Marine Monitoring Platforms

Marine Monitoring Platforms: Paradigms for Development in Ireland

By

Edin Omerdic, Daniel Toal, John Wallace,
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and Anthony Grehan

CAMBRIDGE SCHOLARS
PUBLISHING

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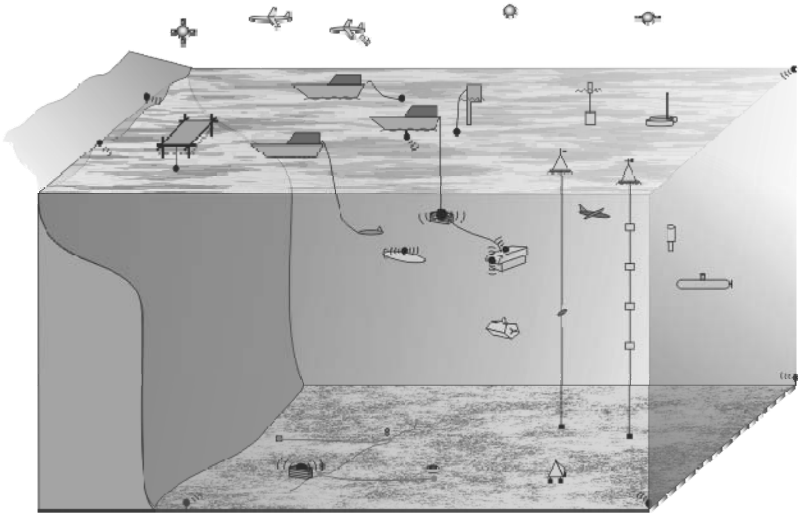
This book first published 2009

Cambridge Scholars Publishing

12 Back Chapman Street, Newcastle upon Tyne, NE6 2XX, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-4438-1356-7, ISBN (13): 978-1-4438-1356-3



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This project (Grant-aid Agreement No. DK/05/003) was carried out with the support of the Marine Institute and the Marine RTDI Measure, Productive Sector Operational Programme, National Development Plan 2000 – 2006 (Ireland).

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LIST OF ACRONYMS AND ABBREVIATIONS

ABE	Autonomous Benthic Explorer
AC	Alternating Current
ACES	Autonomous Coastal Exploration System
ACM	Acoustic phase-shift Current Meter
ADCP	Acoustic Doppler Current Profiler
AESOP	Assessing the Effects of Submesoscale Ocean Parameterisations
AGM	Absorbed Glass Mat
AIC	Argo Information Centre
ALACE	Autonomous LAgrangian Circulation Explorers
ALIVE	Autonomous Light Intervention VEhicle
AMPS	Advanced Mobile Phone System
AMSI	Association of Marine Scientific Industries
AOML	Atlantic Oceanographic and Meteorological Laboratory
AOSN	Autonomous Oceanographic Sampling Network
ARIES	Acoustic Radio Interactive Exploratory Server
ASAP	Adaptive Sampling And Prediction
ASC	Autonomous Surface Craft
ASCII	American Standard Code for Information Interchange
ASV	Autonomous Surface Vehicle
ASW	Anti-Submarine Warfare
AUV	Autonomous Underwater Vehicle
BIM	Bord Iascaigh Mhara
CBN	Chemical-Biological-Nuclear
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEO	Chief Executive Officer
CIMT	Centre for Integrated Marine Technologies
CODAR	Coastal Ocean Dynamics Applications Radar
CPU	Central Processing Unit
CTAC	Control Theory and Applications Centre
CTD	Conductivity-Temperature-Depth
DC	Direct Current
DCT	Depth Control Tank
DELOS	Deep-ocean Environmental Long-term Observatory System
DGPS	Differential Global Positioning System
DHS	Department of Homeland Security
DNA	DeoxyriboNucleic Acid
DOF	Degree Of Freedom
DOLPHIN	Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation

