not too distant future over-age tonnage will have to be replaced. This has led the Association of European Shipbuilders and Shiprepairers (AWES) to forecast a substantial increase in the demand for new ships up until 2005 with activity reducing at the end of this period. Peak annual demand is forecast at 18.4 million corrected gross tonnage (cgt.) which compares with a total world shipbuilding capacity of about 20 million cgt. The UK merchant shipbuilding industry now has only about 0.5% of the world market with a turnover of approximately £200m. It employs some 4,500 permanent employees. The UK has the capability of exploiting the high value end of this market with lower labour costs than other European shipbuilders.

2.27 Opportunities exist for the UK to exploit its skills in niche markets for special purpose vessels and high speed craft, basic research, design integration, operational analysis, risk analysis, formal safety assessment, the supply of marine equipment to foreign built ships and, above all, in education and training in naval architecture and marine engineering. In this field UK universities and colleges have well deserved world?wide reputations for excellence.

Ship Repair and Conversion

2.28 Low freight rates have caused owners to retain existing tonnage rather than replace it with new. However, concern over the material state of many of the world's older ships has led to more inspection and enforcement on the part of Port State Control Authorities. These circumstances have resulted in a marked increase in ship repair and conversions. The global market for ship repair work is set to double in value to over US $20 billion per annum by the year 2000. A recent report on the UK industry [12] concluded that the UK has a good platform of international competitiveness, combined with a steadily improving reputation for quality and reliability. There have been some well publicised conversions to electric propulsion, notably in the cruise market, but of greater significance is the opportunity for conversion of oil tankers to floating production, storage and off-loading vessels (FPSO). The FPSO market provides a large opportunity not only to the shipbuilding and repair industry but also to equipment and component suppliers.

2.29 The shiprepair and conversion industry is probably less susceptible than shipbuilding to efficiency gains through development of novel construction techniques. However, such are the intense pressures on time and cost that this sector will benefit considerably from electronic data interchange to support supply chain partnerships and from business process methods aimed at further reducing the time from enquiry to work completion.

Coastal Waters and Maritime Leisure

2.30 The activities and potential development of the coastal zone are characterised by the unique diversity of the coastal environment, and the political imperative for developments to be sustainable. The latter is a recognition that development for wealth creation cannot proceed unbounded from the need to maintain or improve the quality of life. The link between quality of life and environmental quality in the coastal region embraces a wide range of issues, including visual amenity, biodiversity, clean air, clean beaches, clean water, sustainable living resources, affordable and accessible leisure facilities.

2.31 Over the next 20 years the drive for sustainable development of the coastal zone will gather pace, and this will be facilitated by increasingly integrated management tools. These tools will demand improved and linked knowledge bases of the natural environment and of the socio-economic forces, together with user friendly interpretation and presentation packages for management, whether of development or conservation agencies. The guiding principle and challenge for all coastal management is *sustainable development* [13], as identified in Chapter 17 of Agenda 21 from the Earth Summit at Rio in 1992.

2.32 Each individual market for leisure activities, coastal navigation, living and non living resources, and coastal protection will have its own development agenda, but these will include awareness of the holistic nature of the coastal zone, and therefore to some degree their interactions with each other and the natural environment. It is both possible and desirable that developments have dual or multiple benefits arising from a better understanding of these interactions.

Climate Change and Rising Sea Levels

2.33 The 1996 Review by the intergovernmental Panel on Climate Change acknowledges probable human influence on storms. Projected increases in sea levels, and changes in the intensity and pattern of storms will increase the risks of coastal flooding. Integrated scientific and socio-economic analyses will be needed as the basis for planning future coastal zone development to allow for change.

2.34 Increasingly, there will be a need for prognostic and predictive capabilities to assist planning and operations. Information technology will provide the means to bring data, scenarios, models and interpreters together, and to disseminate the information to specialised users or the general public. This view of the need for integrated approaches to the coastal zone is internationally recognised [14].The existence of holistic information systems will aid operations following coastal accidents, both by speeding up the provision of the relevant databases for the locality, and by transforming dynamic environmental and impact modelling rapidly from standby to operational status.

Electronic Navigational Charts

2.35 Digital Electronic Navigational Charts (ENC) are becoming recognised as the inevitable basis for future mapping of the seas, coastal zones and associated global maritime navigation. This is compatible with parallel trends in the use and exploitation of satellite imagery and development of the global digital information highway. International agreement on a common format is already established and efforts are underway to develop RENCs (Regional Electronic Navigation Chart Co-ordinating Centres) for collation and distribution of the data using the global information highway. ENC systems will not only replace the use of conventional paper charts, but will form the basis for a whole new generation of digital marine information systems referred to as ECDIS - Electronic Chart Display and Information Systems. These range from integrated navigation systems onboard ship to regional port information systems handling everything from vessel traffic management to pollution monitoring and control.

2.36 The timescale for full realisation of ENC based operations will extend over the medium to long term horizon of 10-20 years. This is because ENC exploitation is dependant on its integration with other technologies, and a heightened end-user awareness, and due to the dine needed to implement the underpinning framework to govern global operating standards. This scenario offers long term global opportunities for companies prepared to invest now in addressing the emerging market requirements.

Cross cutting themes

2.37 A number of themes cut across the five marine sectors within the Panel's remit, and these include the following:

Operational Oceanography for Environmental Forecasting

2.38 Systematic operational oceanography is recognised as the next step required to manage coastal seas more effectively, to forecast ocean conditions accurately, to provide the ocean data to complement atmospheric data in making climate forecasts, and to help improve safety at sea and in search and rescue operations. The markets for operational oceanography include: (i) the oil and gas industry (ii) coastal zone management, operations and forecasting services; (iii) global transport; (iv) navies; (v) fisheries, and (vi) science and technology in academia and Government. The development of operational oceanography is a key area for the UK. In due course this will become a global business creating yet more jobs [15].

