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FerryBox

From On-line Oceanographic Observations to Environmental Information

Costs and Benefits of Ferrybox Systems

Ferrybox Applications in the Frame of Marine Monitoring

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Summary of the FerryBox CBE

The FerryBox Cost Benefit Estimate (FerryBox CBE) provides proven information on benefits and costs of Ferrybox systems when applied for a wide range of applications in operational oceanography and routine monitoring of the oceans as well as for scientific applications. It summarises experiences gathered throughout the European FerryBox Project and a therein embedded period of routine operation of underway measurement systems on 9 ferry lines in 8 European countries and in different marine environments. In addition it incorporates information and experiences obtained in the national subprojects as well as from spin-off projects which emerged during the lifetime of the FerryBox project.

For this study we define Ferrybox systems as such kinds of oceanographic underway measurement systems which have achieved a certain grade of maturity with regard to functionality, integration of technical components and application friendliness which allow them to be installed and routinely operated on ferries and other ships of opportunity. These systems provide enhanced ocean observing capacities in terms of increased spatial and temporal coverage of larger marine areas combined with relatively low installation and operation costs and efforts.

Scientific and Operational Benefits

The application of Ferrybox systems shall be considered in two areas.

- Firstly as a versatile tool to contribute to a better understanding of marine processes, spatial and temporal variability for a wide range of scientific applications of which several ones have been demonstrated in the European FerryBox project. These comprised for instance process investigations on eutrophication, application into numerical models by specific means of data assimilation, sediment transport estimates and wax and wane of algal blooms.
- Secondly, they should be considered as an integrated component in operational oceanography and routine monitoring of marine environmental conditions and water quality together with and complementary to other oceanic observing components such as fixed monitoring stations, space-borne remote sensing and research or monitoring cruises. At present such matured systems are limited to a relatively small – but for monitoring the most important – number of “standard” parameters such as water temperature, salinity, turbidity and chlorophyll-a fluorescence as well as automated surface water sampling for subsequent analyses onshore in the laboratory. However, a series of “non-standard” applications such as current velocity profiling, acoustic backscatter or algae group identification have been tested in the project. Some of them have already reached pre-operational stages with foreseeable potential for introduction into operational systems.

For both the scientific and operational oceanography sectors matured Ferrybox systems provide a series of benefits and a wide range of application possibilities.

Ferrybox systems provide a very high spatial coverage which is impossible to achieve by other means especially in routine applications. Considering typical ship speeds between 15 and 20 knots and typical data acquisition cycles between 1 and 30 seconds a Ferrybox system can resolve spatial features of around 10 to 300 metres along the ship’s track. This is sufficient for most processes and spatial scales relevant for ocean and coastal monitoring of the seas and for many scientific objectives (e.g. when compared with local Rossby deformation radii or typical eddy scales). This resolution even provides the ability to detect small-scale features as for instance oil or chemical spills.

The temporal resolution is moderate but compared to other "track-related" and spatial measurements still high. Typical repetition cycles of short-route coastal ferries are several times per day, for ferries across marginal seas typically once per one to two days and even for longer ferry lines a route is served several times a week. The fact that ferry lines are usually identically routed allows derivation of time series which is usually not possible for other en-route measurements as for instance by drifters or floats.

Technical and Operational Benefits

Compared to offshore deployed devices the operation costs of Ferrybox systems are drastically lowered as these works can be conducted in one of the ports the vessel is calling routinely which, however, should be located preferably nearby to the operating institution.

Ferrybox systems do not need a specially designed platform and can be installed on almost all seagoing vessels providing their owners and operators allow it. Installation costs and efforts are relatively low as available infrastructure on the ship like space, water supplies, cable booms, and communication devices can be used supportively.

Many technical problems typical for stand-alone marine measuring systems can be entirely omitted. This includes especially constraints in availability of electric energy, installation and consumable storage space as well as protection of several components against harsh marine environments and prevention measures of longer-term fouling with associated maintenance efforts.

As the measuring device always "comes back to the operator" servicing and calibration can be done directly in port.

Consequently and in summary Ferrybox systems and their sensors and components are much easier and simpler to design, construct and operate than stand-alone marine in-situ devices.

Other Benefits

Ferrybox systems provide the opportunity to achieve a strong public outreach if accordingly applied and supplemented with associated equipment and functionalities. Attractive data and information displays in the passenger areas which can be combined with other information of interest (e.g. on the local environment, information for tourist and travellers, soft advertising) can be used for awareness creation and public dissemination.

Ship owners and operators as well as other public entities and private companies may be also included in such platforms and information services. By this the application of Ferrybox systems can be strongly motivated and it is also possible to encourage direct or indirect contributions to installation or running costs.

Some Constraints of Ferrybox Systems

However, one should not omit here to mention some constraints of Ferrybox systems in relation to other monitoring and measuring means in marine science and operational oceanography.

Shipping lines are not always ideally positioned for the desired objective and thus a Ferrybox application is often a compromise between available routes and scientific or monitoring needs. The installation possibilities depend on the good-will of the vessel operator or owner. The systems have to be designed and operated in such a way that their installation and operation does not disturb the routine works and desired operation of the vessel. Also Ferrybox systems must not interfere with other equipment installed on the ship nor require interference by the crew.

Vessel operators may from time to time close-down services, alter shipping routes, or replace a vessel on short notice. Also ferries can be quickly sold or companies may close-down or change ownership. To cope with this Ferryboxes shall be highly mobile and a good relationship with the vessel's operator is required to maintain sustainable system applications. Especially when used for longer-term assessment and monitoring purposes the selected shipping route needs to be durably served.

The measuring depth of "standard" Ferrybox systems is limited to the mostly mixed surface layer (depth 0-5 m). Although some parameters are possible to acquire also over a certain depth range with advanced systems or special sensors or carrier systems the foreseeable routine applications are limited to the sea surface.

With regard to data quality one ought to keep in mind the use and purpose of the data. Therefore it is necessary to discriminate between lower quality data available in real- or quasi-real-time as typically applicable for warning purposes and quick assessments and with regard to achieving high-quality data sets which usually require additional quality-control and post-processing measures when for instance used for long-term assessment of environmental conditions, variability and changes as well as for most scientific investigations. Compared with other marine monitoring and measuring systems Ferryboxes acquire very large amounts of data. Hence quality control, evaluation and processing means need to be highly automated, robust and reliable. Therefore new measures in data processing and evaluation need to be developed especially when Ferryboxes are used routinely and in increasing numbers in operational services.

Tentative Estimates of Costs and Efforts

The costs for the instrumentation and the sensors as well as for their installation are relatively low as in many cases standard components can be used. Infrastructure which is already installed on the vessel (e.g. rooms, cable channels, water and energy supplies, communication equipment) can be used in support. Depending on system functionalities, sensor configurations, sampling equipment and other functions and capabilities of a Ferrybox system the typical investment costs are in the range of 50,000 EUR for a "standard arrangement" to 150,000 Euro for a system with enhanced capabilities (e.g. with integrated ADCP, automated sampler and/or algae group sensor).

Installation and set-up costs certainly depend on the ferry and the desired level of operation and maintenance friendliness. Low-cost installations in or near the machinery room are achievable for around 10,000 to 20,000 EUR. More sophisticated installations for instance with hull mounted sensors or supported by a moon-pool can be usually made only when a vessel is refitted or new-built. Such installations cost typically several 10,000 EUR but may be supported by ship owner if he is interested (see below). The same applies for installations in the passenger areas which display data and associated information of interest which typically range from around 5,000 to 10,000 EUR (excluding specific programming and multi-media developments).

Operation costs of Ferrybox systems include the following components: Servicing and maintenance, calibration and referencing, system operation and control, data quality control, pre-and post-processing plus archiving up to a stage "ready to use for applications". The main cost factors are personnel efforts which along with the FerryBox project have been experienced in the range of about 3 to 4 person months/year (cumulative for scientist, technicians and support staff) per operational system. A considerable optimisation potential exists when an institution operates routinely more than one Ferrybox system of identical or similar configuration as related operation and maintenance efforts will not increase linearly with the amount of systems. Associated estimates still with few experiences are in the range of an increase by a factor of 0.5 for each additional system.

Associated are costs for consumables, travels and communication which are very much application dependant and summed up in average to 5,000 to 10,000 EUR per year. On long ferry routes the main cost factor are satellite communication fees. However, large ferries and cruise ships have intensive and routine satellite ship-shore / shore-ship communication traffic and if the Ferrybox system can hook on to this the communication costs for control and data transmission become marginal if not negligible and might be covered in support by the vessel's operator. As for every measuring system also the replacement costs for the Ferrybox system ought to be accounted under this cost category. Considering a typical life-time for marine monitoring equipment of 5 years and the aforementioned investment costs for a Ferrybox system a budget of 10,000 to 30,000 EUR per year should be calculated therefore.

With regard to investments, installation and operation costs one should keep in mind that all systems applied in the project were either institution designed prototypes or small pilot-series or prototypes. With increasing applications and further transfer of results, experiences and technologies into the marine industry community it is expectable that Ferrybox systems become more standardised as well as easier to install, calibrate, maintain and operate. In overall this might lead to cheaper system costs and diminished efforts for their operation.

Conclusions and Recommendations

The European FerryBox Project as a whole and the FerryBox CBE in particular proved the benefits and versatility for application and utilisation. Ferrybox systems comprise a versatile and cost-efficient component of ocean observing systems and can be also used for a wide range of scientific objectives.

The future requirements in marine environmental monitoring and operational oceanography as demanded by the Global Ocean Observing System (GOOS) and its regional implementation initiatives but also by several policies as the Water Framework Directive (WFD) in Europe are difficult to fulfil. Without Ferrybox systems as an integrated supplementary component in ocean and coastal observation systems the required capacities, improvements and enhancements of spatial and temporal coverage cannot be gained for relatively low costs or even without cost increase.

Existing monitoring and warning systems can be optimised with appropriate applications of routine underway measurements. For developing countries which have to build-up marine observing capabilities and capacities along with implementation of the GOOS as well as for monitoring their territorial waters and exclusive economic zones (EEZ) Ferrybox systems are a cost-efficient alternative. Agencies and administrations involved in operational oceanography and marine environmental monitoring and management are encouraged to deeply consider the potential and use of Ferrybox systems along with further development of operational oceanographic services.

Also a series of activities and objectives in marine science, earth observation and climate change and impact investigations are hard if not impossible to achieve without increased utilisation of ships-of-opportunity and automated underway measurements. This in particular in times of tough public budgets with associated constraints in research vessel capacities and availability. The marine science community is also encouraged to increasingly transfer experiences, laboratory prototypes, metrologies and evaluation methods into the applied oceanography sector and to the marine industry.

The marine industry community is encouraged to develop higher automated, more modular, less maintenance intensive and more user-friendly devices towards, ideally, plug-and-play Ferryboxes. To become commercially attractive this needs to be stimulated by increasing amounts of applications which will, in return, strengthen the technological lead, competitiveness and market position of European equipment manufacturers and service providers.

Ship owners and operators are encouraged to team up with Ferrybox operators (and vice-versa) and to utilise the indirect benefits and potentials when allowing the installation of systems on their vessels.

Ferrybox systems provide an excellent area for promotion activities and an attractive in-kind service for their customers and passengers. If appropriately initiated win-win-situations between marine science, oceanographic agencies, manufacturers, service providers and the shipping industry can be easily achieved. Increasing applications of Ferrybox systems will also stipulate development of additional applications and utilisation of data.

Preface

This document provides information on costs and benefits of the application of Ferrybox systems in marine environmental monitoring and integrated management of marine areas and coastal zones. Appropriate and integrated monitoring and management of the marine environment and resources including the coastal zones, requires three components: (1) a strong science base, (2) appropriate operational facilities and (3) a comprehensive decision making scheme including support tools. Consequently we tried to analyse costs and benefits of Ferrybox applications in view of a/m three components.

This cost benefit estimate (CBE) was elaborated on the basis of long-term and vast experiences from the European FerryBox Project but founded also on longer-term previous experiences of individual teams operating Ferrybox systems or comparable devices. The CBE also incorporates experiences from affiliated projects and across the marine science, operational oceanography and industry communities concerned.

This document intends to provide valuable information for future applications and use of Ferrybox Systems in operational oceanography as well as for scientific applications. It also may provide some guidance to instrument and sensor developers and manufacturers in which directions future Ferrybox developments might go and which gaps and weaknesses of present systems have been identified along with the European FerryBox Project. Institutions which intend to operate Ferrybox systems might also find certain hints on how to optimise data acquisition, communication, operation controlling, maintenance and calibration as well as data processing and evaluation and, correspondingly, on how to reduce costs and efforts.

Authors: This document was compiled and edited by a task team formed out of the European's FerryBox Project's work package 6 – the so called FerryBox CBE Team with representatives from CTG, FIMR, GKSS, NERC.NOC, NIVA led by FerryBox Partner HYDROMOD.

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Document Reference Sheet

This document has been elaborated and issued by the European FerryBox Consortium.

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P 3	**NIOZ**	**Royal Netherlands Institute of Sea Research**	
P 4	**FIMR**	**Finnish Institute of Marine Research**	
P 5	**HCMR** (formerly NCMR)	**Hellenic Centre for Marine Research** (formerly National Centre for Marine Research)	
P 6	**NERC.POL**	**Proudman Oceanographic Laboratory**	
P 7	**NIVA**	**Norwegian Institute for Water Research**	
P 8	**HYDROMOD**	**HYDROMOD Scientific Consulting**	
P 9	**CTG** **(formerly CIL)**	**Chelsea Technology Group** **(formerly Chelsea Instruments Ltd.)**	
P 10	**IEO**	**Spanish Institute of Oceanography**	
P 11	**EMI**	**Estonian Marine Institute** (in cooperation with the Estonian Maritime Academy)	

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1 Introduction

Underway measurements of oceanographic parameters from ships of opportunities have a quite long tradition in monitoring the oceans. Already more than 50 years ago continuous plankton recorders (CPR) have been applied by the UK. This program expanded and is still operative up to now. Marine monitoring agencies rather frequently use cargo vessels for taking expandable bathythermograph (XBT) and later on also expandable conductivity-temperature depth (XCTD) measurements along their routes. Research and hydrographic survey vessels are usually equipped with a continuous salinity-temperature recorder (thermosalinograph) utilising pumped-in near surface seawater. Many newer research vessels are equipped with additional sensors as for instance acoustic current and/or laser profilers. A special class but probably the most common underway measurements are water depth profiling by echosounders firstly applied on the German Meteor I cruise in the Southern Atlantic Ocean in the late 1920-ties. Nowadays almost all larger survey and research vessels are fitted with swathe or multi-beam echosounders.

Underway measurements (mainly temperature, salinity, depth and sound speed, in arctic submarine operations also ice thickness and characteristics plus a series of other parameters relevant for operation and surveillance) have been and are routinely applied on surface naval vessels and submarines. However, the acquired data are usually classified and not available for ocean monitoring. Affiliated techniques of on-track ocean data acquisition are autonomous floating and submerged instruments as well as towed vehicles. Thus the application of continuous recordings of oceanic parameters from moving vessels or carriers is not generically new but was and still is to a great extent limited to research activities, hydrographic surveying and other special purposes.