DR	Dead-Reckoning
DVL	Doppler Velocity Log
DWL	Douglas-Westwood Limited
EKF	Extended Kalman Filter
EM	Electro-Magnetic
ENSO	El Niño -Southern Oscillation
EPIC	Engineering, Procurement, Installation and Construction
ESA	European Space Agency
ESONET	European Seafloor Observatory NETwork
ESONIM	European Seafloor Observatory Network Implementation Model
EU	European Union
FAU	Florida Atlantic University
FLIP	FLoating Instrument Platform
FOG	Fibre Optic Gyro
FP	Framework Programme
FPSO	Floating Production, Storage and Offloading
GAPS	Global Acoustic Positioning System
GDP	Gross Domestic Product
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GFRP	Glass Fibre Reinforced Plastics
GLOBEC	Global Ocean Ecosystems Dynamics
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GRP	Glass Reinforced Plastics
GSI	Geological Survey of Ireland
GSM	Global System for Mobile communications
GUI	Graphical User Interface
HDPE	High Density PolyEthylene
HEA	Higher Education Authority
HF	High Frequency
HMS	Her Majesty’s Ship
HTML	HyperText Markup Language
HUSCy	Hydrographic Unmanned Surface Craft
HWU	Heriot Watt University
IACMST	Inter-Agency Committee on Marine Science & Technology
ICT	Information and Communications Technology
IED	Improvised Explosive Devices
IFREMER	Institut Français de Recherche pour l'Exploitation de la MER
IMO	International Maritime Organisation
INS	Inertial Navigation System
IOC	Intergovernmental Oceanographic Commission
IPB	Intelligence Preparation of the Battle-space
IRM	Inspection, Repair and Maintenance

ISE	International Submarine Engineering
ISPS	International Ship and Port Facility Security
ISR	Institute for Systems and Robotics
IST	Instituto Superior Técnico
IT	Information Technology
JGOFS	Joint Global Ocean Flux Study
LARS	LAunch & Recovery System
LBL	Long Base Line
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
LEO	Long-term Ecosystem Observatory
LOCO	Layered Ocean COmplexity
LOCO	Layered Organisation in the Coastal Ocean
LOOKING	Laboratory for the Ocean Observatory Knowledge INtegration Grid
LPG	Liquefied Petroleum Gas
MARS	Monterey Accelerated Research System
MBARI	Monterey Bay Aquarium Research Institute
MBT	Main Ballast Tank
MCM	Mine CounterMeasures
MERSEA	Marine EnviRonment and Security for the European Area
MIT	Massachusetts Institute of Technology
MMC	MOOS Mooring Controller
MMP	McLane Moored Profiler
MMRRC	Mobile & Marine Robotics Research Centre
MOOS	Monterey Ocean Observing System
MRU	Motion Reference Unit
MSD	Marine Strategy Directive
MSST	Maritime Safety and Security Teams
MVC	Main Vehicle Computer
MVCO	Martha's Vineyard Coastal Observatory
NAO	North Atlantic Oscillation
NATO	North Atlantic Treaty Organisation
NAVOCEANO	NAVal OCEANographic Office
NDP	National Development Plan
NDT	Non-Destructive Testing
NEPTUNE	North East Pacific Time-integrated Undersea Networked Experiments
NERC	Natural Environment Research Council
NOAA	National Oceanic & Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
NTNU	Norwegian University of Science and Technology
NTSC	National Television System Committee
NUI	National University of Ireland
OBS	Optical Backscatter Sensor

OC	Onshore Centre
OOI	Ocean Observatories Initiative
ORION	Ocean Research Interactive Observatory Networks
PAL	Phase-Alternating Line
PAR	Photosynthetically Active Radiation
PC	Personal Computer
PDO	Pacific Decadal Oscillation
PHINS	PHotonic Inertial Navigation System
PID	Proportional Integral Derivative
POL	Proudman Oceanographic Laboratory
PRTLI	Programme for Research in Third-Level Institutions
PWM	Pulse Width Modulation
QSP	Quality Seafood Products
R&D	Research & Development
RCA	Radio Corporation of America
RCO	Regional-scale Cabled Observatory
REA	Rapid Environment Assessment
REMUS	Remote Environmental Monitoring UnitS
RF	Radio Frequency
RMS	Royal Mail Steamer/Ship
ROV	Remotely Operated Vehicle
RQO	River Quality Objective
RRS	Royal Research Ship
SAUV	Solar-powered AUV
SB	Surface Buoy
SBL	Short Base Line
SCICEX	SCientific ICe EXpeditions
SCOUT	Surface Craft for Undersea and Oceanographic Testing
SDSM	Seawatch Deep Sea Module
SFI	Science Foundation Ireland
SIAM	Software Infrastructure and Applications for MOOS
SIT	Silicon Intensified Target
SLAM	Sequential Localisation And Mapping
SMA	Spatially Managed Areas
SME	Small & Medium Enterprise
SOC/NERC	Southampton Oceanography Centre / Natural Environment Research Council
SPINAV	Subsea Pilotless INspection using an Autonomous Vehicle
SS	Steam Ship
SSDS	Shore Side Data System
SWOT	Strengths, Weaknesses, Opportunities and Threads
TAO	Tropical Atmosphere Ocean
TMS	Tether Management System
TOGA	Tropical Ocean Global Atmosphere
UAV	Unmanned Aerial Vehicle
UHD	UltraHeavy-Duty