The development of operational oceanography in Europe over the next 10 years is expected to lead to the creation of 5000 jobs and an environmental forecasting business with an annual turnover of some £400 million.

2.39 Development of an international approach to operational oceanography is being co-ordinated through the Global Ocean Observing System (GOOS) under the aegis of the Intergovernmental Oceanographic Commission (IOC), supported by the International Council of Scientific Unions (ICSU), the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP). In the UK, GOOS activities are considered under the aegis of the Inter-Agency Committee for Marine Science and Technology (IACMST). Much of the groundwork is being done through Euro GOOS, in which the Met Office, NERC and the Environmental Agency are the UK partners. The observations from the open ocean which GOOS will ensure are essential to provide the boundary conditions for the regional and local models used for forecasting sea conditions and climate. GOOS is expected to lead to savings of at least US $8 - $10 billion on the global maritime industries and services businesses, at a benefit to cost ratio of 10:1 to 20:1.

Education and Training

2.40 Marine education and training is a field in which the UK has a significant scientific infrastructure and expertise. This includes programmes in institutions of higher and further education, and the activities of the professional engineering institutions and scientific learned societies. The latter contribute to course validation, continuous professional development, lecture programmes, periodic reviews of educational needs, and outreach. Nevertheless, the general public have little sense of the opportunities which a vibrant marine sector offers. The Panel has recognised the need for continued investment in appropriate education and training in the established areas of knowledge, but calls for a developmental dimension to provide the skills that will be required in the global market place.

2.41 The Inter-Agency Committee on Marine Science and Technology (IACMST) has recently set up a working group on education and training to assess the present and likely future demands from employers for people to work in marine science and technology related areas, and the extent to which the demands are met through UK provisions for education and training in marine science and technology.

2.42 A report on *Marine Education* for the Marine Panel [16] highlighted the importance of stimulating public understanding of the marine environment and related industries, and providing support for schools and training institutions. For the longer term improved education could be achieved through a programme comparable to the US Sea Grant programme for basic research and educational outreach. A report on the *Skills Base of the Shipbuilding and Shiprepair Industry*, [17], concluded that in general there has been an under-investment in training. A framework was also recommended to ensure the cohesive, cost effective and efficient provision of education and training in this area. A recent study of the UK Marine Equipment Industry [18], recommended a study of the future skill requirements of the industry and the ability of the education and training providers to meet the needs of industry.

Information Technology and Electronic Data Interchange

2.43 Information technology pervades all marine sectors and its current and future application is expected to have the most significant impact on the marine industries. Improved efficiency is expected from the use of information technology and Electronic Data Interchange (EDI) for industry to compete in global markets. Information technologies will enhance logistic efficiency and improve production processes through intelligent manufacturing systems and through information exchange. Maritime information systems will also provide decision support for management and for planning and operational activities within the coastal and offshore marine environment. Advanced super-computers will facilitate marine climate and environmental models, allowing wider contexts and higher resolution. Information technology and electronic data interchange are critical to future success and competitiveness of all the marine sectors.

2.44 The importance of information technology for the marine industries has been recognised by the Group of Seven [G7] countries in their Maritime Information Society (MAKIS) initiative as part of the global Information Society. The objective of this initiative, now extended to non-G7 countries, is to demonstrate the advantage of a global information system through specific applications over a range of maritime activities:

- Maritime safety and protection of marine environment
- Logistics and multimodal transport
- Information exchange for exploitation and protection of marine resources, particularly fisheries
- Intelligent manufacturing through global co-operation

Environmental Pollution and Safety

2.45 There are many sources of pollution to the marine environment: outfalls, dumping, rivers (industrial, municipal and agricultural emissions), land run-off, atmosphere (dry deposition and rainfall); from ships and small boats. The major classes of pollutants discharged into estuaries and the sea are: sewage, which includes domestic liquid wastes, trade and agricultural wastes as well as human waste products; industrial effluents, including heavy metals and organochlorine compounds; cooling water; oil, spoil and drilling contaminants from mining/drilling at sea; radioactive discharges; inert materials such as colliery waste, china clay waste and titanium oxide. The major problems from sewage discharges are potential dangers to human health due to pathogenic bacteria and excessive plant (algae) growth as a result of cutrophication. Other sources lead to contamination of vulnerable fish spawning grounds and nursery areas with heavy metals and high oxygen demand.

2.46 Pollution prevention, EU Directives and a regulatory framework are the drivers for changed management practices, whether based on scientific knowledge or on the precautionary principle.

2.47 Pollution and safety issues attract increasing public and media attention to which a response must be made if the marine sector is not to suffer economic damage. Environmental pollution from ships comprises engine exhaust gases, waste incinerator emissions, engineering wastes, tank washing, human and domestic waste products. Environmental concerns also arise from hazardous cargoes and from marine organisms being transported in ballast water from one ocean environment to another, where they may constitute a considerable hazard. Major oil spills from tankers, such as the *Exxon Valdez, Braer and Sea Empress*, and the aborted disposal of the *Brent Spar* oil storage platform, dramatise the environmental issues and increase public sensitivities. In the report of his inquiry into the *Braer* incident [19], Lord Donaldson called on UK authorities to take new initiatives internationally, nationally and regionally to combat the threat of pollution to the UK coastline.

2.48 The importance of safety of life at sea is now being increasingly recognised, both by the general public and government agencies. Safety is concerned with management, engineering and operation, in the context of human behaviour, decisions and errors. Analysis of marine insurance claims has shown that marine accidents are caused directly (60%) or indirectly (30%) by human factors. This factor was recognised by Lord Cullen's Public Inquiry into the Piper Alpha disaster of 1988 [20], and in consequence the operators of installations now carry the responsibility for all aspects of their safety and are required to prepare and submit a safety case to the UK Health and Safety Executive.