Utilising underway measurements to a greater extent emerged with development and implementation of the Global Ocean Observing System (GOOS) and became increasingly stipulated by organisations concerned with monitoring of coastal water, marginal seas and the open ocean. The demands and objectives of the GOOS and in Europe the WFD caused the marine observing and science communities to consider new ways in data acquisition by increasing data coverage both in space and time (for details one is referred to Chapter 3).

Finland was among the first to take up these ideas already and successively implemented a series of measurement devices to acquire data on sea temperature, salinity and fluorescence with the prime objective to monitor and warn on harmful algae blooms in the Northern Baltic Sea. Similar, initially research driven approaches emerged in France, Germany, Norway, Spain and the United Kingdom. The European FerryBox Project brought these initiatives plus a series of intentions together to demonstrate on European-wide scales usefulness and versatility of routine underway measurements from ferries and supported in exchanging experiences, developing tools and in optimisation and harmonisation of routine operations.

It is more or less common consensus that this can be achieved by appropriately designed flow-through systems, which measure properties of pumped-in seawater at high frequency and, correspondingly, spatial density along the route. For this kind of instrumentation plus some optionally applied sensors or instruments we have created the acronym FerryBox.

2 Scope and Objectives of the FerryBox CBE

With this study we want to provide interested users and potential applicants of Ferrybox systems with cost and benefit information achieved throughout the European FerryBox Project and in various affiliated activities. We consider this as helpful for operators and end-users to further endorse Ferrybox systems to monitor the upper oceans. Furthermore, this study intends to provide operators, developers and manufacturers of sensors and systems with certain hints on requirements and possibilities to optimise the systems and also tries to predict some foreseeable trends in the near future. This study summarises operational experiences gathered during cumulatively 18 years of routine Ferrybox operation in this project.

In this study we limit our investigations to pre-operational and operational issues of Ferrybox systems. However, this study is not a full and exhaustive cost-benefit analysis for the following reasons:

- Firstly experiences and thereby gathered data are too sparse to provide a complete data and information basis for a classical cost-benefit approach.
- Secondly foreseeable rapid technological changes and system improvements along with increased applications will change such input quantities substantially which makes such an analysis questionable.
- Thirdly, it is almost impossible to rank and benchmark “soft constituents” like improved information and data density, better knowledge of processes in the monitored seas or increased and more reliable forecasting and warning capabilities in terms of real costs. Such improvements are highly beneficial for socio-economy, knowledge creation, environmental management and damage mitigation which are usually not accountable in terms of real budgets.

We are also not ranking and directly comparing the application of Ferrybox systems versus other approaches and systems applied in operational oceanography. Moreover, we consider that all these have their specific advantages and disadvantages, areas of applications and also partially feature different objectives. We leave it to the reader to estimate where integration of Ferrybox systems in a monitoring approach is beneficial in terms of data coverage and resolution enhancement and whether such has optimisations potential and may save costs and efforts.

In overall, one should remind that many systems are purpose-built or customer designed rather than standard off-the shelf ones. Ferrybox installation costs depend considerably on individual ship design aspects but also on relations between Ferrybox operating institutions and ship owners. Labour costs differ strongly throughout Europe. Hence personnel efforts are given in time consumption figures only. These are also linked to the recommended personal skills of operating staff.

In the following needs and requirements for enhanced marine monitoring are outlined (Chapter 3). The following three chapters follow the approach “***what one and gets***” – “***what this costs***” and “***what one gains***”. Accordingly Chapter 4 presents needs, applications and perspectives of Ferrybox systems and their potentials. Chapter 5 gives information and estimates costs and efforts to implement and operate such systems. Chapter 6 explains benefits for science, operational oceanography and marine industries more detailed along with application possibilities and future potentials. The study is rounded-off by the main conclusions and recommendations given in Chapter 7. Supplementary information and illustrations are given in Annex A, especially to the topics outlined in Chapters 4 and 5.

3 Needs and Requirements for Enhanced Marine Monitoring and Surveillance

Europe is surrounded by four seas and two oceans, and it has a coastline seven times longer than that of the US and four times that of Russia. The European Union has the world's largest maritime territory. Maritime regions of Europe account for nearly half of the EU's population and GDP. The maritime zones under the jurisdiction of the Member States are larger than their terrestrial territory. The marine environment is subject to a variety of stresses, ranging from the loss or degradation of biodiversity and habitats driven by contamination by dangerous substances and nutrients to the effects of climate change and forces such as commercial fishing, oil and gas exploration. These pressures put at risk the generation of wealth and employment currently derived from our oceans and seas.

It is now recognised in the EU that although there are measures to control these pressures, they have been developed in a sector by sector approach resulting in a patchwork of policies and at EU level there is no overall, integrated policy for protection of the marine environment. For example the current Water Framework Directive does not extent beyond one mile off shore. The EU's Commission services are currently finalising a proposal for a Thematic Strategy on the Protection and Conservation of the Marine Environment. Implementing such a strategy will require regular monitoring of the marine system which should supersede and extend the monitoring that is already done in off shore waters under the auspices of the OSPAR and HELCOM Commissions. The EU strategy will define the requirements for future marine monitoring at a national and European level. Work on defining the strategy started in 2002 and in 2003 OSPAR produced a revised strategy for Protection of the Marine Environment of the North-East Atlantic.

An ecosystem approach to management of marine waters needs a better knowledge of how that ecosystem functions. Key parts of this are not only improved knowledge of levels of contaminants but also what their sources are and how they interact with the ecosystem. Monitoring has to meet requirements that it

- Can cost effectively deliver continuous information of immediate scientific value
- Can deliver data in real time for monitoring and warning of environmental events
- Be reliable from the point of data collection to the transfer of information to management agencies
- Can provide near-real-time information for operational forecasting

EuroGOOS has highlighted the fact that over 800 ferry routes are operating in European waters (EuroGOOS, 1999). This gives rise to second meaning of box. The high number of routes means that several ones can be coordinated to provide boundary conditions for numerical models so that areas of interest can be "boxed in".

4 Ferrybox Applications and Approaches

In the European FerryBox Project on nine ferry routes large amounts of oceanographic data have been acquired operationally throughout a period of at least one year. Generally this data represents underway measurements conducted by automatic measurement systems installed on ferry boats on nine different routes. The large amounts of operational experiences gathered over cumulatively more than 18 years of Ferrybox operation and associated advancements and developments conducted throughout the European FerryBox project are presented in very condensed manner in this study. The FerryBox System Description (deliverable no. D-2.1) provides a comprehensive report on these applications.

Already today Ferrybox systems and related approaches became highly versatile tools for scientific applications and begin to enter into operational observation and monitoring. However, the potential of Ferrybox systems is far from being entirely exploited which will certainly changed along with increasing use and availability of commercialised and more standardised systems.

In Table 4-1 below we compiled an overview on Ferrybox applications as seen today in the framework of marine environmental monitoring and scientific investigation as well as in comparison with other observation methods. Although difficult to estimate as this strongly depends very much on individual objectives and goals, we have also provided a coarse relative ranking scheme to indicate where and how Ferrybox systems are suitable and less suitable to apply. In Annex A-1 further details are summarised to illustrate actual states, foreseeable trends and potentials of Ferrybox systems.

Unlike the laboratory and a prototype systems mostly applied in the FerryBox project, commercial off-the-shelf (COTS) Ferrybox Systems are introduced to the market Current commercially available Ferrybox systems include the Ferrybox of the German manufacturer -4H- JENA engineering GmbH (4H JENA), the UK built Chelsea Technologies Ltd. (CTG) Aqualine Ferrybox and the SeaKeeper from the US company General Oceanics (G.O.). Further details and capabilities of these systems are given in Annex A-2.1 and foreseeable perspectives and developments are outlined in Annex A-2.2. Costs and associated short specifications of the two European systems which nowadays increasingly enter the markets are given in Section 5.2.1. Furthermore, there exist some other manufacturers which may provide small series or customer designed versions of Ferrybox systems (such as the BlueBox of the German manufacturer GO Systems GmbH) which are not specifically considered here due to lack of affiliation with the project. Designs and capabilities of future Ferrybox systems will depend on demands. Currently, the market is being served by a handful of SMEs which have effectively adapted current sensors to be integrated in flow-through systems. If demands increase considerably Ferrybox systems will rapidly develop towards more modularised, standardised and user-friendliy ones. This will also result flexible customers-tailored systems at competitive prices.

A variety of challenges may be faced in fitting Ferrybox systems on commercial vessels, depending on existing facilities offered on the ship. The application of specialised marine sensors and devices on a merchant vessel requires easy installation and operation must not disturb seafarer routines and maritime safety. A Ferrybox system shall run entirely independent of intervention by the ship's crew and should not have excessive operation, maintenance and calibration requirements which have to be accomplishable during usually short port calls. In addition the acquired data shall be efficiently, routinely and automatically transferred ashore, pre-processed, quality controlled and disseminated to the communities of users. Typically associated installations and fittings require pure seawater supply, electricity connections, communication interfaces, installation of sensors, housings and computers plus, if desired, setting-up of passenger displays (refer to Annex A-3 for further details).

Table 4-1: Overview and relative ranking of Ferrybox applications

Overview on and Relative Ranking of Ferrybox Applications Compared with other Marine Measurement Methods				
Observation methods, application areas and focused goals	**Ferry / SOO**	**Single point mooring / ODAS buoy**	**Remote sensing**	**Research / monitoring cruise**
Scientific applications				
Temporal resolution	+	+ +	0	– –
Horizontal resolution	+ [A]	– –	+ + [A]	0 [A]
Vertical resolution	– [B]	+ +	–	+ +
Flexibility to apply to new scientific topics / parameters	+ +	+	– –	+ +
Environmental monitoring				
Regional information	+	– –	+ +	+
Time resolution	+	+ +	0	–
Long term availability	+	+	+	+
Public awareness	+ +	–	+	–
Costs	+	–	0	– –
Number of parameters	+ +	0	0 / –	+ +
Maintenance	+ +	+	0 / –	0
Data availability in time [C]	+ +	+ +	0 / –	– /– –
Long term effect monitoring	+	+ +	0	0

Explanations and notes:

A Ferrybox and underway measurements from research vessels provide along track resolution in the 10 metre scale but are limited to the track line; remote sensing devices have usually much lower horizontal resolution but cover wider areas.

B Possible to improve with application of profiling instruments (e.g. ADP, LIDAR) but this is presently limited to specialised applications.

C Ferrybox and ODAS are available in real- / near-real time with then necessarily lower data quality and accuracy / quality. Delivery of remote sensing and cruise data is in most cases delayed for processing needs, evaluation and/or property reasons.

Table 4-1 continued

Policy support				
Observation methods, application areas and focused goals	**Ferry / SOO**	**Single point mooring / ODAS buoy**	**Remote sensing**	**Research / monitoring cruise**
Proving implementation success / progress	+ D	+ E	+/ – F	+ G
Costs for validation proving	+ +	–	+	– –
Relative ranking scheme	+ + very applicable / suitable or low costs and efforts	0 indifferent or not applicable / suitable or not accessible for this type of application	– Not / less suitable / applicable or high costs / efforts	
Explanations and notes:	D Especially suitable for smaller-scale, short-term or and local features / events E Limited to larger-scale processes or to the fixed position advected quantities F Limited to processes which result in remotely detectable parameters. G Limited to longer-term processes possible to detect at sporadic surveys.			

For scientific and operational oceanography applications Ferryboxes have a great potential. Scientific investigations were conducted already before and during the FerryBox project and are expected to emerge increasingly in the near future (refer to Annex A-5 for details)

Operational oceanography interests from several European agencies and pilot applications already arose during the FerrxBox project. In countries like Norway and Finland they have already achieved operational status and are a strong component in monitoring programmes. Present and future application potentials are more comprehensively described in Annex A-6.

5 Ferrybox Costs

Compared to “classical” monitoring approaches and methodologies costs and efforts for setting up and operating Ferrybox systems are extraordinary low. Moreover, the amount, resolution and coverage of data possible to be acquired with Ferryboxes shall be considered in relation with those achievable by fixed monitoring stations and along with sporadic monitoring or research cruises.

At present it is still difficult to estimate the “true costs” of Ferrybox systems especially when they are included in existing operational observation networks and procedures as these considerably differ from the usually higher costs and efforts for scientific and pre-operational applications. However and as further described below, already these estimates indicate high potentials for saving costs and efforts.

Differences in institutional frameworks, utilisation of already existing infrastructure, experiences and capacities, multi-project applications and certainly cost differences between institutions across Europe make it difficult to directly compare costs and efforts accounted within the Ferry-Box project. This is additionally hampered by the facts that institutional accounting schemes for direct and indirect costs, personnel efforts and overheads are not directly comparable with those from operational agencies. Moreover, most of the Ferrybox systems applied in the project are in-house developed laboratory prototypes which combine and integrate different components and sensors available on the market. In the framework of a science driven project it is also quite difficult to demarcate between routine efforts as operation, maintenance and data processing up to a defined delivery stage and activities for enhanced data processing, evaluation testing and other, more scientifically motivated work components.

Up to now there are only a few of Ferrybox systems applied. Hence experiences and figures for cost and efforts are too premature for a sound validation. Only Finland and Estonia (Alg@line EMI, FIMR), Norway (NIVA) and the Netherlands (NIOZ) have more operational oceanography related experiences although the systems are still in-house developed and individually modified. These institutes have also some experience on optimisation through multiple Ferrybox applications. Multiply applied systems offer strong saving potentials with respect to standardization of methods, procedures and data products as well as bundling or sharing operation and maintenance.

Likely this situation will soon improve when Ferrybox systems are applied in increasing numbers and with the availability of more standardised and commercially available systems. The ongoing or soon commencing activities in the operational oceanography sector will quickly enhance related knowledge and result in more provable figures. However, we have tried to summarise in the following section the costs and efforts for implementing and running Ferrybox systems on the basis of inter-comparisons of data and figures provided by the project partners operating Ferrybox systems and by two COTS Ferrybox manufacturers (CTG and 4H JENA).

In the table below costs and efforts for implementation and operation of Ferrybox systems are provided as per minimum and maximum accounted figures. As individual figures and possibly also accounting schemes differ considerably due to the differences of the Ferrybox systems but also due to differences in accounting associated costs and efforts (please refer also to the explanations given in the subsequent cost descriptions). Some figures are associated with “reasonable estimate” considering operational experiences and consistency of provided information in conjunction with other results from the project.