UHF	Ultra High Frequency
UM	Underwater Monitoring module
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UPS	Undersea Persistent Surveillance
URI/IFE	University of Rhode Island / Institute for Exploration
USB	Universal Serial Bus
USBL	Ultra Short Base Line
USCG	United States Coast Guard
USGS	United States Geological Survey
USS	United States Ship
USV	Unmanned Surface Vessel
UTV	Underwater Towable Vehicle
UUV	Unmanned Underwater Vehicle
VCR	Video Cassette Recorder
VHF	Very High Frequency
VICOROB	Computer Vision and Robotics
VIP	Vehicle Interface Programme
VOS	Voluntary Observing Ship
VTMIS	Vessel Traffic Management and Information System
WFD	Water Framework Directive
WHOI	Woods Hole Oceanographic Institution
WOCE	World Ocean Circulation Experiment
XBT	eXpendable BathyThermograph

EXECUTIVE SUMMARY

The objective of this study is to provide the Marine Institute and other readers with the information required to make judicious decisions that concern investment in R&D in marine platform technology over the next 10 years.

The key constraint to the rate at which this vision is realised relates to the research, development and roll-out of the technological advances necessary to make the vision happen in terms of monitoring platforms, data acquisition and modelling. The creation of sufficient impetus to fulfil this vision will require a substantial or order of magnitude increase in funding for marine technology development. There is an urgent need for more detailed scientific knowledge of the largest biosphere on the planet and the seabed resources of the oceans. These are important to us not alone for reasons of monitory prosperity but more importantly to protect one of the major life systems on Earth. The next 20 years hold for exciting times for marine scientists and engineers.

As Ireland's exploration, monitoring and development activities in coastal and offshore areas continue to grow, so will the need for the marine monitoring platform technology necessary to support that growth, including capabilities in automated underwater intervention. A wide range of activities in the ocean necessitates the use of robots and semi-robotic platforms. These platforms include: Autonomous Underwater Vehicles; Remotely Operated Vehicles; Ocean Gliders; Surface Unmanned Vehicles; Profiling floats, Seabed Observatories, Data buoys, drifters and many more. In an Irish context, there are, and will be, growing requirements to access and maintain in-service weather buoy networks and extend operations to include coastal buoys, surface and underwater oceanographic equipment infrastructure, and future seabed observatories.

This study is aimed at presenting a brief summary of the challenges of observing the ocean environment, at describing state-of-the-art in marine platforms, at providing a vision of platform technology in 2021 and beyond, at exploiting the opportunities in the Irish context and at providing conclusions and recommendations for the Marine Institute regarding future treatment and investments in marine platforms.

After setting the scene in Chapter 1, key drivers that have the strongest impact on development in the marine platform sector over the next 10 – 15 years are identified in the second chapter. A brief review of existing marine platforms has been undertaken in the third chapter. Platforms for marine monitoring covered in this review include ships, submarines, moorings, offshore and inshore platforms, bottom landers, drifters, floats, manned submersibles, ROVs, underwater gliders, moored profilers, autonomous surface craft, propelled AUVs and ocean observatories. Further analysis of present and near-future capabilities of each platform, including present trends, advantages, limitations and future developments, is given in the fourth chapter. The future vision offered in this chapter is of a marine world in which integrated remote sensing, robotics, marine engineering and improved communications will radically change the ways of gathering data about the oceans. The fifth chapter summarises and concludes the findings of the Desk Study. The opportunities identified in previous chapters are assessed in the light of Irish strengths, weaknesses and external threats to establish those with most potential in the Irish context. General conclusions and Irish specific recommendations highlight identified weaknesses while promoting existing strengths, so that Ireland can compete for identified opportunities. A list of stakeholders consulted during preparation of this study is presented in the Appendix.

As an Island nation we should plan to engage fully in the unfolding vision of the future oceans and become a key player in the use and development of platforms of marine monitoring technology. The fiscal commitment to the oceans and marine platforms should be in direct relation to Ireland's ocean resources and seabed territories rather than to our population size. We should strive for a Norwegian level of marine related commercial activity. If we do so, the long-term vision will mean a substantially greater percentage of Ireland's GDP is marine-based than is the case for many of our larger population partners/neighbours.

The following gives a brief summary of the recommendations of this study:

Building Irish R&D capacity - Technopole: There is an existing cluster of research laboratories, SME's and the Marine Institute located along the Atlantic arc from Galway through Limerick to Cork. This is recommended to form the basis of a Technopole building on the academic, research and high technology strengths of the partners and the infrastructure and marine focus operations strength of the Marine Institute.