2.49 Losses of fishing vessels in the UK continue at a high level with an average of 35 vessels and 21 lives lost each year and worldwide losses of bulk carriers average 17 vessels every year. Lord Donaldson's assessment of the circumstances of the loss of the bulk carrier *Derbyshire* [21] underlined the concerns for this type of vessel. Accidents to the Ro-Ro passenger ferries *Herald of Free Enterprise* and *Estonia*, as well as encouraging the adoption of multi-hull designs, have led to new safety regulations as underlining the need for new ways of formulating such requirements.

2.50 Recently, the UK submitted a paper [22] to the International Maritime Organisation (IMO) on a risk based methodology for Formal Safety Assessment of Shipping as a new way of formulating safety regulations. The safety case and formal safety assessment are just two examples of initiatives which seek to replace the traditional approach to safety at sea, based on prescriptive rule making, with a risk based approach which is better suited to allowing innovation and to placing responsibility for safety firmly on the stakeholders. This approach will demand a better educated and skilled design team. Local expertise in this area puts UK consultancies and academia in a leading position.

3 RECOMMENDATIONS FOR IMPLEMENTATION

3.1 This Chapter reviews the high priority areas which provide the basis for the Panel's recommendations. Many possible areas worthy of exploitation were identified by the Panel and by the five Focus Groups by discussions, from the drivers for change outlined in Chapter 2, from consultation and by reviewing the literature [1-23] and the bibliography [B1-B23]. Consultation included expert views on likely developments in the various marine sectors. The main issues emerging from these activities were then considered to identify the opportunities, the priority areas and technology needs.

3.2 A number of generic technology areas identified by the Panel are common to other Foresight Panels and these have been included in the Executive Summary. The Panel will review in Phase III of Foresight these common technologies to ensure that the unique needs of the marine sector are properly satisfied.

Key Recommendations

3.3 The Panel identified several high priority areas which include general themes that are specific to the different wealth creating marine sectors. Improvements in many of these would also help the Government meet its statutory obligations more effectively.

Exploitation of non-living resources

- **Environmental Forecasting:** The development of operational ocean forecasting services, required to improve coastal zone and offshore business management and ship routing, will depend on improvements in numerical modelling and simulation of oceans and shelf seas; increases in data acquisition, management and assimilation into models; and improved understanding of the ocean's role in climate variability. Models will also be needed for climate forecasting.

- **Continuous Monitoring and Real-Time Information:** Further development and application of remote sensing technologies is required to feed the growing demand for marine forecasting services with more data at faster rates to reduce ship (operational) time; satellite-borne sensors are needed for salinity, surface air temperature, all weather sea surface temperature, and organic and other pollutants. Autonomous underwater vehicles are needed as platforms for sensors for sub-surface ocean basin transects.

- **Sensors:** Novel chemical, physical, biological and acoustic sensors are needed to provide a wide range of information about the marine environment and its quality and behaviour; particularly desirable are low cost, disposable sensors and low power sensors useable over long periods without fouling and under high pressure in corrosive seawater. Sensors are also required for monitoring the oceans from space.

- **Acoustics:** Increased demand for high resolution maps of seabed shape and non-living resource assessment demand improvements in acoustic technologies including transducer materials, sonar system design (hardware and software), image analysis, and synthetic aperture systems. Advanced acoustic sensor systems are required for in-water communication.

- **Information Technology:** For acquisition and processing of increasingly large volumes of data, the development of intelligent information systems and GIS-based data management systems is needed, linking satellite remote sensing, GPS navigation, monitoring networks (data buoys, commercial vessels) and hazard databases. Also required is development of a marine information service backed by data acquisition.

- **Materials:** New high strength, lightweight, corrosion resistant and smart materials, including sensor materials, are needed for a wide variety of applications offshore, particularly those which enable operations in seawater

Offshore Energies

- **Technologies for floating structures either F1PS0s or TLPs:** overcoming the difficulties of operating in increasingly deeper water, at greater than 1,000m, in a hostile environment.

- **Construction technologies and materials:** expert design software for advanced structures that self adapt to fatigue and survival loads; improved construction materials and weld design, particularly lighter, stronger, cheaper and corrosion resistant joining materials and adhesives.

- **Pipelines and risers:** development of large diameter, deepwater intercontinental pipelines and large diameter risers for use from floaters in depths greater than 1,000m. New pipeline materials that compete with steel on cost.

- **Technologies for enhanced drilling capability:** downhole processing, subsea processing, long distance transportation of mixed fluids, and floating production

- **Miniaturisation and nanotechnology:** development for downhole applications.

- **Seabed gas hydrates:** studies and development as a potential source of energy.

- **Decommissioning:** offshore installations in the North Sea over the next decade represents a major challenge to the marine industry. This will involve devising cost-effective solutions for removing topsides and complete structures, with many activities requiring safer and more competitive techniques.

Marine Fisheries and Aquaculture

- The future direction of research into **Fish harvesting** should be focused in the areas of technology to aid better **management of fisheries**, rather than simply to increase the rate at which fish can be exploited. Ameliorating the worst ecological damage caused by fishing, by enhancing the biological productivity of marine ecosystems; maximising the return from existing levels of harvest by improving quality and reducing wastes; more effective management of fish stocks, improving the ability to monitor and control fishing activity within desired limits, development of selective performance of fishing gears.

- To support **sustainable management of fisheries** further research is needed in the dynamics of ecosystems involved in marine fisheries and to determine abundance and distribution of stocks.

- Further research is needed into techniques and methodologies of **technology transfer** to achieve successful implementation of mature technology into developing fisheries, which still have the potential for further exploitation.

- Research in **biotechnology for aquaculture** particularly for nutrition, genetic improvement, disease control and prevention.

- Continued investment in appropriate **education and training** in order to maintain the UK's intellectual base particularly for a developmental dimension to provide generic skills that will be required in the global market place

- Research in **systems technology** for improving hatchery systems, development of better water management and feed control systems, development of handling and management systems for larger production levels, and development of reliable off-shore aquaculture systems.