Table 5-1: Overview on costs and efforts of Ferrybox systems

Overview on Costs and Efforts for Ferrybox Applications				
Cost, effort or investment category	**Minimum**	**Maximum**	**Reasonable figure**	**Remarks**
Preparation, Purchase, Set-up and Installation				
Preparation	**7 days**	**40 days**	**20 – 30 days**	Near average of GKSS, NIOZ and FIMR figures
COTS standard Ferrybox	**56,500 EUR**	**67,000 EUR**		
COTS enhanced Ferrybox (as per included sensors and analysers)	**60,000 EUR**	**122,000 EUR**		Minimum for 4H JENA system wit O_2 sensor Maximum: 4H JENA system with O_2 Optode, 4 nutrients and algae classes
Purpose built standard Ferrybox system (does not fully account for previous RTD efforts)	**37,000 EUR**	**45,000 EUR**		Not accounted are earlier efforts for development and personnel costs
Purpose built enhanced Ferrybox system	**~ 65,000 EUR**	**~ 130,000 EUR**		As above and not including CO_2 sensor of NERC.NOC
Installation costs onboard	**4,000 EUR** for COTS system including personnel costs **3,500 EUR and 0.5 days** for purpose-built systems	**5,500 EUR** for COTS system including personnel costs **12,000 EUR and 20 days** for purpose-built systems		Upgrades of already onboard installed systems are not accounted here. Costs and efforts for special installations like hull mounted sensors and moonpools not listed here
Ferrybox Operation				
Operation control and supervision (highly application dependent)	**0.75 months**	**35 months**	**1 – 3 months for fully operational systems** **12 – 14 months for laboratory prototypes**	Near NIVA and NIOZ figures applied for operational and near FIMR figures for purpose-built systems
Quality control and data processing (highly application dependent)	**0.25 months**	**6 months**	**1 – 2 months for fully operational systems** **4 – 6 months for laboratory prototypes**	Closer to NIVA and NIOZ figures applied for operational systems
Consumables Travels and substance Spare parts	**1,500 EUR** **200 EUR** **1,600 EUR**	**7,400 EUR** **5,000 EUR** **3,700 EUR**	**1 – 2 months for fully operational systems** **4 – 6 months for laboratory prototypes**	Closer to NIVA and NIOZ figures applied for operational systems

Table 5-1 continued

Overview on Costs and Efforts for Ferrybox Applications				
Cost, effort or investment category	**Minimum**	**Maximum**	**Reasonable figure**	**Remarks**
Ferrybox Operation				
Consumables Travels and subsidies Spare parts	**1,500 EUR / yr.** **200 EUR / yr.** **1,600 EUR / yr.**	**7,400 EUR / yr.** **5,000 EUR / yr.** **3,700 EUR / yr.**		
Depreciation of investments	**20% per year**	**33% per year** NIOZ recommendation for sensors		
CTD calibration Conductivity analysis HPLC analysis Nutrient analysis	**1,500 EUR / yr.** **1,000 EUR / yr.** **500 EUR / yr.** **3,500 EUR / yr.**	**3,000 EUR / yr.** **1,500 EUR / yr.** **1,000 EUR / yr.** **3,500 EUR / yr.**		
Communi-. GSM cation fees ORBCOMM	**2,400 EUR / yr.** **600 EUR / yr.**	**2,400 EUR / yr.** **800 EUR / yr.**		Not including Internet access and ship-based web services
Onboard passenger display	**5,000 EUR / yr.**	**10,000 EUR / yr.**		Not including application developments
Data dissemination with Internet services	**0.25 months**	**6 months**		Not including application developments

In the following section provided costs and efforts are explained and refined more detailed.

5.1 Preparation and Planning Efforts

Typical work under this item comprises:

- Identification of suitable vessels and installation possibilities
- Negotiating with ship companies or operators
- Designing the overall alignment of the Ferrybox system
- Specifying, evaluating and purchasing systems or components,
- Designing interfaces and installation measures and
- Definition of application and operation objectives.

Related efforts depend strongly on institutional situations, in-house acceptance and application possibilities as well as on cooperation and affiliation with the ferry operator concerned.

Individual figures (where accounted) vary considerably among the institutes spanning from 7 days (NERC.NOC), 16 days (GKSS), 30 days (NIOZ) to 40 days (FIMR). The spread of these figures can be explained by different application requirements as well as application dependant technical and administrative demands (like for NIOZ specific preparations for hull-mounting of sensors and for FIMR integration into the Alg@line system).

Not accounted are efforts for raising interests in user communities, endorsing projects or programmes and acquiring funds or allocating institutional budgets: This is almost impossible to estimate and depends too much on external factors like political and programmatic preferences or public households.

5.2 System and Equipment Costs

5.2.1 COTS Ferrybox Systems

The investment cost for commercially available "basic" Ferrybox systems with standard sensors (water temperature, salinity, turbidity and chlorophyll-a) are in the range of 37,000 to 67,000 Euros.

System costs considerably vary between manufacturers, with the types, specifications and manufacturers of sub-components and sensors. Most Ferrybox systems allow the integration of user-specified sensors and other periphery parts. The systems also differ with regard to embedded cleaning and self-calibration facilities which also influence the costs.

When equipped with additional sensors the range is open atop. A typical system with water samplers, 4 nutrient analysers and algae group detection goes in the range of 100,000 to 150,000 Euros. Systems with acoustic current profilers and hull mounted sensors require typically investments in the range of 150,000 to 200,000 Euros.

5.2.1.1 CTG Ferrybox System

The CTG Ferrybox system costs net ex. factory approximately

67,000 EUR (~ 46,000 £ – prices as per October 2005).

The system includes

- Interface unit to include; enclosure, 17" TFT display, embedded PC, hard disks, power management system
- Sensor cabinet to include; MINIpack CTD-F (chlorophyll), MINIpack flow through chamber, MINI^{Tracka} II turbidity and flow through chamber, deaerator, aluminium frame, pipe works and fittings
- GPS/GPRS receiver module to include; ruggedised enclosure, GPS module, GPS Antenna, GPRS Module, GPRS Antenna
- System Handbook, deck cable (sensor cabinet to interface unit), GPS/GPRS interconnecting cable, maintenance box

5.2.1.2 4H JENA Ferrybox System

The net ex factory price (as of October 2005) for a standard 4H JENA Ferrybox I system is

59,150 EUR (2,700 EUR less without oxygen and ph sensors).

The system includes:

- The 4H JENA Ferrybox I Basic System with house/rack, electronics, GPS/DGPS positioning, UPS, GRPS communication, GPS/GSM antenna box with ruggedised housing, interfaces, tubes, valves, cleaning facility, documentation
- 4H JENA's standard set of sensors comprising salinity and temperature (FSI), chlorophyll-a (Scufa II), turbidity, pH and oxygen (Iras)
- An automatic antifouling unit for every sensor / water system
- Embedded industrial PC with 12" LCD display
- Land station PC with control and communication software

Above all-inclusive price does not include costs for individual adaptations and modifications as specified by many Ferrybox customers.

The less sophisticated Ferrybox II Base System with the same sensors, land station and software is 6,000 EUR cheaper (53,150 EUR).

The system components are also available separately.

4H Ferrybox I Base System	31,000 EUR
4H Ferrybox II Base System	25,000 EUR
Land station, PC and software	6,400 EUR
FSI T-S	4,700 EUR
Scufa II Chl-a, turbidity	7,100 EUR
Iras ph/oxygen	2,700 EUR

when purchased at and installed by 4H.

Fitting a 4H JENA Ferrybox with optional sensors and equipment costs as follows:

Algae classes	19,300 EUR	
Oxygen Optode	2,820 EUR	
Nutrients (Systea)	22,100 EUR	for a single unit (1 parameter)
	25,100 EUR	for a double unit (2 parameters)

The basic Ferrybox system can be equipped with different sensors and analysers. The sensor prices as given above include mechanical integration into the basic system and implementation in the data system. Optionally other sensors can be integrated on request.

Optionally 4H JENA offers a large screen display in the passenger area for about 8,000 EUR as well as installation, training and maintenance services / contracts.

5.2.2 Costs of Purpose- and Institute-Built Ferrybox Systems

Ferrybox systems for which different sensors and components are combined and integrated by the institutes themselves may be cheaper but correspondingly the efforts for pre-leading research, engineering and constructing the systems increase. As these figures are poorly possible to estimate respectively were not accounted below given costs reveal considerable uncertainties respectively do not account earlier conducted design, research and development efforts. Several institutes used components and sensors from previous systems which are not on the market anymore, prices are partly unknown or no more valid. Also the individual sensor configurations and specifications differ considerably.

5.2.2.1 FIMR

The cheapest in-house developed standard flow-through system is reported by FIMR (equipped with a Turner Scufa II fluorometer and an Aanderaa thermosalinograph) with 15,500 EUR for the pure measurement device (thereof 10,000 EUR purchasing costs and 3,500 EUR accounted for in-house building and installation). When additionally fitted with an ORBCOMM satellite communication and related electronics and cable runs a cost adder of about 7,000 EUR applies including in-house construction and testing. Enhanced data logging and communication devices are calculated with 14,500 EUR (including software developments and system testing). Thus in total the costs for the operational FIMR Ferrybox systems with standard sensors amounts 37,000 EUR. ♦

5.2.2.2 NIOZ

The costs for the standard Ferrybox system of NIOZ equipped with SBE hull-mounted T-S sensors (9,600 EUR), OBS and fluorescence sensors (exact prices unknown as taken from an earlier project – estimated with 3,000 EUR) DGPS positioning (7,100 EUR) positioning and including computers (5,000 EUR) and hardware (e.g. pipes, steelwork, pumps – 10,000 EUR) sums up to 31,700 EUR.

In addition the NIOZ system incorporates a hull mounted Nortek ADP which accounts for 33,000 EUR (purchasing price) resulting in pure system costs of 64,700 EUR.

The enhanced system of NIOZ installed later incorporated an ADP with computer for 36,000 EUR.

NIOZ has accounted 9 person months for design and system related development efforts with

- 6 person months of a software engineer for the automated data acquisition unit and the data transfers to the institute and to the passenger area on the ferry and
- 3 person months for a technician for constructions works (e.g. piping and wiring).

♦ EMI has been supplied by FIMR with one of its designed and built standard Ferrybox system for which they paid together with data acquisition and navigation software 19,000 EUR. In addition this system was fitted with a ISCO 3700R water sampler for 4,000 EUR (purchase price) and an phycocyanin flourimeter (Cyclops 7, Turner design) for 1,900 EUR. Therewith the total costs for the EMI Ferrybox system were 24,900 EUR.

5.2.2.3 NERC.NOC

The standard Ferrybox system of NERC.NOC equipped with CTG MINIpack and MINI^{Tracka}, ORBCOMM satellite communication and including housing, hoses, water take-off and return valves, cable runs and glands amounted to nearly 43,000 EUR (thereof about 25,000 EUR purchases). Personnel efforts were estimated with 10 labour days for design and 32 for building the system.

In January 2005 a refit and replacement of the ORBCOMM communication system cost about 18,200 EUR including installation work on the ferry with 28 days accounted cumulatively for work of institute staff.

In January 2005 NERC.NOC upgraded data logging and telemetry devices accounted in total with ~ 24,000 EUR. Work days for institute staff conducting electronic and software design / development works, testing and required fittings on the vessel account for 48 days.

For a system enhancements NERC.NOC calculated for

- Purchase of and supplementary fitting with an Aanderaa Optode oxygen sensor about 5,970 EUR (thereof ~ 4,370 EUR for the sensor) with 2 days work for design and installation.
- Design, construction and installation of a supplementary system to measure partial pressure of CO_2 in surface waters cost about 111.400 EUR (thereof about ~ 81,500 EUR for a subcontract for building the systems and purchasing components). Costs include also laboratory testing, specific fittings on the ferry and training. Associated labour time of institute staff is accounted with 55 days.

5.2.2.4 NIVA

NIVA's cost calculations assume that they have experiences from earlier systems which they repeat for installation on another ferry. Thus costs for development and design are not accounted.

NIVA cumulatively accounts purchase costs with 40,000 EUR and assumes work efforts for in-house (onshore) assembly of the system with 10 days.

5.2.2.5 GKSS

The purchase costs of the standard Ferrybox system of GKSS (4H JENA design) are given with 45,000 EUR.

For the enhanced system following costs applied:

pH and oxygen sensor	3,000 EUR	(purchase)
	plus 4 days for building and installation works	
Nutrient analysers	65,500 EUR	(purchase of ME APP system for nitrate, phosphate, silicate, ammonia with filtration unit)
	plus 4 days for building and installation works	

In-situ nitrate	12,000 EUR	(purchase of optical device) plus 1 day for building and installation works
Algal classes	12,000 EUR	(purchase) plus 1 day for building and installation works

Cumulatively the equipment costs for the full-scale GKSS Ferrybox system to 137,000 EUR plus 10 labour days for design and installation.

5.3 Onboard Installation Costs and Efforts

Under this item costs for fittings, wiring, piping and peripheral installations on the Ferry are estimated as well as the efforts for testing until the Ferrybox reaches operational status.

For their COTS Ferrybox systems CTG estimates installation costs (including labour costs) with about 3,650 EUR for an approved fitter and 4H JENA with 5,500 EUR. These figures are subject to individual situations on a ferry.

Initial installation efforts for the purpose-built Ferrybox systems in standard or enhanced configurations vary between 0.5 days (GKSS), 4 days (EMI, NERC.NOC), 7 days (HCMR), 14 days (NIOZ) and 20 days (NIVA).

Where accounted, estimates for onboard installation costs (e.g. for wires, pipes, water intakes and outlets) vary between 3,500 EUR (EMI), 5,500 EUR (HCMR), 6,800 EUR (NERC.NOC), 7,000 EUR (FIMR), 10,000 EUR (NIVA including internet connections and power supply provided by the ship owner) and 12,000 EUR (GKSS). These differences arise from variations in vessel designs and system requirements.

Above given costs, can rise considerably with the sensor arrangement (like for the NIOZ application for hull-mounted sensors requiring the vessel to dock or when installed in a specially therefore constructed moon-pool (40,000 EUR in the NIOZ case which, however, was covered by the ferry company).

5.4 Operation Costs of Ferrybox Systems

Operation costs of Ferrybox systems include following components: Supervision and maintenance, calibration and referencing, system operation and control, data quality control, pre-and post-processing plus archiving up to a stage “ready to use for applications” and depreciation.

5.4.1 Supervision, Maintenance, Spares and Replacements

Personnel efforts for supervision and maintenance works are estimated across a quite broad range. This differs partly for reasons of advancements and standardisation of the different systems but depends also on the experiences of the operators. Also the system complexity, travel schedules and data amounts retrieved influence this figure considerably. Another factor for these differences is caused by what is accounted under supervision. Some institutions considered this as purely keeping their system running whereas others also accounted here for efforts which could be also associated with data processing, validation and delivery into operational systems, information services or third party end-users.

Figures provided for this item were as follows:

GKSS	0.75 person months for standard and 1.5 person months for non-standard sensors (not demarcated in personnel categories)
NIVA	1.25 person months thereof 1 for scientists, 1 for engineers and 1.5 for technicians
HCMR	3.5 person months thereof 1 for scientists, 1 for engineers and 1.5 for technicians
NIOZ	4 person months thereof 3 for scientists and 1 for technicians
EMI	11.5 person months thereof 6 for scientists, 1 for engineers and 4.5 for technicians
FIMR	14.5 person months thereof 2 for scientists, 0.5 for engineers, 9 for technicians and 3 for students
NERC.NOC	35 person months thereof 12 for scientists, 3 for engineers 2 for technicians and 18 for students

Note: The above given labour and work efforts accounted under this topic by EMI, FIMR and NERC.NOC include a certain amount of data post-processing and scientific evaluations not explicitly demarcated here.

In summary we estimate the efforts for supervision and maintenance, once a Ferrybox is set-up and operationally running, in the range of 2 to 4 months depending on aforementioned factors in system complexity and acquired amounts of data. This figure does not include efforts for data processing, quality control, evaluation and dissemination.

Direct maintenance costs arise for travels, consumables, spares, repairs and routine cleaning and maintenance works. These costs certainly differ along with distances between institutes and ferry ports as well as with the length of ferry legs and the complexity of the different Ferry-boxes.