Growth and consolidation of professional grade graduate engineers and scientists: Within the third-level institutions and government agencies (MI, GSI, BIM, etc) there is a strong research and professional marine science community. The situation is not balanced though with the numbers of professional grade engineers engaged in the (marine) agencies and marine related industry in Ireland. This is in contrast to the professional make up of agencies such as SOC/NERC, WHOI, MBARI, IFREMER, etc. The vision for marine platforms in the future involves significant use of high technology in the oceans. Within the rollout of NDP implementation and Sea Change strategy, it is recommended that the investment in human capital address this balance issue with professional level scientists and engineers: scientists; hydrographers, surveyors, oceanographers, zoologists, geophysicists, geologists, biochemists, climatologists, etc. and Engineers; marine engineers, naval architects, electronic engineers, electrical power engineers, instrumentation & control engineers, robotic engineers, mechanical engineers, computer engineers, structural / civil engineers, etc.

Ships: For the envisioned level of activity the requirement for ship support will increase. R/V Celtic Explorer is a very good multi-purpose research vessel, but heavily subscribed. The Naval Service is in the process of replacing part of the fleet. At least one new naval vessel should be acquired capable of deploying ROV and AUV. This vessel would need dynamic positioning, suitable deck space and winch. Beyond this significant growth in the requirement of ships of opportunity will be required to support activities for deployment of platforms with high levels of autonomy, reduced size and cost per item (e.g., increased use of floats, drifters, gliders, small near surface propelled AUVs etc.). Increasing the use of Ships of opportunity will require the Marine Institute to undertake awareness programmes to promote such activities.

Landers/moorings, data buoys, ocean gliders, drifters and tide gauges: Irish funding should be targeted to build up a track record within Irish teams in the development and operation of moorings, buoys, landers, drifters, etc. This will facilitate Irish involvement in the multi-million euro/dollar European and global business of technology development for cabled observatories. Expertise in oceanographic moorings in NUI Galway and with data buoys in the Marine Institute is of international standard. Teaming up with research teams in sensor development and diversifying the suite of sensors carried on moorings and data buoys is recommended as well as the acquisition/development of flexible modular lander systems to stimulate capacity building. Lander platforms are very useful for site-specific measurements of environmental conditions and for testing of sensors intended for ocean observatories over periods of 1 to 12 months.

ROVs: Ireland needs ROVs to roll out the vision of the future in marine and marine platforms. With the growing level of marine activity going forward a single large work class ROV (which is tied to research vessels such as the RV Celtic Explorer) will not deliver all that is necessary. The recommendation is for a number of ROVs including (a) inspection class ROVs with minimum sensor payload of 30kg and depth rating 200 – 400m, (b) mid range all-electric ROV with optical fibre umbilical and payload of approx 80 - 100kg and depth rating of 1,000m – 1,200m and (c) a larger ROV with payload of 100 – 150kg and depth rating to 3,000m with a tether management system for work on the edge of the continental shelf, in canyons and at planed Porcupine Ocean Observatory sites. This mix will provide operation flexibility with the ROVs offering overlapping depths of operation capability and flexibility of operations for the smaller ROVs on smaller vessels as against a single tied to RV Celtic Explorer ROV.

AUVs: The increase in ocean monitoring envisioned will require order of magnitude increase in use of platforms for marine monitoring. The main driver behind development and uptake of AUV technology for this expansion will be their increasing application portfolio and significantly reduced cost compared to ship based science and ROVs tethered to surface ships. The recommendation is for a mix of AUVs; Acquire two shallow and inshore marine monitoring propelled AUVs, which are comparatively low cost; access, through partnership in Europe and with North America to larger vehicles (Autosub, Hugin, etc) for AUV ocean science experimentation. In the rolling out of cabled observatories, Ireland has an opportunity in technology development and field trials of AUVs (docking systems, battery technology, intervention class AUV development, long deployment AUV technology infrastructure and resource management). Much of this could be trialled inshore or at a lake site such as Lough Derg.

Cabled observatories: Through ESONET, ESONIM and proposals for CELTNET Ireland is actively involved in the European development of cabled observatories, specifically a node in the North Atlantic (Porcupine) off west Ireland. The majority of investment in cabled observatories over the coming decades will be in the development of the technology, installation and ongoing operation of the observatories. Therefore, it is strongly recommended that Ireland aim to engage in all these aspects of cabled observatory development and roll out and avoid simply ending up with planning and operational responsibility of a single node which employs technology developed and installed by other partner states. It is recommended that we use as far as possible Irish research vessels, Irish technology solutions, Irish technology project management, support and logistics for Atlantic cabled observatories. Management of maintenance and expansion of networks (addition or replacement of sensors) will be expensive. This will be a global problem with significant business opportunity for niche providers. Maintenance and seabed intervention intervals or expected frequency of 3 to 6 months can be expected (based on data buoy maintenance experience).