Maritime Transport and Construction

- Technologies for **Intermodal Marine Transport Systems**, including port facilities, focusing on **50 knot passenger and freight ferries**, with fast, high-capacity loading/unloading

- Technologies for a **Clean ship**, focusing on minimum emissions and risk of spills, with low-wash wave disturbance and low noise performance;

- Continued development of an **all-electric ship**, focusing on propulsion systems and the replacement of other non-electric systems.

- Technologies for **design and system integration** for marine vehicles and the development of virtual manufacturing and operating systems making use of advanced informatics, focusing on time-to-market cost reduction, and life cycle optimisation.

- Development of improved **business processes and scenario modelling**

tools, addressing the complete supply chain from marine equipment manufacture to facility construction and operation, and accommodating simulation based design (SBD) and concurrent engineering (CE) practices. This will permit optimisation of business processes across the full product life cycle from project conception through to operation and disposal. Scenario building techniques will also be needed to optimise investment in future intermodal marine transportation systems.

Coastal Waters and Maritime Leisure

- The drive for sustainable development will be facilitated by **information systems** for integrated approaches to the **coastal zone**. These management tools will require improved and linked knowledge bases of the natural environment and the socio-economic forces, together with user friendly interpretation packages for managers. Increasingly there will be a need for information systems with prognostic and predictive capabilities to assist planning and operations.

- Research and development of **coastal zone modelling** will be needed on the interdisciplinary processes including physical forcing, sediments, the bio-geo-chemical fluxes from land to sea, biodiversity, ecotoxicology at all levels from genetic and cellular to whole animal, and populations.

- Research on processes must include the impact of climate change and variability, including rising sea levels.

- Interdisciplinary studies of the links between the natural environment and the socio-economic forces in the coastal zone.

Actions for Implementation

3.4 The Marine Panel recommends the following actions to drive forward the implementation of its recommendations:

- The Government should appoint a lead Department to act as the **UK authority for coordinating and sponsoring marine policy in support of industry**. This recommendation was made by the industry and academic members of the Panel.

- Government Departments with a marine remit should each develop a **strategy for marine technology** in their areas of responsibility, consistent with overall policy.

- There is a need for effective **coordination of individual Government Departments' strategies for marine technology**, together with Research Councils and other funding agencies, in support of competitive development of the marine market sector (consistent with the individual requirements of Government Departments). The Office of Science and Technology [OST] may wish to consider broadening the role of IACNIST to meet this recommendation, consistent with its recent review [23].

- The Engineering and Physical Sciences Research Council **(EPSRC)**, the Natural Environment Research Council **(NERC)** and the Biotechnology and Biological Research Council **(BBSRC)** should each continue to play a leading role in supporting strategic and targeted research in marine science and technology in HEIs.

- All relevant Government departments and transport sectors to engage in strategic planning of an intermodal transportation infrastructure, working closely with international initiatives.

- To improve the **public understanding** of the importance of the marine sector and the value of the oceans in global markets, the Government, with the help of industry and academia, should promote greater awareness for the benefit of UK industry. COPUS awards in marine science and technology should also be promoted.

- The opportunities to apply **Digital Information Technology** to the marine environment are many and varied. Industry should lead this initiative in consultation with academia and government. The Panel recommend the setting up of a user led interest group and a LINK programme for the application of Digital Information Technology to the marine environment.

- The requirements for marine specialists need to be addressed nationally and the resources for **marine education and training** matched to them. The national assessment of these requirements is a task for the Inter-Agency Committee on Marine Science and Technology (IACMST), the professional institutions, trade associations, academia and the engineering and marine training authority (EMTA).

- **SME's in the marine sector** are a valuable source of innovation but often need resources and assistance to pull this through into the market place. The Government should consider research and development and marketing programmes for SME's for focused areas in the marine sectors - this will be assisted greatly by the appointment of a lead Government Department.

- Government in consultation with industry and academia need to **develop consensus on the contribution for supporting international collaboration in major ocean technology**. This would make the best possible use of the UK's resources for the development of expensive marine systems such as oceanographic measurement systems and deep drilling technology.

- The Government should accede to the **Law of the Sea Convention** in order to maintain a position of credibility and influence in legislation from which UK industry might benefit.

- In order to position the UK for global markets the Office of Science and Technology (OST) and Overseas Development Agency (ODA) should support the **Global International Waters Assessment** proposed by the World Bank through its Global Environmental Facility.

- Concerted action by Government (NERC, ODA) is needed to win a substantial share of the **Global Environment Facility** budget of US $250m over three years and to assist with other international opportunities.

- In recognition of the growth potential for ocean forecasting, the Government should promote **research and the infrastructure for the development of operational oceanography**, and enable a significant contribution to the Global Ocean Observing System called for by UNCED (Rio, 1992).

- To provide a focus for technological development for the exploitation of marine renewable energy the Government, in co-operation with the European Commission and industry, should set up a UK focus for **Marine Energy Technology**.

3.5 Marketing opportunities that have been identified by the Panel for industry and academia are given below:

- Create and take to market demonstrator stage environment forecast models for sea variables such as currents, sea temperature, salinity, primary production, algal blooms.

- Exploit new global market opportunities for environmental information services with respect to the atmosphere and earth's surface for a wide range of end users and to assist in the execution of environmental policy.

- Exploit new global market opportunities resulting from the UN Convention on the Law of the Sea (e.g. exploitation of Exclusive Economic Zones (EEZs).

- Exploit market opportunities in developing countries for marine technology products, information services and technical expertise. Much of this will be channelled through international agencies and the World Bank.

- Promote the marketing of technology from the offshore oil and gas industries to other countries, particularly developing countries. The UK is the market leader in some offshore technologies, such as sub-surface technologies, and these have been underpinned by extensive research and development, resulting in expertise and know-how which need to be sustained for future challenges.

- The UK offshore supply industry needs to develop significant exports from the expertise acquired over the last two decades.

- Exploit global market opportunities for high added-value marine equipment, resulting from trends towards higher ship speeds and calls for reduced environmental impact.