- Travels and subsidies 200 – 7,400 EUR / year
- Consumables 1,500 – 5,000 EUR / year
- Spare parts 1,600 – 3,700 EUR / year

Depreciation of investments:

- Considering commercial calculation schemes for replacing of a Ferrybox system within a period of 5 years (estimated lifetime for a system and/or to be kept on state-of-the-art, also compliant with commercial depreciation periods), one fifth of the investment costs price must be added to the figure above (i.e. 10,000 to about 30,000 Euro / year).
- NIOZ recommends replacement of Ferrybox sensors already every 3 years (~33% depreciation for sensor related investments).

5.4.2 Efforts for Data Quality Control and Processing

This figure is difficult to estimate due to lack of routine experience and for reasons of so far not clearly defined objectives under these items. They also strongly depend on the degree of operability and automatation of the Ferrybox systems.

Figures differ considerably and range between 0,25 person months (NIVA), 3.5 person months (EMI), 4 person months (thereof 2 each for a scientist and a software engineer), 4.5 person months (NERC.NOC), 5 person months (FIMR and GKSS – 6 months with initial quality check after set-up).

Costs for calibration services and analysis of reference water samples depend on individual sensor arrangements and can be provided as follows:

- CTD calibration 1,500 – 3,000 EUR / year
- Conductivity analysis 1,000 – 1,500 EUR / year
- HPLC analysis 500 – 1,000 EUR / year
- Nutrient analysis 3,500 EUR / year

5.4.3 Other Related Costs and Efforts

Communication costs and fees are estimated to amount 800 to 2,400 Euros per year.

This figure depends strongly on access and data amounts and transfer frequencies and certainly on the operation areas and communication systems used.

The cheapest system is mobile phone communication (including GRPS and other advanced services). GSM applications are limited to routes and transect segments with coverage by these usually shore-based links.

- GKSS has accounted annual GSM costs with 2,400 EUR

For more distant ship-shore/shore-ship communication satellite communication is necessary. Pure data transfer can be made through e.g. the Inmarsat, ORBCOMM or ARGOS satellite links.

- Provided ORBCOMM costs vary between 600 (NERC.NOC) and 800 EUR / year (HCMR).

For permanent availability, on-line and real-time access as well as for web-based applications ORBCOMM or Inmarsat data links are most suitable. When applied on cost basis communication fees are open atop especially when accessible through public web servers like the NIVA systems. However, when possible to link with the routine and excessive data traffic typical on large ferries through almost permanently open data links (e.g. for passenger credit card authentication, web- and e-mail services) Ferrybox related data traffic is a marginal add-on and might be even covered by the ferry company. It is expected that with the rapidly increasing application of mobile data traffic and services across the world (e.g. e-mail and web-services for cruise ships, ferries and airliners) satellite communications fees become drastically lower.

5.4.4 Data and Information Displays in the Passenger Area

When Ferrybox data shall be presented on-line in real time, communication costs increase rapidly by undeterminable third party access. However, such systems are usually covered by the ship operator when set-up on the routine intensive electronic traffic (see below).

Typical investment and installation costs for presentation devices in the passenger area are in the range of 5,000 to 10,000 Euros when assuming that such includes a standard personal computer unit and a large screen together with “standard” display software (as e.g. provided COTS from the two manufacturers CTG and 4H JENA – see above). The prices for large display screens are presently one of the main cost factors.

Installation costs are usually marginal when considering pure wiring and interfacing only but this may vary from installation possibilities and fittings required in the vessel passenger area itself Costs also depend on the individual layout and design of the display system on the ferry (e.g. for daughter displays and terminals in other areas of the vessel) and accounted here, where applicable under system installation.

Costs for additional software developments and integration of other information are open atop and not accounted here. Such applications may range from pure data displays together with some navigational information or track plots to multi-media applications which for instance combine Ferrybox data displays with other information for travellers and on landscapes, tourist attractions or marine environmental conditions as for instance on the Den Helder – Texel ferries.

Usually related software and multi-media applications are made within separate projects and are not feasible to account in conjunction with direct investments and costs of a Ferrybox system. However one ought to keep in mind that contents and way of presentation of such applications need to be kept up to date and comply with advancing computer and multi-media technologies in order to keep attractiveness to ferry passengers. Ferry companies may consider such displays as overall attractive and beneficial and thus may be willing to substantially contribute to installation and software costs of passenger displays (see below).

5.4.5 Ferrybox Data and Information Dissemination

Direct costs for presenting Ferrybox data on web servers and disseminating them in near-real-time through land-based Internet services are negligible as they are usually associated with Internet facilities already implemented in the institutes with practically unlimited traffic possibilities (direct high-speed connections or flat rates).

Personnel efforts for supervising automatic or semi-automatic data processing and managing web-based services vary between 0.25 person months (NIVA), 0.5 person months (NERC.NOC and GKSS) and 6 person months (FIMR).

This does not account for software developments which may be in the range of several months or even years for more sophisticated database, XML or WebGIS applications. Such developments base either on adapted tools and applications which already exist previously or are developed in separate projects.

5.5 Cost Sharing and Reimbursements

Applications of Ferrybox systems provide several possibilities in terms of cost sharing with ship operators and users of data and information. Also reimbursement opportunities are possible by utilising Ferrybox data for specific tasks and projects and along with value adding works. Examples and possibilities as experienced during the European FerryBox Project are shortly described below.

5.5.1 Contributions from Ship Owners and Ferry Operators

Any application of SOO measurements requires the willingness and cooperation of the owner and/or operator of the vessel. When Ferryboxes are applied in the commercial sector even marginal looking activities and work provided from a company or ship crew may account in company operation budgets. The fact that a ship owner agrees on installation and operation of a Ferrybox itself is already an important, although not accountable contribution.

Apart from this pre-requisite and related “routine” measures a considerable potential is seen to further commit ship owners and operators to Ferrybox application and to involve them therein. It is therefore important to achieve a win-win-situation which gives direct or indirect value in return. Such are often soft ones like enhanced profiles and image for the shipping company but may also include opportunities for soft advertising along with such sponsorships. Another strong motivation can be provision of interesting information to passengers and customers and thereby attract them to consumer areas on the vessel.

The NIOZ recognised such opportunities already several years ago and has developed an interface on their Ferrybox on the Texel – Den Helder ferry. On a large display in the cafeteria information is provided on a variety of tourism matters combined with regional environment information with the actually measured and attractively displayed Ferrybox data.

This application was so successful that on the new ferry boat which entered into service in 2004 the ferry company (TESO) financed the construction of a moonpool for the current profiler of the new NIOZ Ferrybox system with 40,000 Euro and also sponsored 50% of the large display screen plus 5,000 Euro for cabling on the ship. This is an outstanding example of long-term good cooperation and merging of interests especially if one keeps in mind that every shipping company is highly concerned about structural modifications and especially about breaks through the ship’s hull in any excess of purpose-designed needs as here for the moonpool.

Some of the Norwegian ferry companies have contributed significantly to the installation of the systems and have invested between 10,000 and 15,000 EUR on hardware installations as cabling, welding and constructions of new water inlets.

5.5.2 Data Fees

As for most environmental monitoring and observation activities commercialisation possibilities for measured and quality controlled data are rather poor. Data acquisition in marine environmental monitoring is considered as a public service and financed by public money. Data are only valuable if they are used by a wide community and for as much as possible objectives rather than being banked and unused due to high costs.

Ideally such data shall be available in the public domain for everybody like usually applied for non-security relevant environmental data in the United States. In Europe there exist different views on this issue but the general tendency goes in directions of low cost or even free availability. EuroGOOS has established a data policy which also anticipates that a considerable part of data is available free of charge or for marginal costs (e.g. handling and distribution fees) only.

In Europe most earth observation data are provided for free or very cheap for scientific research and use in other agencies and public bodies whereas much higher data fees are applied for commercial purposes.

In general fees achievable for pure and already existing data can only marginally contribute to the overall set-up and operation costs of a Ferrybox system. This in particular as there is no mass market therefore.

5.5.3 Value Adding Applications and Activity Sharing

A large potential is considered for value adding activities and projects. As such we may account specific analysis measures or specialised measurements which can be conducted with Ferrybox systems in an efficient manner. The same may apply if Ferrybox systems are specifically applied for a dedicated task. Such projects or activities are usually beyond routine and operational monitoring. The same applies for value added data products like specifically compiled databases, GIS applications or data assemblies combined with tools.

The few examples below of activities and projects already endorsed during the lifetime of the FerryBox project shall illustrate the value adding potential:

- A typical example for such a value adding and task specific project was acquired by NIOZ. In October 2006 the institute will start a project in which the Dutch Ministry of Transport (Rijkswaterstaat) pays for ferry observations and special analyses based thereon. This is done in the frame work of measuring the far-field effects of coastal works near Rotterdam harbour. It is difficult to give a specific amount for data fees. However, Rijkswaterstaat pays roughly 400.000 Euro for this 3.5 years project, including 75,000 EUR for calibration cruises.
- On the ASLO conference 2004 two FerryBox projects were presented which are sponsored by oil companies. Also in the Netherlands, the oil company NAM (a part of Shell) presently discusses with NIOZ possibilities to install Ferrybox systems on all ferry routes in the Wadden Sea, completely sponsored by the company. Their motivations are related to demonstrating care for the marine environment to the public along as a part of demonstrating Corporate Social Responsibility (CSR) which has become an emerging issue for the oil and gas exploiting as well as for other big industries.
- The Brazilian oil company PETROBRAS envisaged recently to sponsor the development of an oil-in-water sensor and its pilot application in a cooperative German-Brazilian research project funded by the countries' ministries of research. Also some large ship owners are willing to directly or indirectly support Ferrybox application in order to gain a "greener profile".

Public relation, image enhancement and CSR related sponsoring of environmental protection and monitoring activities may also become important drivers for Ferrybox applications in the future although there are also concerns in the research communities that such includes risks for loosing freedom and independency.

5.6 Optimisation Potential

There exist certain optimisation potentials which are not fully exploited and experienced yet. These are related to increased Ferrybox applications, enhanced standardisation, multiple system applications, increasing commercial availability and larger COTS series of Ferryboxes.

5.6.1 Operation of Multiple Systems

Present estimates and experiences show that personnel efforts and costs do not increase linearly with increased numbers of Ferrybox systems operated by the same institution. The related multiplication factor is presently estimated in the range of 1.5 when two or three Ferrybox systems are operated in the same institutional or collaborative framework.

Trans-boundary and European cooperation is very much supportive for this objective as partner institutions can assist in servicing Ferrybox systems and thereby considerable amounts of time and travel costs can be saved. Already during the project such collaborations were implemented for instance with in the joint operation of the Southampton – Bilbao ferry by NERC.NOC and IEO an affiliated cooperation between NERC.NOC and IFREMER as well as by EMI and FIMR. Present plans incorporate cooperative approaches between NIVA and NERC.NOC, NIVA and GKSS, EMI and the Polish Institute of Marine Research and between institutes from Finland, Russia and Estonia.

5.6.2 Optimisation through Standardisation and Commercialisation

Standardisation and commercialisation is expected to have a large potential firstly in terms of more reliable and automated systems which will decrease installation, maintenance and calibration costs and secondly by increased series which will decrease development shares, production costs and, accordingly, sales prices.

Increasing competition between manufactures may additionally stimulate lower Ferrybox prices.

6 Benefits for Users and Applications

The most important driver for the use of Ferrybox systems in Europe in the next few years will be the new EU Directive on Marine Waters which requires both an improved monitoring base for the measurement of contaminants and an associated better understanding of hydrological changes both in relation to transport of contaminants, the growth of plankton and for fisheries management.

The other driving force is the increasing realisation that Ferrybox systems provide very cost effective means of monitoring surface water conditions. This report clearly demonstrates how low that cost is relative to any operation that requires research or survey vessel time or even when compared with the costs of a network of fixed monitoring stations. It can now be shown that the data can be reliably recovered from Ferrybox systems throughout the year and even in conditions in which research vessels cannot operate or satellite cannot collect optical data because cloud cover is too extensive.

A large advantage of Ferrybox systems is that they provide the kind of regular data that is needed both for the validation of and assimilation into numerical models. Use of the data in association with models allows the data from the Ferryboxes to be extrapolated below the surface for understanding processes. Another advantage of Ferryboxes is their potential for carrying more complex instrument packages than has been the case with the limited set of standard Ferrybox parameters.

Work at NIOZ as part of the project has shown the potential for the use of Ferryboxes to carry acoustic Doppler current profilers (ADP or ADCP) so that subsurface properties can be measured. This type of use of SOOs is now being taken up by other groups round the world and has also potential for observations in deeper waters.[♦]

6.1 Marine Science Benefits

The majority of data obtained within the FerryBox project is still predominantly used for research or the development of operational systems. However, the example set by the project has already encouraged more predominantly operational agencies such as the Swedish Meteorological and Hydrological Institute (SHMHI) in Sweden and North Sea Directorate of Rijkswaterstaat (RIKZ / DNZ) in the Netherlands to start their own trials of Ferrybox systems. This equally mixed mode of use is likely to be the norm for some time to come as the potential for these systems and optimum usage are explored both by scientific labs and operational agencies.

Scientific applications of Ferrybox systems will continue to see their use in the study of specific processes or problem areas. In addition there will always be a need for the development, evaluation and quality control of new instruments and data transmission and control system. This is likely to be carried out by collaboration between research institutes, agencies and commercial partners.

Important in the near future will be the improved automation of data processing and transmission from the ships so that the data can be used in real-time for forecasts, warnings and operational models. This will pose the need to make data more widely available by the improvements in web semantics that will ease data retrieval through web services by interested users.

♦ Refer for instance to: *Flagg, C.N., M. Dunn, D.-P. Wang, H.T. Rossby and R.L. Benway (2005). A study of the currents of the outer shelf and upper slope from a decade of shipboard ADCP observations in the Middle Atlantic Bight. Submitted to JGR. Sea Research.*

Many of the ferries have Internet connection and this can easily be used for transmission of Ferrybox data. This is applied now on all the Norwegian ships and real time data are available to a wide user community and the general public.

Within the FerryBox project there are also good examples of how the collected information can be transferred to operational systems and services. The work of the FIMR Alg@line is a world leading example of what can be done. The FerryBox project provided examples of what can be achieved now and what is needed in the future so that the methodologies that have and are evolving can be transferred from this operational and/or pre-competitive stage to operational oceanography by commercial manufacturers and service providers. It is likely that a number of niche markets are being created for data collection tools, data transfers and in software for data processing archiving and interpretation.

The European FerryBox project incorporates all of the above depicted research motivated activities as demonstrated on Annex A-5.

6.1.1 Direct Benefits for Marine Science

6.1.1.1 Cost Effectiveness

The FerryBox project and Ship of Opportunity based observations in general can now be shown to provide both cost effective data that can be used effectively. The data presented in chapter 5 demonstrate how cost effective SOO data collection is compared to using research vessels which cost in the order of 20,000 Euro per day before any science is done. The benefit of the low cost is that it becomes easier to maintain time series data collection. In the first instance the collection of data on a nearly daily basis within the timescale of the FerryBox project has proved effectiveness in gaining understanding of processes that had not previously been possible with research ship cruises.