Development of virtual underwater simulation capability: With significant increase in costs and technical complexity of marine deployed platforms, it becomes of paramount importance to carry out as much engineering development, system testing, and scenario 'what-if' analysis in the design phase of these complex systems rather than in the roll out, deployment and operational phase. It is recommended that Ireland (Technopole/research centres) develop virtual underwater simulation environments and significant hardware-in-the-loop testing abilities. Complete virtual reality simulation of the seabed cabled networks, power, connections, data transmission and physical characteristics can provide a virtual test bed prior to field deployment with associated cost benefits. Many integration problems could be detected, isolated and resolved in advance, yielding significant costs saving and improving the reliability of the overall system. Business opportunities exist if this area is resourced up quickly.

In final summary, for Ireland to have an active role in the envisioned future for Platforms for Marine Monitoring, we need substantial and vigorous investment in infrastructure (both human experts and capital / equipment). The vision of this desk study is reflected and reinforced by the vision of 'Sea Change, a Marine Knowledge, Research & Innovation Strategy for Ireland 2007 – 2013'. We should embrace this high-tech marine future for Ireland with the resolve to significantly transform Ireland's status as a maritime nation in terms of science, engineering and economic activity.

SECTION 1

INTRODUCTION

1.1 Background

Our ability to make sustained observations over large areas is currently one of the main limitations for major advances in our understanding of the oceans. Continuous, long-term measurements of physical, chemical, geological, and biological variables in the oceans and the seafloor are required to understand trends and cyclic changes and to capture episodic events such as major earthquakes, tsunamis and harmful algal blooms. Enhanced capabilities for making sustained measurements of the ocean will open up new research opportunities and lead to improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems, and climate. These advances will provide the tools for improved management of ocean resources such as fisheries, and better-informed decisions on the use of the coastal zone for recreation, development, and commerce.

Major tools for achieving sound scientific understanding of the mechanisms and feedbacks involved comprise integrated ocean platforms that can provide adequate observational and manipulative skills. These platforms will have many facets with varying deployments stretching from the seafloor to the atmosphere, from the sub-meter to the global scale and for durations varying from minutes to years.

The schematic shown in Figure 1 illustrates a variety of platforms, several of which can utilise physical, chemical, bio-optical, acoustical and geophysical sensors or systems. The time-space diagram shown in Figure 2 provides an overview of the performance scope of some of the more familiar platforms currently employed in marine measurements. It provides a rough means of estimating the utility of different platforms in space and time. It also reemphasises the need for deploying sensors from both in-situ and remote platforms. Nesting of platforms (e.g. AUVs as sub components of larger observation platforms) can optimise the use of these observational assets.

The highly coupled nature of processes in the oceans calls for comprehensive approaches which combine (geo-) physical, chemical and biological parameters. Design of platforms for marine monitoring will vary accordingly to include classical tools (e.g. research vessels, multiple mapping and sampling devices, moorings) as well as innovative autonomous observatories (multi-sensor floats, observing ships, seafloor observatories). As the demands for greater observation continues to increase in demands for more operational oceanography with initiatives like the Global Ocean Observing System (GOOS) and various programmes concerned with climate change, so to does the demand for innovation in platform design to achieve improved performance and/or reduced cost.

The objective of this study is to provide the Marine Institute and other readers with the information required to make judicious decisions that concern investment in R&D in marine platform technology over the next 10 years. The report will provide the reader with a description of the state-of-the-art, provide some informed commentary on what are the drivers for platform development in the foreseeable future and will present a vision of how the technology is likely to change over the next 20 years. The report will identify some of the significant gaps between the current state and this vision, and ultimately provides recommendations for the Institute that will position Ireland in a strong position to capitalise on what will be significant opportunities.