4 ACKNOWLEDGEMENTS

The Marine Foresight Panel wishes to express its appreciation to the Office of Science and Technology for the facility to highlight the opportunities in the marine sector. It is also very grateful for the contribution to its work by the Members of the Panel and its Focus Groups and by the wide range of outside bodies and individuals, all of whom contributed willingly without payment. David Pugh is thanked for his contribution to Chapter 1 - Marine Related Activities in the UK Economy.

BACK BACK TO INDEX FORWARD

5 REFERENCES

[1] An analysis of Marine-Related Activities in the UK Economy and Supporting Science and Technology, Pugh D.T. and Skinner L,. IACMST Information Document No. 5, December 1995.

[2] The UK Marine Industries, a report to the Office of Science and Technology, Douglas Westwood Associates, 1996.

[3] Marine Science and Technology in the UK - A Strategic Framework - Report to Government by the Coordinating Committee on Marine Science & Technology (CCMST), HMSO 1990.

[4] Marine Foresight Panel - Exploitation of non-living Marine Resources Focus Group Report, published by OST, 1997.

[5] Marine Foresight Panel - Offshore Energies Focus Group Report, published by OST, 1997.

[6] Marine Foresight Panel - Marine Fisheries and Aquaculture Focus Group Report, published by OST, 1997.

[7] Marine Foresight Panel - Maritime Transport and Construction Focus Group Report, published by OST, 1997.

[8] Marine Foresight Panel - Coastal Waters and Maritime Leisure Focus Group Report, published by OST, 1997.

[9] Graff J, 1996, Marine Information Technology and the emerging global markets for information products, Oceanology Internat. Brighton, March 1996, Spearhead Publications.

[10] The State of World Fisheries and Aquaculture. FAO, Rome 1995.

[11] Report to the European Parliament Scientific and Technological Options Assessment (STOA IV/STOA/95/SCI/P/1/a)

[12] Study of UK Ship Repair and its International Competitiveness for the Department of Trade, First Marine International Limited August 1995.

[13] Policy Guidelines for the Coast, Department of Environment, HMSO 1995.

[14] Clark J.R., Integrated Coastal Zone Management. Sea Technology, 37(6), 1996.

[15] Woods, J.D. Dahlin, H., Droppert, L., Glass, M., Vallerga, S., and Flemming, N.C 1996. The Strategy for Euro GOOS Publication No. 1, Southampton Oceanography Centre, Southampton.

[16] Marine Foresight Panel - Marine Education, May V and Heep C, School of Conservation Studies, Bournemouth University, December 1996.

[17] The Skill Base of the Shipbuilding and Shiprepair Industry. Shipbuilders and Shiprepairers Association and University of Newcastle upon Tyne. January 1997.

[18] Study of the UK Marine Equipment Industry and its Competitiveness for the Department of Trade and Industry. First Marine, November 1996.

[19] Safer Ships, Cleaner Seas: Report of Lord Donaldson inquiry into the Prevention of Pollution from Merchant Shipping. (CM2560) HMSO 1994.

[20] The Public Inquiry into the Piper Alpha Disaster - The Lord Cullen, HMSO, 1990.

[21] Lord Donaldson's Assessment (Derbyshire), CM3128 HMSO, December 1995.

[22] A Methodology for Formal Safety Assessment of Shipping, IMO MSC 66/ Informal Paper submitted by the UK, May 1996

[23] Review of the Inter-Relationships Between the Science, Engineering and Technology Expenditure of Government, Office of Science and Technology, December 1996.

6 BIBLIOGRAPHY

IACMST Working Group Reports:

[B1] Technology Transfer , Report No. 1, April 1994.
[B2] Marine Environmental Data , Report No. 2, November 1994.
[B3] Global Ocean Observing System, Report No. 3, February 1995.
[B4] Operational Marine Environment Network, Report No. 4, July 1995.

IACMST Information Documents

[B5] International Marine Science and Technology - A summary of organisations and programmes of interest to the United Kingdom. 3rd Ed, 1996.
[B6] United Kingdom Public Sector Research Vessels. 2nd Ed, 1996.
[B7] Survey of Large Marine Science and Technology Experimental Facilities. April 1995.
[B7] Directory of Marine Environmental Data Sets held by UK Laboratories. April 1995.
[B8] An Analysis of Marine-Related Activities in the UK Economy and Supporting Science and Technology. December 1990.

General Publications:

[B9] The Case for GOOS (Global Ocean Observing Systems), GOOS Publication Series: No. 1 January 1993.
[B10] IACMST Survey of UK requirements for GOOS Data and Products, prepared by N C Flemming, December 1993.
[B11] New Challenges for Maritime Industries - Communication of the European Commission COM(91) 335 final 20 September 1991.
[B12] The Energy Report - oil and gas resources of the United Kingdom, Department of Trade and Industry, HMSO, 1995.
[B13] The European Renewable Energy Study - Prospects for Renewable Energy in the European Community and Eastern Europe up to 2010. Main Report and Annexes. European Commission 1994.
[B14] Energy in Europe - Energy Policies and Trends in the European Union ~ European Commission No. 23,1994.
[B15] Energy in Europe - Energy Policies and Trends in the European Union - European Commission No. 24, 1994.
[B16] Thomas Gray Memorial Lecture, Let's Build a Ship, P.J. Usher, President of the Royal Institution of Naval Architects, May 1995.
[B17] The Future Development of the Common Transport Policy - A Global Approach to the Construction of a Community framework for sustainable mobility, European Community, COM(92) 494,2 December 1992.
[B18] Towards a New Maritime Strategy. Communication of the European Commission COM(96) 81 final March 1996.

[B19] A Common Policy for Safe Seas, European Commission, COM(1993) 66,24 February 1993.

[B20] The Maritime Industry R&D Master Plan, Maritime Industries Forum July 1996

[B21] Towards a Marine Policy for Ireland, Marine Institute, September 1996.