This is illustrated e.g. by the success of the NERC.NOC system in identifying the source of relatively low salinity waters in the western English Channel (Kelly-Gerreyn et al., submitted). This has been a question that has puzzled hydrographers since salinity measurements started in the early years of the 20th century.

6.1.1.2 Time Series

On longer time scales a SOO system that has been in operation since the 1930-ties, the Continuous Plankton Recorder (CPR) is proving increasingly valuable in providing information on how marine ecosystems changed.[♦] The success of the CPR has been in the identification of changes. But because the CPR has only collected data on plankton half the story is missing in terms of being able to identify other processes responsible for biological changes.

The future success of FerryBox projects is likely to be in providing data that show how changes in biology are related to changes in the surrounding hydrodynamic and geo-chemical environment.

[♦] See e.g.: Reid, P. C., M. F. De Borges and E. Svendsen (2001), "A regime shift in the North Sea circa 1988 linked to changes in the North Sea horse mackerel fishery." Fisheries Research 50(1/2): 163-171.
Wiebe, P. H. and M. C. Benfield (2003). "From the Hensen net towards four-dimensional biological oceanography." Progress in Oceanography 56(1): 7-136.

6.1.1.3 Range of Measurements

An important aspect of the development of Ferrybox systems is that most ships are relatively large platforms with plenty of power available to fit and running a large range of sensors at high data rates for long periods of time. This not the case for most buoy based systems. The potential ease of expansion of Ferrybox systems is an important advantage when it comes to designing systems that can return the data required to understand particular problems.

6.1.1.4 Usable Data

Another advantage of SOO systems is that they tend to be reliable and the types of ships used run for all seasons. This overcomes a major problem in oceanography which is the lack of data collected during winter months. The lack of observation on the European Shelf in winter was evident in the data assembled by the EU project NOWESP.♠ For ocean waters this has led to problems in estimating winter nutrient concentrations this being essential information for estimating the quantity of the spring bloom.♦

6.1.2 Constraints for Marine Science Applications

The largest constraint on interpreting data collected with the normal configuration of a Ferrybox or SOO system is that data is only collected from surface waters so that it only has one spatial dimension. This creates difficulties in being able to ascribe changes to water flow across the track or change at location. This requires that some knowledge of likely water movement is needed in order to able to interpret the data. This can come from previous experience but interpretation is best supported where data from other observing systems such as buoys and satellites is available. Information on subsurface change is only available where the SOO itself is fitted with profiling instruments or with supplementary data from research cruises which collect vertical profiles.

The greatest potential for interpreting subsurface information is by coupling Ferrybox data to models which are assimilating data from profiling systems such as XBTs or profiling floats. However, where a limited amount of local knowledge is available and the time series of Ferrybox data is sufficiently long the existence of advection effects can be detected and interpreted successfully form Ferrybox data as for example the tracing of the flow of French river water from the Loire and Gironde estuaries into the surface waters of the English Channel.

♠ Refer to e.g.: Radach, G., et al., (1988), The NOWESP research data base. Deutsch Hydrogrographische Zeitschrift, 48, 241-260.

♦ Refer to: Koeve, W. (2001), Wintertime nutrients in the North Atlantic - I. New approaches and implications for estimates of seasonal new production. Marine Chemistry 74, 245-260

6.2 Operational Oceanography Benefits

Ferrybox systems have large potentials and benefits for operational oceanography. This in particular to match the present and future needs for marine monitoring as demanded by policies (e.g. the WFD) and for appropriate implementation of the GOOS. Several operational oceanography applications already implemented or in an advance stage of operational implementation are presented in Annex A-6.

6.2.1 Benefits for Operational Oceanography

Especially for countries with very long coastlines traditional monitoring programs can only cover a very limited part of the coast. Many coastal areas reveal high and/or temporal variability like in the central and Southern North Sea where large river plumes extend into the sea or in the highly variable Norwegian coastal current. Traditional monitoring of processes in areas with low regular signals like the low-tide and further north practically tideless areas in the Central and Northern Baltic Sea is a challenge of its own. As processes are mainly triggered by longer periodic signals and stochastic events as well as by small-scale eddies and low-level signals every possibility to enhance temporal and spatial coverage of observations with reasonable efforts are highly beneficial.

Presently applied monitoring approaches will likely not be in compliance with the requirement for European Water Framework Directive (WFD) once it is fully implemented with its extension to marine waters. Adequate monitoring surface and near-surface waters requires also higher frequencies and different observational approaches and sampling strategies than of intermediate and deep / bottom water masses. Most of the routine observation of surface waters required in a comprehensive (WFD and GOOS compliant) operational monitoring programme can be covered with Ferrybox systems.

The possibility to simply efficiently and remotely control sampling units and data acquisition rates upon events are highly beneficial. Water samples can be brought rapidly to shore for further investigations (e.g. during HAB or other pollution events). Calibration and maintenance of routinely operated Ferrybox systems is much less resource and time consuming. Especially reaction times on sensor malfunction or equipment breakdown is much quicker and does not require ship cruises to offshore deployed devices. Also the synergies of Ferrybox data with satellite data and the assimilation of Ferrybox data into models are an important step forward to improve operational observing systems and forecasting of largely extended areas.

When Ferrybox systems are supplemented with adequate sensors the detection probability and possibilities of accidental or deliberately released spills and marine pollution events is much higher. Although medium to larger oil spill can be relatively well detected by airborne surveillance and sometimes also by satellites the spatial coverage (detection range) and pass-over schedules are relatively low. With a series of Ferrybox systems which usually also operate in high-dense traffic areas this can be greatly improved quasi as a costless side-effect, in case adequate sensors are put in place.

Improving forecast ability and quality and continuously operating operational forecast models desperately need real-time and quasi-real time data and especially larger-scale spatial distributions from satellite remote sensing for data assimilation and to quickly react on drifts of modelled results versus situations in nature.

In many cases routinely provided and quickly referenced data products and lower quality but fast available data fulfil these requirements (at least they are better than no information at all). Ferrybox systems can provide these data with much higher spatial and temporal density.

The presently ongoing attempts to use Ferrybox data for rapid ground-truthing and compilation of suitable near-real-time data products from remote sensing data will contribute to overcome present constraints in this field.

6.2.2 Constraints for Operational Oceanography Applications

Prior to considering this topic one ought to keep in mind for which Ferrybox systems are preliminary made and applicable (refer to Table 4-1). Ferrybox data and applications are a supplementary component in marine monitoring and thus have their place and application areas. At least for now they are not aiming on acquiring highest data quality although this is expected to improve step by step with increasing use, standardisation of systems and new sensor technologies. They are certainly neither a component for monitoring of the water column nor for acquisition of high-frequent time series at a fixed position. One also has to live with the fact that ferry operators terminate services or close down routes without much lead time and this fact, in general requires a more flexible approach than a traditional fixed position observation grid.

When the Ferrybox project started considerable rumours and concerns were addressed by parts of the operational oceanography community. Frequently these concerned the large amounts of data produced by Ferrybox systems compared to stationary observation systems. Others addressed problems with quality and incompliance to long implemented routine procedures. Several interventions addressed also capacity problems in the agencies and this in parallel with strong budget reductions and reduced personnel resources. [1]

These arguments are understandable in view of the traditional implementation and operation of marine monitoring at governmental agencies focussing frequently on sampling of high precision and quality data and production of high-quality long (climatological) time series of a few (standard) parameters at relatively few positions. Although this is an utmost requirement and demand in overall monitoring strategies and programmes and of utmost importance for climate and climate change investigations it is only a part of comprehensive marine monitoring along with the WFD and GOOS requirements.

As documented above these can be only matched with enhanced inclusion of real-time and quasi-real time data and data products in which Ferrybox data have their strength and share even if they are less accurate and verified. It is obvious that these data require high-degrees of automated processing and utilisation and a lower degree in verification by high-precise reference samples. In face of constraints in resources likely only few spatially or temporally selected subsets of Ferrybox data may undergo similar post-processing and quality control procedures as applied for climatological time series to subsequently finally match the standards for high-quality data sets. However, for the anticipated and matching utilisation of Ferrybox systems such high confidence is also not necessary.

Already around mid-term of the project some agencies revised their opinions. This became obvious at first in those countries where the agencies strongly changed their organisational structures and ways of operations to facilitate them to match both, demanded increase in routine and real-time observation and considerable constraints and even drastic reductions of their budgets.

[1] During the lifetime of the European FerryBox Project the German light vessel Elbe 1 which acquired the longest high-quality time series in the North Sea (if not in the world) capsized in a heavy storm. The Federal Maritime and Hydrographic Agency (BSH) responsible for its operation addressed requests for support and funds to the government as well as to the German and European marine communities to re-establish this important station as quickly as possible.

Actually one should have expected broad support throughout all stakeholders and users concerned and especially from those who need such long time quality series. However, the opposite was the case and thus after more than 100 years in operation this station passed silently off the marine observational network.

Countries like Finland and Norway already started this “new way” quite early and are now in the stage that Ferryboxes supported monitoring has reached almost full operational stage. They were followed by the Netherlands and Sweden who nowadays respectively soon will operate pilot and test applications of Ferrybox systems along with their monitoring activities. Similar plans are considerably advancing in the United Kingdom and in other small countries like Estonia or Iceland.

6.3 Marine Industry Benefits

The Marine Industry Community are an important potential user of Ferrybox data as it is this group that can offer significant funding to support these systems if direct benefits to their individual businesses can be demonstrated. This sector has been identified as a major target for engagement by EuroGOOS to promote operational oceanography.

Major investors in marine technology over the last 50 years have been those companies involved in offshore oil and gas exploration and production. Apart from regulatory monitoring obligations this industry has a direct interest in the environment at its operation areas, particularly in weather monitoring and forecasting. Adverse environmental conditions can disrupt operations and cause significant costs. The same applies for disregarding environmental concerns (cf. the Brent Spar case). As ferry lines lead frequently far away from offshore installations Ferrybox systems can be installed on service and supply vessels which routinely, regularly and in long-terms service these devices. The oil and gas industry is also willing to fund targeted developments as for instance low dose oil-in-water monitoring depicted in Annex . It has already been recognised from both sides that public-private co-operation is also desirable for marine monitoring (cf. Dr. Peter Ryder as on the EuroGOOS Conference 2005).

On the other hand, there will remain requirements and obligations for monitoring authorities to supervise offshore exploration activities to ensure that their activities are not harming the environment. This in particular for long-term and low-dose effects and impacts which more and more raise environmental concerns. Monitoring demands are expected to increase substantially with operations shifting to deep and ultra-deep waters far off the coast as well as harsher environments like the Arctic. Also unmanned subsea production and transportation systems will determine higher monitoring efforts.

For offshore renewable energy production requirements and application benefits are almost identical as for the oil and gas sector. When such installations are combined with aqua-culture activities as frequently proposed monitoring will become even higher relevance. In more coastal areas, sand and gravel extraction is another activity that has prompted environmental monitoring before and after operations. Another field is ocean mining of minerals or gas hydrates which is predicted to become future commercial reality. These activities call for similar services and impose high environmental monitoring requirements which will surely supersede the ones currently applicable for the offshore oil and gas industry.

Ferrybox systems may also meet monitoring requirements of the marine construction industry. Cable laying and pipeline laying demands are the same as the offshore oil and gas business of working in a safe environment. Port construction and operation maintenance as well as coastal protection require the same type of environmental information (refer to the NIOZ project depicted in section 5.5.3).

Ferrybox manufacturers gain direct benefits from increasing numbers of system applications especially when these are conducted in more standardised ways. This goes hand in hand with improvements and larger series of COTS Ferryboxes and related benefits including cost reductions for the users as described already above.

Ferrybox applications may also provide some benefits and business opportunities for servicing companies as well as for consultancies if they have access to and utilisation permission of Ferrybox data.

Ferrybox type systems can be of real benefit to those involved in the marine living resources including fisheries, aquaculture and plankton harvesting. Ferrybox data can contribute to fishery research with versatile background information and the aquaculture industry benefits from HAB warnings. This has already been demonstrated within the FerryBox project and becomes increasing relevance especially in Norway. In Norway interest for Ferrybox data was also raised by the industry transporting live fish from farms to processing plants. The densely packed fish in the transport tanks are very sensitive to the quality of water which needs to be continuously exchanged along the transport route. Ferrybox data are considered to be beneficial for improved route planning and avoiding potentially hazardous areas. Fisheries will continue to be a major recipient of Ferrybox data and with expectable increases in aquaculture and fish farming such demands will rise. Hence Ferrybox installations on larger fishing vessels as well as on fishery research and guard vessels can be very beneficial.

The sea transport industry is one of the most important partners in any Ferrybox applications as the systems are usually installed on commercial vessels. It is therefore critical that those intending to operate Ferryboxes clearly explain benefits to operators of cargo vessels, ferries, and cruise liners and enter in a win-win-position. Ferry companies themselves can benefit from supporting Ferrybox systems with a positive reaction from the passengers as they perceive their operator as caring and contributing to the environment.

Tourism can benefit from Ferrybox data as this will provide information on oncoming algae blooms which can disrupt coasts and beaches but also by enhanced possibilities to provide attractive information. Especially for large companies supporting Ferrybox applications provide also excellent opportunities to raise environmental profiles and to demonstrate related care and responsibilities. This has been already taken up by parts of the offshore energy sector for which CSR has nowadays very high relevance (refer to the supportive intentions by a major oil company in the Southern North Sea and the Dutch Wadden Sea mentioned in section 5.5.3).

6.3.1 Constraints for Marine Industry Applications

Constraints in use of Ferrybox data within the offshore industry will be dependent on how involved this industry becomes in data collection activities. Ferry Routes may not be geographically relevant to the geographical interests of this community. Offshore operators are usually very cautious in sharing their data and allowing third party installations on their facilities. Thus they need to be strongly convinced on benefits in linking up with institutions operating Ferrybox type systems and on achievable advantages when Ferryboxes are installed on service and supply vessels.

Limitations on relevance of Ferrybox derived data may exist for fisheries as ferry routes often do not cross relevant regions. This may change with increasing applications. Certain limitations are recognised for shore based aquaculture such as shell fish farms, which are often remote from industrial ports which would mainly be the destination of many ferry routes (apart from small island ferries). However, Ferrybox data in these instances would be relevant if fed into a larger network, as already done in Norway.

Similar issues can be raised in relation to the tourist industry which are usually also concerned about forewarnings and publishing of data which potentially hamper their business.

Difficulties for Ferrybox manufacturers and service providers are often related to variety and heterogeneity of instrument configuration and systems. Even all of the few COTS Ferrybox systems sold so far incorporate individual modifications and fittings. This increases developing efforts, hampers more standardised designs and prevents larger serial production and, lastly, motivation, return of investments and associated reductions of sales prices. For service providers and consultancies and especially for the majority of SMEs it is presently unclear how and to which extent they can become involved in operational oceanography activities and which role they can play in conjunction with large scientific institutes and agencies. It is therefore important that these industries are end-to-end involved in and associated with developing projects as well as with pre-operational and operational activities. Therefore it is also necessary that industry engagement in RTD projects is stipulated. This is at best done by easier access possibilities, simpler administration requirements and project opportunities with dedicated tasks for straight forward development of products and services and application of existing ones.