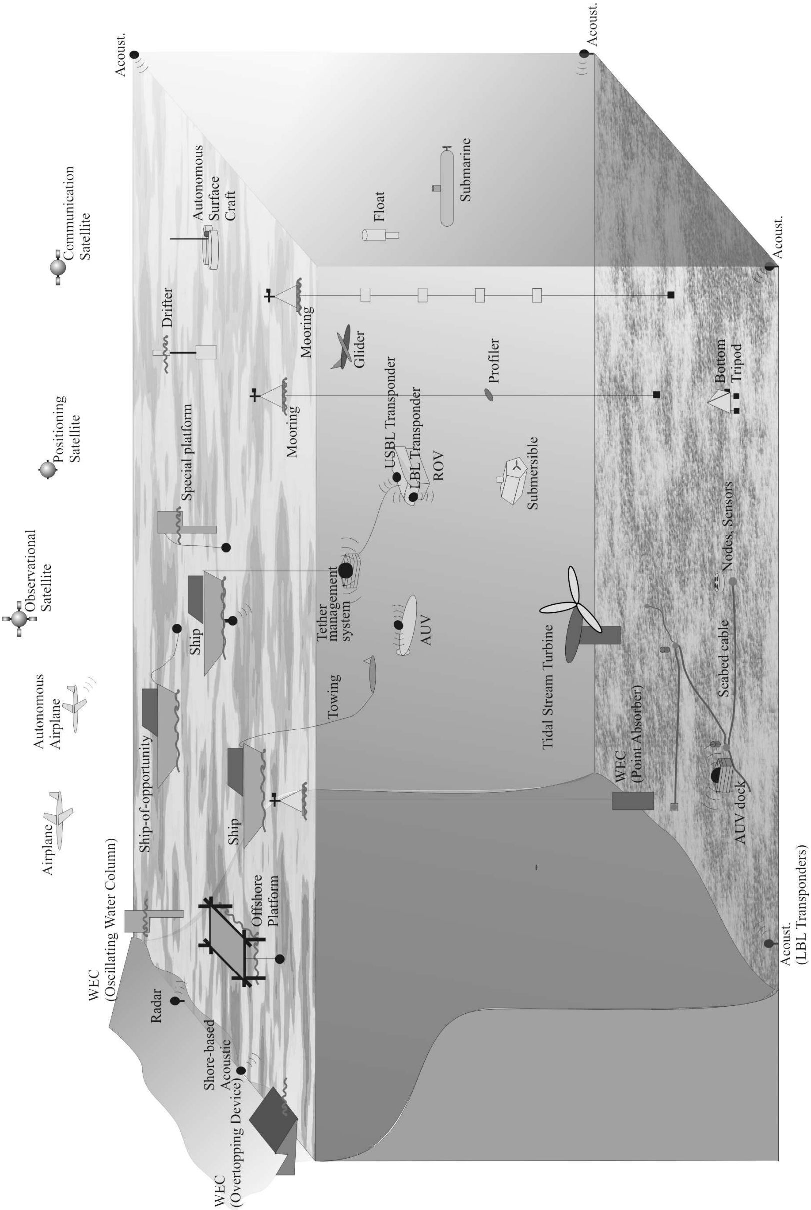

Figure 1: Schematic illustrating a variety of sampling platforms for ocean observations (Field *et al*., 2002).