[B22] Plan Strategique 1996-2000, IFREMER 1996

[B23] Marine Industry Development Strategy, Australian Marine Industries Science Council, January 1997, Department of Industry, Science and Tourism.

BACK BACK TO INDEX FORWARD

7 ACRONYMS

AUV	Autonomous Underwater Vehicle
AWES	Association of European Shipbuilders and Shiprepairers
BBSRC	Biotechnology and Biological Sciences Research Council
CE	Concurrent Engineering
cgt	Corrected Gross Tonnage
COPUS	Committee of Public Understanding of Science
CRINE	Cost Reduction in New Era
DoE	Department of Environment
DTI	Department of Trade and Industry
DOT	Department of Transport
DOWA	Deep Ocean Water Applications
ECDIS	Electronic Chart Display and Information Systems
EDI	Electronic Data Interchange
EEZ	Exclusive Economic Zone
EMTA	Engineering and Marine Training Authority
ENC	Electronic Navigational Charts
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FPSO	Floating Production Storage and Offloading
GDP	Gross Domestic Product
GIS	Geography Information Systems
GOOS	Global Ocean Observing System
HEI's	Higher Education Institutes
IACMST	Inter-Agency Committee for Marine Science and Technology
ICSU	International Council of Scientific Unions
IDC	Intergovernmental Oceanographic Commission
IMO	International Maritime Organisation
MAFF	Ministry of Agriculture, Fisheries and Food
MAGP	Multi-Annual Guidance Programme
MARIS	Maritime Information Society
MoD	Ministry of Defence
NERC	Natural Environment Research Council
ODA	Overseas Development Agency
OSO	Offshore Supplies Office
OST	Office of Science and Technology
OTEC	Offshore Thermal Energy Conversion
PPARC	Particle Physics and Astronomy Research Council
RENC	Regional Electronic Navigation Chart
SBD	Simulation Based Design
SME	Small/Medium Size Enterprise

SOAEFD	Scottish Office Agriculture, Environment, Fisheries Department
TLP	Tension Leg Platform
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UKCS	United Kingdom Continental Shelf
UNEP	United Nations Environmental Programme
WMO	World Meteorological Organisation

BACK BACK TO INDEX FORWARD

ANNEX 1
SUMMARIES OF FOCUS GROUPS' REPORTS

EXPLOITATION OF NON-LIVING MARINE RESOURCES

1 The Vision

Within the next 20 years many businesses will expand their operations on the continental shelf. An increase is also expected in the exploitation of the deep ocean floor. Trends will continue towards unmanned and remote activities, the use of digital communication systems and information control, the development of deep ocean industries and the control (including policing) of exploitation.

The Analysis
The analysis considered several potential markets, the activities they require and the technologies those activities need. Many of the technologies needed by these sectors also apply to other sectors, so the analysis cuts across the interests of the other Focus groups of the Marine Foresight Panel.

2 Opportunities and Needs

The report focuses on (i) general offshore business opportunities excluding the energy, transport, fishing, and coastal zone and leisure sectors handled by the other Focus groups, (ii) seabed mining, (iii) communications, and (iv) waste disposal. It excludes the oil and gas sector, although much of what is described here relates also to that sector. It includes the instruments and survey markets, including remote sensing, and in the case of mineral deposits is concerned also with resource assessment and reserve evaluation as well as exploration and extraction.

Three major areas have been **identified for major market growth and export potential**:

- offshore information and forecasting services.
- seabed survey in support of engineering of all kinds, military activity and transport.

- exploitation of deep waters beyond the edge of the continental shelf.

The UK should aim to secure a large share of the developing markets in these three areas. Substantial benefits will accrue from focusing the UK's activity in these sectors. The technologies fall into three bands, following OST practice:

Top Priorities in Key Topics, which affect the widest spectrum of users are:

- Environmental Forecasting
- Continuous Global Monitoring and Real?time Information (from Satellites and AUVs) Sensors (including satellites)
- Acoustics

Secondary Priorities, affecting all marine markets include;

- Information Technology (IT)
- Above Water Navigation
- Marine Education
- Materials

Top Priorities for Intermediate Topics, some of which affect a less wide spectrum of users, but others (e.g. robotics, automation, miniaturisation) which affect most users are:

- Automation and Robotics
- Miniaturisation
- Optics

Secondary Priorities include:

- Resource Assessment and Extraction (Aggregates)
- Environmental and Hazard Impact Assessment
- Anti-Fouling (especially for marine sensors)
- Disaster Forecasting

Top priorities in Emerging Topics in which sonic investment is warranted for social reasons, or where technologies which remain to be proven for widespread application are poised for breakthrough and need nurturing are:

- Continuous Monitoring and Real-time Information (Local/Regional)
- Energy (including Fuel Cells and OTEC)
- Waste Disposal (Organic; Radioactive; Carbon Dioxide)

Secondary Priorities include:

- Resource Assessment and Extraction (deep water)
- Underwater Navigation
- Global Bathymetry

OFFSHORE ENERGIES

1 The Vision

The Foresight objective is to make the UK the leading supplier of marine-based energy technology, by providing a cheap, long-term source of domestic energy and a major export industry which strongly influences world energy economics.

The move to production in deep water exposed locations is setting new technical challenges for the offshore industry, particularly in the development of robotic and automated production systems. For the UK offshore supply sector this will provide major opportunities in international markets as energy production moves into more challenging locations.

The strong UK offshore expertise will be important in developing new renewable energy systems for world markets, such as offshore wind and wave energy.

2 Marine Energy Source

There are two distinct categories of energy sources from the marine environment: the existing international offshore oil and gas industry which can be expected to make incremental advances within the Foresight time frame; and the development of new sources of renewable energy from the marine environment - wind, wave, tidal and ocean thermal conversion. Although these are not economic in today's energy market and may not be within the Foresight time-scale, they do represent possible future opportunities for UK industry if the technologies can be developed and demonstrated.