In general, costs of setting up a full operational oceanography system will be expensive, and although there are current moves to implement such systems across Europe, there is a certain drive that needs to be reached to establish a large enough network which can provide real benefits to the marine industry community. Initial costs are prohibitively high for any single member of this community and so a combination of contributors will be required to make this a reality.

6.4 Other Benefits

6.4.1 Increasing Public Interest, Knowledge and Awareness

Display of Ferrybox data together with other interesting information to the passengers of ferries and cruise liners gives excellent opportunities to raise interest and knowledge on marine topics and environments. Large ferries and cruise ships can host 1,000 to 2,000 passengers which frequently have time and mood to customise onboard information services. This has enormous potential to address large numbers of people when Ferrybox data are presented with attractive displays and combined with other information services they provide additional attractiveness for the passengers. How such can be approached is already impressively demonstrated on the Ferrybox systems operated by NIOZ. In addition ship owners and operators can achieve a certain profile when supporting installation and operation of Ferrybox systems on their vessels with simultaneous opportunities of awareness creation and soft advertising. When appropriately addressed and communicated to the public such cooperation and associated sponsorships in a win-win-situation for both the shipping and oceanography communities could have a large potential especially in times of tight public budgets.

Also attractive web sites and web-based information services can achieve high outreach to the general public especially when combined with accompanying measures as press releases and associated with other information and commercial information services (for instance by linking to and from ferry or travel booking services).

6.4.2 Maritime Security and Naval Applications

Since 9/11 Maritime security has become an important issue and is enforced for world-wide implementation by the IMO with recent amendments of the SOLAS and MARPOL conventions respectively their annexes and the implementation of the ISPS code. Ferrybox operation in several areas might be even an issue of maritime security (e.g. infringement of policies and regulations) but also provide chances especially with regard to detection possibilities (e.g. by current and optical profilers, sonars) in future within specially designed systems.

It is presently unclear in which areas and to which extent Ferrybox systems can support maritime safety and security issues but the operator and development communities will carefully watch the requirements and needs and discuss opportunities with stakeholders and system operators from the marine and port safety and security sectors.

In defence and naval applications Ferrybox-like systems have a long tradition. They were and are increasingly used on submarine and anti-submarine combat vessels to routinely measure for instance sound speed, water temperature and salinity and other parameters relevant for vessel operation, reconnaissance, sensors and weapons while underway. For underwater and anti-submarine warfare Units (USW, ASW) these data are an utmost requirement for instance for passive and active sonar performance, online data correction, buoyancy calculation or transparency estimates. Nowadays needs in littoral combating and changing operation requirements including operations in poorly known areas and near shore will even require Ferrybox-like sensors and systems capable to operate on remotely controlled or autonomously operated underwater and afloat operating vehicles (SAV, AUV).

Although a closed and partially secret sector, naval instrumentation developments have already highly stipulated Ferrybox developments at various manufacturers especially if they have to meet MIL standards and specifications. Vice-versa civil Ferrybox developments may find there way into the defence sector once they further prove their reliability, applicability along with higher degrees of modularisation, automation and flexibility. Apart from such commercial opportunities the benefits for the civil sectors are considered as low as data from naval operations are usually not available to the public or, if disclosed, are delivered with large time lags. Such data may even feature modification to disable backtracking of operations or system capabilities as it is the case for disclosed bathymetry and ice thickness data acquired by naval vessels or data from subsea deployed surveillance and listening devices.

7 Conclusions and Recommendations

In overall and condensed we can conclude the results of this study as follows:

➔ **Ferrybox systems provide a wide range of application possibilities and are highly beneficial and cost-effective for a wide range of scientific objectives.**

- The application areas and future potential are not fully exploited yet but foreseeable demands and trends provide even larger application areas than already proved or tested at present.
- Some constraints of Ferrybox systems especially with regard to "look into" deeper water columns can be overcome with new profiling sensors and technologies.
- Marine scientists shall consider in-situ measurements and sampling with Ferryboxes as a versatile and cheap method supplementing and even replacing in parts expensive and more resource consuming research cruises.

➔ **Ferrybox systems have proven capability, application potential and cost-effectiveness in operational oceanography and routine marine environmental monitoring. Their application is considered as supplementary to "classical" approaches and methods.**

- The foreseeable policy endorsed monitoring demands cannot be fulfilled by classical methods alone especially in conjunction with tougher public budgets.
- Agencies concerned with marine and also inland water monitoring and operational forecasting shall consider Ferrybox applications and review application areas in which use of Ferryboxes can supplement or even partly replace presently implemented methodologies and procedures.

➔ **The largest operational advantages of Ferrybox systems are in increased temporal and spatial observation and sampling coverage.**

- This enables better understanding of processes, increases detection possibilities of hazardous situations, deliberate or accidental releases of harmful substances.
- This also enables monitoring of several processes which are impossible to access in longer-term by means of sporadic research cruises or point-wise measurements by deployed instruments.
- Real- and near-real-time available data will also increase quality, availability of remotely sensed data and data products which can be much faster referenced.
- Forecast quality and ability with operational models can be improved by assimilating Ferrybox data in near-real-time.

➔ **The highest cost advantages of Ferrybox systems are in the areas of investments, maintenance efforts as well as in the per-data and per-sample unit costs.**

- Measuring and sampling does not need research or monitoring cruises.
- System maintenance and calibration can be done in ports and ashore.

- ➔ **Ferrybox systems have a certain application potential for the offshore industry especially when installed on service, supply or standby vessels.**

- ➔ **Ferrybox systems provide great benefits and are a cost-efficient tool for sustainable fishery, aquaculture and exploitation of living resources.**

- ➔ **Ferrybox systems have large application potentials for specialised monitoring tasks and specific investigation objectives.**

- ➔ **Ferrybox systems and data can reach high public outreach and are very useful for communicating marine topics and creating interest and awareness.**

- ➔ **Applications of Ferrybox systems are highly beneficial for owners and operators of ferries and passenger ships as well as supportive for offshore operating companies in demonstrating corporate social responsibility.**
    - Operators of Ferrybox systems shall establish and maintain tight links with these industry communities which, when convinced and entering in a win-win-situation are willing to substantially support installation and operation and may even directly contribute to Ferrybox costs.

Annex A

to

Costs and Benefits of Ferrybox Systems

Ferrybox Applications in the Frame of Marine Monitoring

Detailed Information on the Present Status and Future Perspectives

A-1 Actual State and Future Trends of Ferrybox Systems

The following supplements chapter 4 and provides further information on present and foreseeable future applications of FerryBox systems. During cumulative more than 18 years of Ferrybox operation in the European FerryBox Project on nine ferry routes large amounts of oceanographic data have been acquired and vast experiences have been gathered accordingly. The data acquisition systems are operated jointly or individually by the project partners concerned in order to acquire a series of oceanographic parameters. For a detailed presentation on the ferry routes, the measuring systems, metrologies and sensors, as well as about the acquired parameters plus applied methodologies of quality control please refer to the FerryBox System Description (deliverable no. D-2.1) available for download on the project web site

A-1.1 Ferrybox System Applications

Ferrybox Systems have a wide range of applications both for scientific investigations in marine and likely in future also inland waters as well as for operational monitoring purposes. Hence both the marine and inland water science communities as well as agencies responsible for monitoring of marine and more general aquatic environments can apply Ferrybox systems as a relevant component in their projects and programmes.

Today Ferrybox systems and applications have found their way in scientifically motivated investigations like monitoring of algal blooms, eutrophication, sediment transport uptake and storage of CO_2 by the ocean. Also more application related investigations like ground-truthing and calibration support for satellite remote sensing, related data products and for new instruments on the satellites have already greatly benefited from Ferrybox measurements. Especially in Finland and Norway Ferrybox measurements are already a strong component in marine monitoring strategies and methodologies and become more and more major component in national operational oceanography programmes.

With increasing acceptance, standardisation and commercial availability Ferrybox systems will be more and more introduced in activities, projects and programmes as a reliable and cost-efficient measure to observe near-surface parameters and processes in a quasi-synoptic manner and over larger time and space scales. New sensors are and will be developed which will increase the application range of Ferryboxes towards more parameters which are so far difficult or too expensive to be observed routinely. The beginning was made by the European FerryBox Project which in its relatively short lifetime of 3 years (compared to time scales observation programmes are changed or supplemented) could endorse many of such applications of which some reached already operational or pre-operational stages.

In the following sections a series of applications are presented which have been conducted within or affiliated to the European FerryBox Project. These range from already operational ones to pre-operational, demonstrative and testing approaches and demonstrate the application range and potential of Ferrybox systems in the near future.

The following items shall briefly illustrate a few applications which are considered as beneficial:

- Monitoring of potentially harmful alga blooms (HAB) in areas of high aquaculture activities can be significantly improved by using Ferrybox systems. The real time information of phytoplankton concentration and the possibilities to remotely and event-controlled collection of water samples for further investigation of HAB species increases the possibilities of surveillance of dangerous or damaging situations and issuing more precise and faster HAB warnings.
- The combination of Ferrybox and satellite data for direct validation of satellite data products and for developing new combined data products are becoming an important application. This will speed up availability and enhance quality of data products from satellite remote sensing.
- Fisheries laboratories within the UK have for many years applied underway measurements. Increasing interest is apparent from fishery laboratories throughout Europe on these types of systems. This has been driven by a requirement to develop an ecosystem approach to fisheries management. Information from Ferrybox systems can be highly beneficial for monitoring of fish and other marine livestock and their sustainable use and protection.
- Long coastlines and areas with high spatial and temporal variability such as the Norwegian coast are almost impossible to monitor by classical means as data buoys and monitoring / research cruises. Hence Ferrybox observations are already a strong component in monitoring of coastal waters of Norway as well as for monitoring surface variability and algae in the Baltic Sea.
- Increasing pressure on public budgets forces agencies to apply more cost efficient means of monitoring whereas in parallel the demands for increased spatial and temporal resolution of observations is endorsed by the policy and legal sectors. This has been quite early adopted by Finland and Norway and other countries like Estonia, Sweden, the Netherland and soon also Germany and the UK take this into consideration by initialising test and pilot projects for operational Ferrybox applications.

A-1.2 Laboratory Prototypes Applied in the FerryBox Project

The project itself has required the development of several Ferrybox systems, and most of the Ferrybox systems applied within the project can be categorised as laboratory prototypes. Furthermore, with no apparent commercial off-the-shelf (COTS) systems available at the start of the project, other systems developed and operated outside the project could be placed under the same category. Although the hardware and components adopted by the partners within the project are different, much of the effort within the project has been committed to ensure that these disparate systems provide inter-comparable quality controlled data.

Most project partners operating Ferrybox systems are fundamental research organisations, and many of the applications are research focused, with the aim to push such systems into the operational oceanography arena. However, a number of operators already link these systems into real time networks, combine the datasets with those acquired via satellite and/or provide near instant reporting as to the state of the sea. Within a geographical context, most of the ferry routes operated by the partners were located within the Baltic and North Sea areas, with other ferry routes set up in the Irish Sea, Atlantic Ocean and Aegean Sea. The locations of the ferry routes themselves have provided a useful spread of marine environments and have allowed interesting comparative observations within the datasets themselves.

The Finnish Institute of Marine Research (FIMR) has applied their long established system to *Alg@line*, a project which uses Ferrybox systems to monitor phytoplankton biomass and species composition as well as other parameters in the Baltic Sea. Broad dissemination has been enabled via the Baltic Sea Portal. What has been achieved is a near real time information system, providing up to date algae distribution, bloom forecasting and algae species reports. From summer 2005 onwards, the measurements of phycocyanin, the main pigment of bloom which form cyanobacteria in the Baltic Sea, started with two Ferryboxes operating between Helsinki – Travemünde and Tallinn – Helsinki (see also Section A-5.2).

The Estonian Marine Institute (EMI) has started with Ferrybox measurements in 1997 in cooperation with FIMR for monitoring of harmful algal blooms. The obtained data during 9 years of operation have been used in research of cyanobacteria blooms and have enabled to understand the influence of different abiotic factors which influence the development of these blooms in this sea area. The data were also used for intensive research on near-shore upwelling events using the Ferrybox data. Since 2005 EMI is also engaged in a trilateral cooperation with Russia and Finland to operate a Ferrybox system between Helsinki and St. Petersburg. The institute also assists in establishing a Ferrybox between Gdynia (Poland) and Karlskrona (Sweden) planned to enter into service in 2006. This system will also collect water samples for nutrient and phytoplankton analysis from predefined stations once per week and a Continuous Plankton Recorder (CPR) to collect zooplankton samples will be deployed once per month.

The Norwegian Institute for Water Research's (NIVA) Ferrybox System is assisting in their eutrophication related observations in the Skagerrak area to discriminate between natural and anthropogenic sources. The data and sample analyses are also applied for inter-comparisons and ground-truthing purposes for satellite remote sensing data (as for instance for the MERIS sensor onboard ENVISAT). The use of Ferrybox data for satellite validation has increased during the project and in parallel with the FerryBox project another EU-project has tested and implemented above water radiance sensors for direct validation of the ocean colour signal measured by the satellite. The European Space Agency and the Norwegian Space centre have dedicated a specific project for this activity. Interest was raised at several Norwegian institutions to utilise Ferrybox data for operational monitoring purposes. The Ferrybox systems in the Skagerrak have been used for HAB monitoring and will be used in the long term monitoring of the coastal areas. The project has already stipulated outfit of two ferries with Ferryboxes which routinely serve all along the Norwegian coast and will routinely provide data sets on the nearshore and coastal environments of Norway. One of the ferries will also improve monitoring of the North Sea between Bergen in Norway and Newcastle in the UK.

The GKSS Research Centre Geesthacht has applied a Ferrybox system to determine variability of phytoplankton and water mass distribution along the Cuxhaven – Harwich route. The data are utilised for developments of phytoplankton models as well as for developments of pre-operational systems. The GKSS Ferrybox acquires also a series of water quality relevant parameters such as nutrients and the institution continuously stipulates new and enhanced sensor developments in close cooperation with the industry. The industrial system applies advanced automated cleaning and antifouling procedures.

The Netherlands Institute of Sea Research (NIOZ) has developed a Ferrybox system which includes an acoustic Doppler current profiler. This system measured tidal currents between the island of Texel and Den Helder. The frequent coverage of this relatively short route enables estimates of sediment transport across this transect as well as monitoring morphological changes in the tidal inlet.

Proudman Oceanographic Laboratory (NERC.POL) applied their Ferrybox system in the Mersey Basin within the Coastal Observatory Pilot Project. They are looking into effects of storms and river discharges causing transport of contaminants and nutrients into Liverpool bay as well as eutrophication effects and possible harmful algae bloom occurrences.

The National Oceanography Centre (NERC.NOC) in Southampton operated two Ferrybox systems during the FerryBox project. The first of these was installed in 1999 and used from spring through autumn on a 17 km transect between Southampton across the Solent to Cowes on the Isle of Wight. It was operated between 1999 and 2004. The system enabled development of data collection and transmission methods first with WS Ocean Systems Ltd and then with Chelsea Technologies Group. The work was initially funded by the UK DEFRA (Department of the Environment and Rural Affairs). This was to look at the intensity of algal bloom development in an estuarine system that was subject to detailed studies with respect to the EU Nitrates and Water Frameworks Directives and possible eutrophication of the estuary. The observation also contributed to the EU Framework 5 IST project IMARQ (Information System for Marine Aquatic Resource Quality).