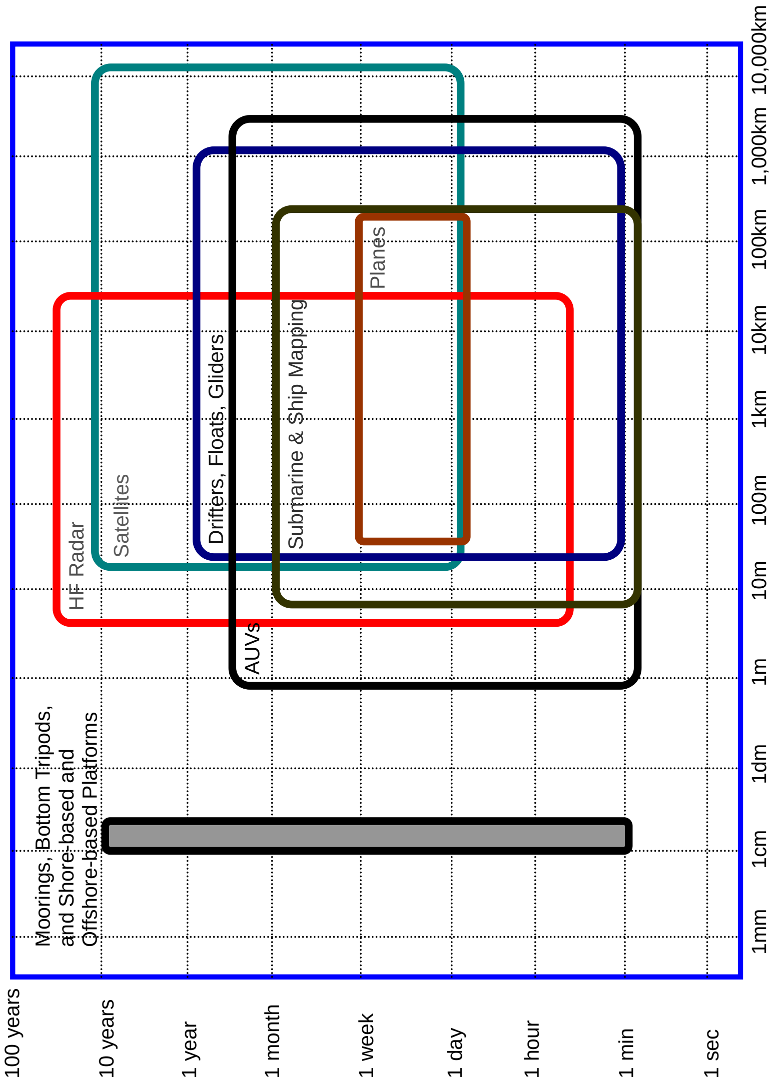

Figure 2: Time and horizontal space domains accessible with different observing platforms (Dickey, Ch. 9 in Field *et al.*, 2002).

1.2 Intended readership

The intended readership of this report includes engineers, scientists and other decision makers that already have expertise and experience in marine science and technology.

1.3 Assumptions

In preparing this report it was necessary for the authors to make a number of what they felt were reasonable and informed assumptions, as follows:

- The authors assume that there is wide recognition of the need for monitoring of the marine environment and a variety of platforms is required for working in this marine environment.
- Based on various published literature it is assumed that the need to understand and forecast the oceans and their resources is going to increase over the next twenty years. Safe and sustainable exploitation of marine resources will depend on enhanced capacity to understand and monitor and we can expect the relatively new field of operational oceanography to grow to meet these needs. It will become increasingly important to provide operationally useful information for a wide range of users and customers about the present state of the marine environment, and the boundary data required to predict future states as far ahead as possible.
- When considering opportunities for Ireland in the Marine Technology sector and specifically in platform related technologies, the opportunities must be considered in a global context. While Ireland may be a very important seed bed for new ideas and innovative development, long-term commercial success requires global vision when considering achieving returns on investment (especially commercial returns).

1.4 Rationale

The National Marine Research & Innovation Strategy for Ireland envisions our geographical location of great importance to our future economy and it recognises that we (Ireland Inc) must endeavour to strengthen our marine nation status in many respects. Furthermore, as well as enhancing economic activity in fisheries, aquaculture, tourism, energy (oil, gas and offshore renewable), shipping, marine biotechnology and others, there is a recognition that Ireland also must grasp opportunities in the various marine technology sub-sectors. In 2005, the Marine Institute foresight initiative not only identified the technology sector as an opportunity for development in itself but recognised that the implementation of new technologies and the development of indigenous expertise in these technologies will be a key factor in achieving success in the various other marine disciplines.

Among sub-sectors, such as sensor technology, biotechnology, renewable energy technologies, the technology of marine platforms was identified as an area with opportunity. This report is therefore intended to elaborate on the collective term of “platform technology“, and on some of the potential in this sector.

1.5 Scope

The overall objective of the study is to inform decision makers concerning the opportunities to invest in platform related technology over the next decade.

For the purpose of this study the authors considered the definition of a “Platform” to be “*any structure or object that will host a sensor or suite of sensors used to measure some aspect of the marine environment. Platforms can be fixed, floating or include propulsion systems. They can be manned or unmanned and can be submerged, shore based, airborne or buoyant on the surface. The Platforms include not just the mechanical structure of the platform but also the subsystems, such as sensor systems, platform control, communications and power.*“

This desk study is intended to give answers to the following questions:

1. *Which drivers lead development of platform technologies today? What will change in the near future?*
2. *Which marine platforms exist today?*
3. *What are the present capabilities and limits of these platforms today? What is likely to happen in the near future?*
4. *Which platforms and which aspects of platform technology should be considered for future investments?*

1.6 Approach

Information presented in this study were acquired and prepared combining a variety of methods, including a review of a selection of EU and international projects, searching of public domain data about best practice in the area of marine platform technologies using the Internet and available literature, consultation with a significant number of technology providers, technology users and researchers (a full list of stakeholders and events visited by the authors during preparation of the Study is given in the Appendix).

In addition, a total of five one-day workshops were held at UL to brainstorm, review and prepare material for the Study.

1.7 Report structure

The report structure is relatively simple and is consistent with the approach adopted in the study.

Chapter 2: Section 2
The Role of Monitoring in Sustainable Marine Resource Development. This chapter will describe some of the key drivers for the industry and what might be realistically anticipated over the next 10-15 years. This includes an analysis of literature and some discussion on technological requirements in identified key areas such as operational oceanography, monitoring related to global warming, the exploitation of the ocean as a food resource, exploitation for energy, exploration for bio-medicine and security at sea.