Technologies in Offshore Energies

oil & gas	wind
waves	OTEC floating systems
DOWA	tides and currents
geothermal	biomass as energy source
communications	bioremedation
environmental protection	structures
decommissioning	subsea operations
energy storage	energy transmission
supply & pipelines	logistics
safety	human factor

3 Technology Priorities

3.1 Offshore Oil and Gas

The main priority is to maximise hydrocarbon yield. The undiscovered UKCS recoverable reserves is 7.31 billion Bbl and world Yet-to-Find 500-1000 billion Bbl. Additional recovery from existing fields could yield up to 400-500 billion Bbl with improved reservoir recovery.

- **Technologies for floating structures either FPSO's or TLP's;** overcoming the difficulties of operating in deep water, down to 2,500 m, particularly in hostile environments.

- Improved **construction technologies and materials**; expert design software for advanced structures to include details such as weld design; and advanced structures that self adapt to fatigue and survival loads; improved construction materials - lighter stronger cheaper and corrosion resistant, joining materials, particularly adhesives.

- **Pipelines and risers**: development of large diameter, deepwater intercontinental pipelines and large diameter risers for use from floaters in water depths down to 2,500m. New pipeline materials that compete with steel on cost.

- Technologies for enhanced **drilling** capability, downhole processing **subsea** processing, long distance transportation of mixed fluids and floating production systems.

- Studies and development of **seabed gas hydrates** as a potential source of energy.

3.2 Renewable Energy Sources

Continued investment and Government support is required for marine energy sources:

- **offshore wind**
- **wave**
- **tidal and marine currents**
- **offshore thermal energy conversion and deep ocean water applications**

In many areas related to development of marine energy sources, the technologies have been developed to the stage where they need demonstrator projects. Furthermore, most of the areas of technology are familiar to the offshore industry.

- To provide a focus for technological development for the exploitation of marine renewable energy the Government, in cooperation with the European Commission and industry, should set-up a UK Centre for Marine Energy Technology, as a focal point and centre of excellence.

3.3 Some Marine Foresight Challenges

- improve present recovery from reservoirs by 50%
- estimate flaring
- seabed or in-situ processing
- single-well oilfield development
- electricity generation at wellsite
- development of gas hydrates
- self-decommissioning offshore platform
- energy storage and low loss energy transmission

MARINE FISHERIES AND AQUACULTURE

1 The Vision

Better management of fisheries particularly the monitoring of fishing activity and optimising the return from existing levels of harvest to achieve a balance between fishing capacities and sustainable fish stocks.

The sensitive and sustainable management of the rapidly growing aquaculture industry, throughout the world, to increasingly offer an alternative supply of seafood, reduce pressure on fisheries and avoid long term environmental damage.

2 Key Opportunities for the UK in marine fisheries

The UK has an established reputation in particular areas of fisheries science and management, and this expertise can be marketed in order to help ameliorate the problems currently facing the fishing industry in many parts of the world. UK expertise included specialisms such as fish stock assessment, bio-economic modelling and fisheries project appraisal, as well as complementary areas of knowledge such as environmental valuation and coastal zone management. The potential for the UK lies in the scope for using this expertise to help eliminate the economic waste which is implicit in global fishing.

Many developments in fisheries in the past have been derived from strategic research carried out in other fields, such as defence and the marine industry generally. Although such developments can be expected to continue in the future, consideration has only been given to research (probably of an adaptive nature) required for further developments specifically in the field of fishing.

3 Key Priorities for Fisheries

- The future direction of research into **fish harvesting** should be focused in the areas of technology to aid better **management of fisheries**, rather than simply to increase the rate at which they can be exploited. Ameliorating the worst ecological damage caused by fishing: enhancing the biological productivity of marine ecosystems; maximising the return from existing levels of harvest by improving quality and reducing waste; more effective management of fish stocks improving the ability to monitor and control fishing activity within desired limits; development of selective performance of fishing gears.

- Further research is needed into techniques and methodologies of **technology transfer** to achieve successful implementation of mature technology into developing fisheries, which still have the potential for further development.

- Continued investment in appropriate **education and training** in order to maintain the UK's intellectual base. This would be more than simply training in established areas of knowledge, and calls for a developmental dimension to provide skills that will be required in the global market place.

4 Aquaculture

It is widely predicted that over the next 10 years major changes will take place in the world aquaculture industry. There is likely to be a wider range of farmed species, stricter quality standards, innovative product and market development, more stringent environmental control, larger and more influential companies and producer groups, and reduction in production costs. Production in the UK is expected to increase by approximately 10% per year in the next 3 or 4 years.

Major constraints to future development include the dependence of aquaculture on fishmeals and oils from the capture industry, environmental concerns and controls, impact on wildlife and possible interactions with local population genetics, import and spread of disease, tissue residues of treatment chemicals and animal welfare, shortage of suitable /acceptable coastal sites for new farms.

5 Key Priorities for Aquaculture

- Research in biotechnology for aquaculture particularly for nutrition, reproduction control, genetic improvement, disease diagnosis and control, fish behaviour and welfare.

- Research in systems technology for offshore fish farming, improving hatchery systems, development of better waste management control systems, development of handling and management systems for larger production levels, environmental impact analysis and management.

MARITIME TRANSPORT AND CONSTRUCTION

1 The Vision

With the globalisation of industry, just-in-time deliveries will become more important for manufacturers and suppliers. Shipping, which is the most environmentally friendly of all transport systems, is well prepared to meet this challenge in the medium and long term. No other transport medium offers the expansion potential of shipping with so many related benefits to society.

New types of vessels employing sophisticated communication/tracking systems, new port infrastructures, new materials and advanced automated production techniques - all will play a vital role in maritime transport renaissance.

2 Innovation Opportunities

By developing and exploiting leading edge technologies, targeting specific market objectives, the UK industry can bring innovative, high-value products and services successfully to many global markets. Analysis has identified five potential innovation opportunities which are market led.