The second NERC.NOC system started operation on the P&O Ferries ship “Pride of Bilbao” which operates a service between Portsmouth in the UK and Bilbao in Spain. This route has a length of 1000 kilometres and the turn round time of the ship is 3 days. This system was first installed in April 2002. It runs year round except when the ship is in refit in January. It is planned to continue measurements until October 2007 when the ferry is planned to be withdrawn from service. The science behind the project includes (1) improving understanding of plankton bloom succession in the range of conditions along the route from eutrophic harbours to the deep ocean waters of the Bay of Biscay which are oligotrophic in summer (2) improved detection of water movement on the shelf and from the Atlantic Ocean across the shelf break (3) identification of the trophic status of different waters and the potential draw down of CO_2. In addition to the standard Ferrybox continuous measurements of dissolved CO_2 and O_2 were added to the system in early 2005. In autumn 2005 measurements of trace gases starting with methyl halides will be added. In addition to work carried out along with the FerryBox project the ship has also been fitted with meteorological instruments and a sea surface radiometer for a project looking at the validation of satellite surface temperature measurements funded by DEFRA, ESA and the UK Met Office (lead by Ian Robinson at NERC.NOC).

The Spanish Institute of Oceanography (IEO) respectively its branch in Santander operates the Ferrybox on the route between Southampton and Bilbao across the Bay of Biscay jointly with NERC.NOC. Highly precise measurements and analyses obtained from their research vessels are compared with the Ferrybox data. Furthermore, IEO uses these data to determine the occurrence of algae blooms.

The NCMR of Greece operates a Ferrybox within the Aegean Sea. They plan to utilise the soon to be expanded POSEIDON network of monitoring buoys to compare with the Ferrybox data, which will augment the current data with information such as daily thermal cycles.

Most of the systems within the project have been well maintained to provide quality data. Various levels of maintenance are applied to each system, some requiring more maintenance than others, and this is an important aspect to the project. Costs of maintenance are acceptable for the project partners providing these costs are not too high. Some of the systems used by the project, including the 4H JENA system operated by both GKSS and NCMR, have automated cleaning cycles which greatly assist in preventing biofouling and therefore reducing maintenance.

A-1.3 Future Application Potential

Applications for Ferrybox systems may also expand in the future in particular if such systems are applied in routine monitoring and operational oceanography as e.g. proposed by GOOS and EuroGOOS. Currently the selection of routes and platforms are still predominantly research driven and science is expected to keep as an important driver. However, operational oceanography applications increase already (see below). It can be expected that more Ferrybox type systems will be fitted to commercial passenger ships, as well as to merchant vessels. Fitting on cruise liners may also be very perspective as these cover more remote and less routinely served routes and areas.

Passenger displays installed on ferries and cruise liners provide excellent opportunities to create public awareness and interest on the sea. They even result in strong motivations as they can encourage ship companies to substantially fund Ferrybox applications and gain benefits in terms of improved profile and chances for advertising (see also Sections 5.5.3 and 6.4.1).

Fishing fleets can also be considered, but these would still need to be most likely funded by government agencies unlike fishermen can see a clear benefit in terms of raising catches or saving track kilometres in utilising Ferrybox data during trawling or gear deployment.

For long, underway measurement systems are routinely applied in the military sector although for others than monitoring purposes. The most standard application was and still is measurement of sea temperature, conductivity and sound velocity essentially relevant for underwater warfare. Modern naval concepts and strategies require more precise surveillance of marine and especially coastal parameters like turbidity, particulate suspended matter or organic compounds. This could provide application possibilities for Ferrybox systems and opportunities for manufacturers to adapt specific components tailored to MIL-standards and demands (see also Section 6.4.2).

Interests in Ferrybox systems are expected to emerge also from inland water authorities. These agencies are under increasing pressure to supply cost effective data demanded by national and international directives, in Europe particularly the WFD and in future the European Marine Strategy. If Ferrybox systems can match these demands, increasing application opportunities are expectable on ferries crossing larger lakes and on passenger ships or even on transport vessels on rivers.

A-2 Commercial Off-the-Shelf Ferrybox Systems

Unlike the Laboratory Systems described above, the current **commercial off-the-shelf** (COTS) Ferrybox Systems are marketed towards government agencies and services which are directly involved in monitoring the environment under European and National directives. If Ferrybox products are to be purchased by such agencies in considerable numbers, it can be expected that the overall cost of such systems as well as aspects of lifetime, modularity, maintenance, stability and sustainability under operational conditions will be strong factors in product selection. These systems have therefore to be easily installed, maintained and designed for unattended operation.

A-2.1 Present COTS Ferrybox Systems

Current commercially available Ferrybox systems include the Ferrybox of the German manufacturer -4H- JENA engineering GmbH (4H JENA), the UK built Chelsea Technologies Ltd. (CTG) Aqualine Ferrybox and the SeaKeeper from the US company General Oceanics (G.O.). Furthermore, there exist some other manufacturers which may provide small series or customer designed versions of Ferrybox systems (such as the BlueBox of the German manufacturer GO Systems GmbH) which are not specifically considered here due to lack of affiliation with the project.

There are also a number of thermosalinographs on the market, which are fitted to the majority of research vessels. Current models include the Seabird SBE21, the Seabird SBE45 and the Ocean Sensors OS500 TSG. These instruments are designed primarily to measure surface water temperature and salinity and have a suitable input to take in navigational data precisely reference recorded data with date, time and position. Some Ferrybox systems applied in the project use thermosalinographs to determine sea surface salinity and temperature.

Unlike the thermosalinographs, Ferrybox systems have been designed specifically to take in a number of sensors and provide a certain amount of flexibility as to which parameters are to be measured. Due to the current ecosystem approach to coastal and ocean monitoring, both biological and chemical sensors are nowadays more frequently demanded. With both increased parameter requirements and flexibility, these systems have all been developed with a modular architecture, allowing easy addition and removal of sensors for specific applications.

All three systems have currently operated with a range of parameters. Significantly, the SeaKeeper system is the only one out of the three that entails a purpose built 7 parameter sensor module. All sensors within the 4H JENA and CTG systems are existing sensors already utilised and well proven in other applications (both for stationary in-situ and flow-through measurements). Common to all three commercially available systems, the following parameters have been in operation: Sea surface temperature, salinity respectively conductivity, turbidity and fluorescence. The G.O. Seakeeper system currently offers dissolved oxygen and pH and is also equipped with a redox sensor. The 4H JENA Ferrybox is designed as an open system and can integrate almost every sensor or system suitable for flow-through measurements (e.g. oxygen, redox, nutrient analyser, algae class analyser; integration of an oil-in-water sensor is presently under development).

The G.O. SeaKeeper and the 4H JENA systems have in addition already included a range of meteorological sensors including wind speed and direction, air temperature, relative humidity and barometric pressure. This is also easily achievable by the other CTG Ferrybox systems by interconnecting a standard ship weather station or a separate weather data recorder.

With much emphasis on minimum maintenance and unattended operation, ease of cleaning these systems is of great importance. The CTG Aqualine Ferrybox system is currently designed for ease of removal of sensors to access sensor heads for cleaning. Both the 4H JENA Ferrybox and the G.O. SeaKeeper systems have built in self cleaning systems which flush the tubes, pipes and sensor heads on regular or user configurable schedules. This feature will soon be available with the CTG Aqualine Ferrybox system as well. Unique of the 4H JENA design is a 3-step automatic antifouling unit for every sensor surface / water system and pressure cleaning.

Common to both the 4H JENA and CTG system is the availability of a de-bubbler unit to reduce bubbles generated in the flow system. De-bubblers may not be required on certain installations if the flow of water and pressure is consistent (as with the NERC.NOC Pride of Bilbao System).

All three Ferrybox systems offer integration to GPS systems for precise position and time stamping of the data. They are also all capable of various methods of data transmission (GSM/GRPS, satellite communication services e.g. ORBCOMM).

All systems are delivered together with peripheral components required for onboard installation and operation control and data pre-processing software. Optionally the CTG and 4H JENA Ferrybox systems can be supplemented with onboard display facilities in the passenger areas. Both manufacturers also provide installation, maintenance and training services on client's request. The 4H JENA system allows for remote supervision and maintenance possibilities via the ship-shore bidirectional communication links through GSM and, if available, satellite Internet connections.

A-2.2 Future COTS Ferrybox Systems

The form and design of future Ferrybox systems will depend on demands. Currently, the market is being served by a handful of SMEs which have effectively adapted current sensors to be integrated in these flow-through systems. If demands increase considerably in the future, more targeted engineering designs will address these requirements and larger engineering companies may take an interest as well. However, as with any marine monitoring system, the market is not expansive yet and for the immediate future, Ferrybox systems will likely evolve in their current form, developing upon the flexible integration approach.

Further steps can be taken in designing within a plug and play environment. Standards such as IEEE 1451 are now being proposed which will assist in building flexible sensor systems in an efficient and cost effective manner. This is part of a sensor industry drive in general to meet requirements of interfacing different sensors. Such approaches will also mean that future sensors, whichever parameters are to be recorded, should easily be integrated.

Open system designs and modularity will not only be offered within the sensor suite itself, but also with the system peripherals. Customers will be able to choose which communications system is best suited to their requirements (GSM, Satellite or Radio) with no direct impact on the cost of the central control system itself.

These trends will likely result in customers being offered tailored systems at competitive prices.

A-3 Typical Fittings Required on the Vessel

A variety of challenges may be faced in fitting commercial Ferrybox systems to candidate vessels, depending on existing facilities offered on the vessel. The application of specialised marine sensors and devices on a commercial vessel like a ferry boat poses a series of demands and requirements. The measuring system must be easy to install, not disturb routine vessel operations, electronics or communication and must not require specific maintenance by the crew. It should not have excessive operation, maintenance and calibration requirements which have to be accomplishable during usually short port calls. In addition the acquired data shall be efficiently, routinely and automatically transferred ashore, pre-processed, quality controlled and disseminated to the communities of users.

For most vessel fits, it can be expected that a sea water cooling system line can be utilised onto which a Ferrybox type system can be fitted. In these cases, care still has to be taken in selection of the Ferrybox location. Water from such lines must be taken by a pump upstream from engine cooling, preferably as close to the intake as possible, as experience within the project has shown that seawater can quickly increase in temperature once entering a vessel. In such cases a separate temperature sensor should be mounted near the water inlet. Taking water directly from the ship chest can cause more problems with air bubbles into the system since air is sometimes trapped in the ship's chest and can be drawn into the Ferrybox system if no special measures are taken.

If utilising water from the cooling systems or separate intakes, Ferry companies may insist on the Ferrybox system to be pressure rated to a defined safety level. For instance, P&O Ferries has defined that all flow manifolds within the system fitted to the Pride of Bilbao had to be rated to 10 Bar.

When already built-in flow circuits are not available or possible for fitting in a Ferrybox system, a new flow line has to be fitted. Moreover, associated constructional restrictions and frequently concerns of the ship owners or operators regarding modifications of standard vessel installations need to be overcome. Piping should not be too large in diameter as this provides difficulties in fitment and is unnecessary. If the diameter of the piping is too small this can cause problems with clogging. For instance, the Chelsea Aqualine System uses a 12 mm diameter tube.

A Ferrybox system should offer a selection of main input options, whether 120 VAC, 240 VAC etc. Facilities such as UPS or battery backup is recommended for these systems (and offered with the current commercial systems). Data wiring should be shielded both ends, and flexible enough to be routed easily through a vessel. In many cases data pre-processing is conducted in the same location as the sensor units and therefore routing of cables is only an issue with regard to the GPS system, the data transmission system and the passenger display if fitted. Costs will naturally be incurred for cable routing, which is usually necessary to be conducted by a certified company.

Size and dimensions of a Ferrybox system have to address the often limited access areas available for transporting equipment within a vessel. Systems such as the G.O. SeaKeeper have separable modules which may assist in fitment. However, modern and modularly designed Ferrybox systems match the typical dimensions of access doors or holds to suitable installation positions onboard. Moreover, modern Ferrybox systems become smaller and smaller. For instance, the GKSS laboratory prototype Ferrybox had the dimension of a medium sized cupboard whereas a module of the 4H JENA system has the size of a small freezer.

A-4 Ferrybox Sensors, Parameters and Data Acquisition Potential

Both laboratory-based and commercial (off-the-shelve) Ferrybox Systems have been designed to take a wide variety of sensors which cover a wide range of applications. As mentioned in the previous section, moves are being made within the sensor industry to standardise on sensor outputs to allow for ease of integration. Most instruments are available with either 4 to 20 mA output, analogue voltage output, RS232 and RS422. The latter formats have become more prevalent within the last few years as they bring benefits of stored calibration coefficients within the sensors themselves which gives true plug and play potential.

Most sensors provide a single parameter which defines the state of the variant. These data types can be easily handled and simply presented in graphs and tables. There may be occasions when more complex data from a sensor is desired, for example direct image data, optical or sonar, which require broadband links for fast data transfer. In these cases problems can potentially arise in merging this data with standard parameters, and at present such sensors are commonly fitted as separate systems, and come with their own pre- and post-processing hard- and software.

However, if Ferrybox type systems are to be targeted towards environmental monitoring authorities, then the data must be of a form that can be easily interpreted by surveyors and technicians. Basic parameters will have to be used to derive water quality indicators.

When Ferrybox data are used within routine monitoring systems and, moreover, in operational oceanography or, even more, for forecasting and warning purposes specific demands are posed on data availability, recovery rates and accuracy. Moreover, such data must be available in real- or at least quasi-real time to match the requirements of data demands for assimilation and/or integration into forecasting and warning procedures and methods (including numerical models). Generally the level of criticality of the process in which such data are used determines the demands and specifications of the data acquisition system including the pre-processing, quality control and real-time validation measures plus the requirements for data transmissions and backend handling. Consequently this determines the grade of reliability and robustness of the sensors but also the redundancy of critical components as well as the maintenance and replacement schedules. There is no doubt that modern, modularly designed and specification-built Ferrybox systems can match these requirements. Most of the prototypes applied in the European FerryBox project have already reached a high degree of quality and data recovery rates of 80% and more. As always, significant increases in related threshold and liability levels are associated with usually exponential rising of equipment costs and most likely also maintenance efforts.

The scientific community usually has different demands on Ferrybox systems and may well require more advanced state of the art sensor systems to be integrated together with the standard parameters. It is recognised here that there exists a certain evolution of data from new instrumentation, where a large quantity of data is provided with early prototype systems, but once the measurements are better understood, single parameters can be evolved to describe the state of the variant. For example, the Fast Repetition Rate Flourimeter originally provided up to 5 separate parameters to describe how phytoplankton manage photosynthesis in water bodies. It is now recognised that relevant information for basic monitoring can be provided by a single parameter, the photochemical quantum yield.

Subsequently, new designs have provided less sophisticated instruments which can provide this basic parameter, or can form part of a larger system to provide the full definitions for the scientific community.

All systems are capable of both time and position stamping the data. The required frequency of data recording can vary with the requirements of the user. Ferrybox systems are not constrained by the demands of remote stations, where sampling frequencies are often dictated by maximising deployment from finite battery power. However, too much data can become onerous in management, and if data is being transmitted continuously by either GSM or satellite, costs of data transmission can become excessive. However this can be overcome by a series of measures and procedures like intelligent data pre-processing and compression, transmission cycles based on detected events or irregularities and/or complying with typical scales of temporal and spatial variability along different sections of the ferry track.