Chapter 3: Section 3
Review of Existing Marine Platform Technologies. When considering future opportunity, it is necessary to have reference start point. This chapter provides a review of the existing marine platforms (e.g. AUVs, ROVs, gliders, drifters, buoys, etc). It provides a brief description of their historical development, principle of work and some description of their current application(s). A description of the key perceived weakness & limitations (e.g. power supply, navigation, communications, endurance, etc) is also included in this part of the report.

Chapter 4: Section 4
Toward the Future - Vision of Marine Platform Systems in 2021. This chapter combines output from a selection of existing literature, a number of brainstorming sessions and other commentary. It describes the anticipated change in the technology between now and 2021 and beyond. This section will identify key areas where significant changes are likely to

occur along with some indications of what these changes might be. It concludes with a vision of how monitoring might evolve up to 2021.

Chapter 5: Section 5
Conclusions and Recommendations. This chapter presents a SWOT analysis of the current status of marine monitoring in Ireland. The opportunities identified in chapters 2, 3 and 4 are assessed in the light of Irish strengths, weaknesses and external threats to establish those with most potential in the Irish context. Recommendations are put forward which address identified weaknesses while promoting existing strengths, so that Ireland can compete for identified opportunities.

Chapter 7: References. This chapter lists relevant sources of information used throughout the study.
Appendix provides a list of stakeholders consulted during preparation of this study.

SECTION 2

THE ROLE OF MONITORING IN SUSTAINABLE MARINE RESOURCE DEVELOPMENT

2.1 Introduction

The recent Green Paper 'Towards a future Maritime Policy for the Union: A European vision for the oceans and seas' (Commission of the European Communities, 2006) identifies the three pillars of the Lisbon Agenda (Economic, Social, and Environmental) as the principal drivers for future development in the maritime sphere. Achieving growth and prosperity while maintaining environmental services are key factors to realise this vision. Implementation of the Water Framework Directive and the proposed Marine Strategy Directive will ensure good environmental status of EU's marine waters by 2021. Environmental monitoring is a key component of the implementation of this legislation. Monitoring is also important for the management of Special Areas of Conservation, hydrocarbon extraction, fisheries and shipping and early warning of the effects of natural hazards (e.g. tsunamis) and climate change.

The Green Paper is also accompanied by a number of Annexes prepared by the European Commission through expert groups which address issues of relevance in determining the likely future trends for monitoring in the European Union. These include:

- Competitiveness of the European Maritime Industries.
- The European Marine Observation and Data Network.
- Improving European Integration in Maritime Reporting, Monitoring and Surveillance.
- Climate change.

It is clear that environmental monitoring will be required as part of an ecosystem-based management approach, including marine spatial planning; coastal zone protection and management; sustainable management of resources and restoration of degraded marine ecosystems. New environmental monitoring technologies may be required for GOOS (Global Ocean Observing System) and GMES (Global Monitoring for Environmental Security) assessment and to secure maritime structures. Ocean monitoring systems arising from advanced communication technologies can provide data for both the environmental programmes and for monitoring the movements of ships for security and regulatory purposes, not only in Europe but in other parts of the world as well. Co-operation in the sharing of data with neighbouring Member States and contributing to a European data network will be an important monitoring responsibility.

Some of the key drivers for the industry now and over the next 15 years are described in this chapter, including a realistic prediction. This includes a review of recent market research, an analysis of literature and some discussion on technological requirements for operational oceanography, legislative issues & government initiatives, monitoring related to global warming, natural hazards, the exploitation of the ocean as a food resource, exploitation for energy, exploration for bio-medicine and other areas such as security at sea. Concluding remarks are given at the end of the chapter.

2.2 Market opportunities

Identifying market opportunities in this sector over a period 10 - 15 years in the future is always a difficult task. In the early 1980s, experts continually predicted that deep seabed mining would be a multi-billion dollar business within twenty years, and we are sure that many will still make the same claim. Even if one can identify market drivers, it is not always clear what the implications would be for more specific sectors; in this case marine platforms and associated sensors. For example, the future exploitation of Marine Biotechnology is predicted to be significant, but it is not clear what demand there will be for underwater technology to supply this industry, which is primarily a pharmaceutical business. The following is a summary of recent market research, in the public domain, that has been undertaken in this subject area.

Over the last ten years there have been a number of market surveys of the marine sector undertaken, but the specific sector covered by this study has not been dealt with in detail. For example, an IACMST (Inter-Agency Committee on Marine Science & Technology) survey, “A New Analysis of Marine-Related Activities in the UK Economy with Supporting Science & Technology” (Pugh and Skinner, 2002) found that “marine related