- Optimisation for Ship Speed, Safety and Stability
- Least-cost Cargo Transportation
- Cost-effective Ship Construction and Conversion
- Minimum Environmental Impact of Ports and Shipping
- Rapid Development of New Craft

3 R&D PROGRAMMES

In order to gain the technology advantage, significant investment in R&D is needed. The Maritime Transport and Construction Focus Group identified a number of R&D topics which could address the needs for cost reduction and performance improvement.

3.1 Cost Reduction

Market-led innovation has significant potential to reduce costs in the design, construction, conversion, operation and repair of ships.

In terms of ship design, construction, conversion and repair this will be achieved through:

- Better organisation (inside and outside the firm)
- More streamlined processes
- Increased automation

For ship operators, costs can be reduced by:

- Automated ship control
- Automated systems for cargo handling
- Reduced maintenance requirements.

3.2 Performance Improvement

New regulations on environmental and safety performance, coupled with more specific user requirements, have increased the range of performance criteria applied by operators. This represents an opportunity to offer added value to customers, through:

- Reduced time to market with novel designs
- Improved capability against transport needs
- Reduced whole-life cost of ownership

In particular, there are real opportunities to develop intermodal transport facilities, offering cost-effective transport solutions. Growth in these services would stimulate demand in all segments of the industry.

4 KEY PRIORITIES

To address these challenges, generic research, applied research and implementation through technology is required in the principal areas of:

- Hydrodynainics and control
- Materials and structures
- Propulsion and actuation
- Human factors and safety
- Emissions control and remediation
- Automation and information
- Reliability and risk modelling
- Business processes

The high priority areas for maritime transport and construction are:

- Technologies for **Intermodal Marine Transport Systems**, including port facilities, focusing on **50 knot passenger and freight ferries**;
- Technologies for a **Clean ship**, focusing on minimum emissions and risk of spills, with low-wash and low noise performance;
- Continued development of **all-electric ship**, focusing on overall propulsion

systems and associated marine equipment, including structural implications;

- Technologies for **design and system** integration for marine vehicles and the development of virtual manufacturing and operating systems making use of advanced information technology and computer technology;

- **Business Process and Scenario Modelling**: for the complete life-cycle supply chain for marine equipment and manufacture to facility construction and operation and to optimise intermodal marine transportation systems.

COASTAL WATERS AND MARITIME LEISURE

1 The Vision

The drive for sustainable development of the coastal zone will depend upon management information systems with integrated and holistic approaches. These integrated management systems will need improved understanding of natural processes, improved monitoring at key sites and greater integration with socio-economic models to aid decision making.

2 The Coastal Zone

The coastal zone is a complex area of interactions that need careful management. All economic developments have to recognise potential impacts on the local and global environment, but in the coastal zone the consideration can be very difficult because of the diversities of interests and interactions.

The challenge overall is to appreciate that the shorelands and the coastal waters are an interactive region that needs to be managed sustainably, within the context of population pressure, increased demand for amenities, complex institutional interest, wide natural and socio-economic diversity, and uncertain climate change.

The markets for living and non-living coastal resources, ports, harbours, crossings, marine renewable energy, all interact with those of coastal markets. The markets where the interactions are particularly strong include:

- Leisure at the seaside

- Recreational boat use, leisure craft industry and marinas

- Recreational diving

- Navigation and safety

- Waste disposal and pollution

- Coastal protection, defence and remediation

Each of the coastal market areas has its own special technologies, and is strongly influenced by technologies from other sectors, such as materials, information technology, communications. Developments are generally seen as evolutionary and there does not seem to be any one dominating technology in this marine area.

3 Market Opportunities

- The export market for **clean environment technology** and associated services to developing countries (e.g. the rapidly expanding economics in the Far East) is expected to grow. Their requirements will evolve to those of Europe and include: improved prediction of environmental impact of pollution by development of integrated modelling (hydrodynamics, sediment transport, chemical processes, ecology, human interactions, climate, air-sea exchange, land-sea interchange) and more advanced biological monitoring to identify the longer term impact of pollution.

- **Research and Technology Developments are required for** combining coastal protection with habitat creation or storm water storage and further development of multi-stage beach ground water control; these include: remote sensing of waves; currents, sediment, transport and beach changes; climate variability and the consequences for coastline processes; construction technology for the surf zone.

4 Key Priorities

- The drive for sustainable development will be facilitated by **information systems** for integrated and holistic approaches to the **coastal zone**. These management tools will require improved and linked knowledge bases of the natural environment and the socio-economic forces, together with user friendly interpretation packages for managers. Increasingly there will be a need for information systems with prognostic and predictive capabilities to assist planning and operations.

- Research and development of **coastal zone modelling** will be needed on multi-disciplinary processes including physical forcing, sediments, the bio geo-chemical fluxes from land to sea, biodiversity, ecotoxicology at all levels from genetic and cellular to whole animal and populations. Research on processes will have to include the impact of climate changes, including rising sea levels.

BACK BACK TO INDEX FORWARD

FORESIGHT PROGRAMME

The Foresight Programme will help to ensure that resources are used to best effect in support of wealth creation and improving the quality of life. Its purpose is to help business people, engineers and scientists become better informed about each other's efforts. It is bringing these communities together through networks which will help to identify emerging opportunities in markets and technologies. The results of Foresight are informing decisions on spending by Government and industry. The results are available to small and medium sized enterprises which may not have the resources to undertake Foresight work on their own account.

The Foresight Programme is co-ordinated by the Office of Science and Technology (part of the Department of Trade & Industry). Foresight panels have been working in each of the following 16 sectors:

Agriculture, Horticulture & Forestry	IT, Electronics and Communications
Chemicals	Leisure & Learning
Construction	Manufacturing Production & Business Processes
Defence & Aerospace	Marine
Energy	Materials
Financial Services	Natural Resources & Environment
Food & Drink	Retail & Distribution
Health & Life Sciences	Transport

BACK BACK TO INDEX