The frequency of data gathering, water sampling, recovery and maintenance is often dictated by the length of the ferry track. For instance, the shortest and most frequently served ferry route runs almost once per hour between Texel and Den Helder. The ferries are equipped with Ferrybox systems operated by NIOZ. The Texel berth is a few minutes away from the operating institution which allows quick response and easy access for maintenance, trouble-shooting and manual recovery of data and/or samples. Contrary, the ferry across the Bay of Biscay has a transit time of more than one day and most of the route leads outside GSM range. The ferry between Helsinki and Travemünde is the longest crossing within the project.

In practice Ferrybox systems can record data at 1 Hertz. If a ferry travels at 25 knots, this equates to a recorded measurement every 13 metres.

On the Norwegian ferries which at the moment cover almost 80% of the Norwegian coast as well as the important Skagerrak area where HAB sometimes occur have real time access to the data through the ships internet connections. Since the ships are ending up either in Oslo or Bergen maintenance is easy, fast and cheap as it is conducted by the local technical staff at the nearby NIVA offices. For the coastal steamer which uses 11 days for the round trip the branch offices of NIVA in Trondheim, Bodø and Tromsø assist in routine maintenance and take care of the collected water samples.

It can be assumed that each organisation operating Ferrybox systems in maritime countries can establish cooperative networks and team up with institutions or companies situated in or nearby the ports called by the ferry. By this a proper maintenance including in time collection and analysis of water samples and rapid trouble shooting can be easily ensured. The European Research Area, common endeavours to implement the European GOOS and the collaborative networks established throughout many years of trans-boundary cooperation certainly stipulate such cooperation for ferries which call ports in different countries. As a side benefit operation costs may be shared and the end-user community can be increased accordingly.

A-4.1 Parameters Acquired by Ferrybox Systems

This section depicts the type of sensors that have been fitted, operated or tested to Ferrybox systems within the project. For extensive information one is referred to the FerryBox System Description (deliverable no. D-2.1) and to the report on applications and testing of new sensors and instruments (deliverable no. D-2.4).

A-4.1.1 Ferrybox Standard Parameters

The core instruments fitted to all the Ferrybox systems within the project are sea water temperature, conductivity, Chl-a fluorescence and turbidity. These were chosen by the project partners as they would provide the baseline information required monitoring the three areas of water quality, eco-system dynamics and ocean climate variability respectively change. These parameters are already common parameters which most fixed monitoring stations in nearby areas measured at the start of the project. Thus it was recognised that the fixed station measurements provide useful reference and inter-comparison data for the Ferrybox measurements.

A-4.1.2 Non-Standard Parameters

Parameters to be considered for marine environmental and water quality purposes could typically be included in addition to the Ferrybox standard parameters given above:

- pH
- Nutrients (nitrate, ammonia, phosphate, silicate)
- Algae group detection
- Photosynthetic parameters
- Trace metals and other substances

Considered future developments include for instance

- Trace metals
- Selected hydrocarbons and
- Several other substances

It is expected that this list will increase to meet the demands of monitoring demands from such legislation as the Water Framework Directive (WFD) and the European Marine Strategy implemented throughout the European Union, and as new technologies and sensors to measure the required parameters evolve (i.e. parameters that can only currently be measured by laboratory techniques). These would include the current priority substances, including optionally hazardous substances as listed within the WFD.

Other instrumentations have been added by individual partners to their Ferrybox systems which included e.g. dissolved oxygen, algae groups, current speed, acoustic and optical backscatter.

Out of all these additional parameters, dissolved oxygen has probably been the most referenced within the project group. Recent developments have provided more robust, low maintenance sensors.

As such, it would probably be worth inclusion into the standard parameter category providing it can be ensured that oxygen contents remains unchanged in the water supply cycle and the measurements are not falsified by air bubbles.

Only one Ferrybox system (GKSS) accommodated a pH sensor. The pH value is relatively easy to measure and can provide versatile information on marine environmental and water quality conditions and variability. The same Ferrybox accommodates a sub-system allowing for determination and quantification of algae groups. For instance the applied BBE Moldaenke Algae Monitor excites different pigments within phytoplankton and cyanobacteria. This type of instrumentation has evolved during the course of the project, and has already provided versatile data. However, there remain issues and open questions regarding calibration of these systems which require locally dependent settings on each route. Along with future research these issues will inevitably be resolved and such tools will provide useful data on harmful algae bloom studies.

Measurement of nutrients, including nitrate, phosphate, silicate and ammonia is an evolving technology, as in addition to wet chemistry analyzers increasingly optical based systems and sensors are being brought to the market. Wet Chemistry based systems were fitted to the GKSS Ferrybox, and such systems bring the benefit of allowing direct comparison with laboratory measured samples. Wet chemistry systems have also higher costs for consumables and such might be necessary to adjust to regional climate conditions when installed in non-air-conditioned spaces.

A light sensor measuring the Photosynthetic Available Radiation (PAR) was fitted to the NIVA system. Such data can assist in a better understanding of Chlorophyll-a fluorescence data. Issues can arise in the fitting of such simple PAR sensor without special attention to electronic noise on the data as well and placement of such sensors. New sensors using RS 432 connection with the system are needed. New sensors like the Ramses radiometers from TriOS which measure both irradiance and radiance can be used in Ferrybox systems. Such systems have been installed on two of the ferries in Norway in another EU-project.

NIOZ has included an acoustic current profiler on their Ferrybox system. The information from such a system is of great value. Apart from direct and real-time current measurements along the route the data can be used to determine sediment transport rates which is a high matter of concern in this tidally dominated and highly variable area of the Dutch Wadden Sea. Moreover bottom track data can be used to monitor bathymetry changes and morphodynamic processes. However, the installation on commercial ferries is not straightforward as the sensor needs to be either deployed in a moon-pool or mounted outside the hull which requires docking of the vessel. NIOZ benefits from an excellent relationship with the ferry company host, and could achieve direct input into the design of the new ferry which entered into service 2005. This ferry boat accommodates a moon-pool and other installations which facilitate installation, operation and maintenance of their new Ferrybox system. However, such co-operation cannot be considered as generally achievable in all cases. Hence installation of acoustic current profilers and other moon-pool deployed or hull mounted instrumentation or sensors is a considerable task and likely not evitable for most routine installations on commercial vessels.

Other acoustic and/or optical based sensors will inevitably be considered in the future. Laser systems scanning en-route optical parameters of the upper water column have been already applied on several research vessels. Most commercial vessels are fitted with a navigation echo-sounder and several ones with ship weather stations. It may be possible to obtain signals from these instrumentations to integrate routinely depth and meteorological information into Ferrybox data sets.

A-4.2 Instrumentation Trials

A number of other instruments have been trialled during the European FerryBox project. These instruments include:

- Aanderaa Optode – an optical dissolved oxygen sensor
- CTG Fastracka – a fast repetition rate fluorimeter
- CTG UV Aquatracka hydrocarbon fluorimeter

The Aanderaa optical dissolved oxygen sensor made successful trials on a number of Ferries within the group. Its robustness and data relevance suggest that it could be included in the standard parameter set of future Ferrybox systems.

The CTG Fastracka has been trialled by NERC.NOC and much data has been collected for processing. It is also planned for trials on the GKSS system. The Fastracka can provide useful information on photosynthetic parameters, but in its current configuration is not ideally suited for Ferrybox operation. However, data recorded from these Ferrybox systems will allow assessment on how useful this instrument can be with regard to eutrophication studies. Its successor, the Fastracka II, currently under development, will be more suited for integration into Ferryboxes, as this application has been specifically highlighted as desirable within its marketing specification.

Interest has been expressed in the integration of hydrocarbon fluorimeters within Ferrybox systems to monitor oil pollution both at sea and close to harbours. Recent trials have been planned, with the Chelsea UV Aquatracka integrated to the NERC.NOC system.

Data recorded from these Ferrybox systems will allow assessment on how useful this instrument can be with regard to pollution studies and detection of accidental or deliberate oil spills.

A number of Ferrybox systems incorporate an inside flowmeter. This gives useful performance indications of the system and provides the true volume of water flowing through it. A flowmeter provides both important status and scientific information, and is therefore recommend as a standard fit to any future Ferrybox system. Results of trials with these instruments are documented in deliverable no. D-2-4.

A-4.3 Perspective of Additional Parameters and Sensors

Zooplankton species / abundance tools such as commercial Plankton Samplers (the CTG APS and the Spartel Ltd Plankton Sampling Mechanism) have been designed to offer the same type of zooplankton collection as obtained by the CPR, can provide very detailed information, but such systems require significant processing post-deployment (visual inspection for identification and quantification) and are therefore not to lend themselves to operational systems. More automated systems such as the Optical Plankton Counter and the more recent Laser Optical Plankton Counter from Brooke Ocean Technology Ltd lend themselves more to Ferrybox type systems, where there is a finite amount of data that can be stored to describe size and abundance of particles. These systems will not distinguish between sediment and plankton, but when the data is compared with other parameters such as chl-a, judgements can be made.

It can be expected that these types of instrumentation and sensors will evolve in the future, making use of low cost imagery electronics now currently available. Currently demanding fast communications and high memory, work is underway to design intelligent front-end processors that will identify plankton groups if not even demarcate between single species.

Other tools available today that can assist in determining plankton and phytoplankton groups are those that measure the bioluminescence emitted when certain species are mechanically stimulated. These tools offer possible solutions for harmful algae bloom monitoring with possible applications for the fish farming industry.

Ferrybox sensor data from the flow through systems have been tested for validation of satellite data. This was conducted for both sensor data as chlorophyll-a fluorescence, temperature and turbidity as well as for automatically collected water samples with analysis of Chlorophyll-a and total suspended matter. Only the data from the water samples give directly the quantities to be used for validation while the sensor data need to be converted. Installation of radiometers measuring the ocean colour signal water leaving reflectance onboard a ship can in real time validate the satellite signal. Such systems are now possible to use in conjunction with Ferrybox systems and have been successfully applied in the Skagerrak through the EU-project DISMAR. Extensive results are presented in deliverable no. D-5-4.

A-4.4 Ferrybox Data and Data Products

In principle data acquired by Ferrybox systems are easy to handle. They are all possible to be uniquely referenced by the date and time, geographical position and water depth (below sea level) when the measurement was obtained or sample was taken. Satellite positioning systems like nowadays GPS but in future also GALILEO provide even in standard and generally accessible modes sufficient position accuracy (several tenths of metres) on a globally and commonly used coordinate system (WGS-84) and a high-precise unified time signal. No special equipment is required to obtain this data as all feasible vessels on which Ferryboxes can be installed have today GPS navigation.

The typical data products derived from Ferrybox systems are time series at certain positions as well as two-dimensional time series along the route (usually presented in isoplete graphs) and easily to store and handle as two-dimensional matrices.

Also the meta-data which need to be always comprehensive in contents and associated with numerical data have a relatively simple structure. We have used a tabular scheme incorporating information about the operating institution, the platform (ferry), the Ferrybox system and the measured parameters together with information on the individual sensors or sub-systems. For reasons of standardisation throughout Europe we have applied the BODC parameter dictionary which is one of the most (if not the) comprehensive oceanographic parameter dictionary worldwide which is also continuously maintained and supplemented.

According to international standards every single measurement datum is associated with a quality flag for which we applied the flags used by BODC but also allowed optionally inclusion of more detailed individual quality flags. In addition measured data can be optionally assigned with a so called reference flag which indicates when a water sample (respectively sample analysis) or another reference measurement is available at or nearby the measurement position.

For the project we have developed a simple and unified tabular data format for each measured parameter. Although the format allows inclusion of more than one (practically infinite numbers) of parameters in one table we preferred the single parameter approach to avoid empty fields and missing values and to better encompass the different measurement cycles of instruments and sensors included in each Ferrybox. For reasons of wide applicability and usability by users with different background and facilities in data processing we have compiled the data in plain ASCII files.

This data structure and formats facilitates almost all formats and processing requirements and easily allows conversion into preferred data formats like NetCDF, import in spreadsheets and other post-processing software. Also subsequent import into data bases is easy to do and the meta-data structure defines (respectively proposes) a hierarchical data model with unique referencing and relations.

The above depicted items are comprehensively documented in a guideline which we made publicly available for interested users and other operators of Ferrybox systems (deliverable no. D-3.1-B). Although these guidelines are specifically defined for Ferrybox applications they can be also applied in a wider manner for geo-spatial time-dependant data and even data products and other uniquely space and time referenced information.

The project makes also all the data acquired during the two “FerryBox years” available on a DVD to demonstrate their usefulness and provide interpretation and application possibilities to interested third parties.

In the project several Ferrybox operators have also demonstrated higher levels of data integration and presentation such as combining them with other data, remote sensing images or numerical model results, inclusion into GIS systems and dissemination in numerical and graphical form through the Internet. Further directly derived information like sediment transport estimates, changes in bottom topography along a ferry route were compiled to illustrate some possibilities of further use.

A-5 Present and Future Application Potential for the Scientific Community

Before, during and associated with the European FerryBox Project a variety of scientific applications were conducted. Accordingly FerryBox data have been used for a broad area of scientific and development work spanning from research on eutrophication processes to data assimilation techniques into numerical models (see the deliverables of the project's work packages 4 and 5) the following sections provide certain details on research work with Ferrybox data and also outline future activities which are already foreseeable or even in advanced stage of preparation.

A-5.1 Present Scientific Applications

Throughout Europe a series of scientifically motivated Ferrybox applications were conducted as for instance:

- The Finnish Institute of Marine Research (FIMR) has the longest experience in both research driven and operational Ferrybox applications and conducted research and pre-operational developments on improvements of algae detection and demarcation by flourimetry (see sections A-5.1 and A-6.1 for further details).
- GKSS Research Centre in Germany operates presently the most complex Ferrybox system with regard to the amount and diversity of acquired parameters (see above). The GKSS Institute of Coastal Research applied laboratory prototypes of Ferrybox systems on a ferry previously operating between Cuxhaven and Harwich. These experiences were combined with simultaneously achieved ones with flow-through land stations and have been developed towards nowadays commercially available Ferrybox systems in team with the German equipment manufacturer and engineering company 4H JENA GmbH.

  Prime goals of GKSS are development and pre-qualification of operational systems to a stage that they can be transferred to the operational oceanography and marine industry communities. Consequently and complementary with their basic and applied research activities, GKSS has further developed instrumentation and methodologies in this direction and continuously applies, tests and assists in development of new sensors and components which may be used in future Ferrybox systems. This can be demonstrated in the application of a variety of other sensors and components like nutrient analysers and fluorimeters and the pilot application of new developments as for the discrimination of algae groups or the detection of low-concentration hydrocarbons.
- Experiences on how Ferrybox data can be used for pre-operational modelling were gathered NERC.POL and HCMR which developed and tested assimilation schemes of Ferrybox data in operational models as well as by HYDROMOD which combined Ferrybox data with pre-operational transport and dispersion simulations.
- The Hellenic Institute of Marine Research (HCMR) operates a Ferrybox between Athens and Heraklion, Crete. HCMR was the first unit which collected experience with a COTS Ferrybox.

A key problem in shelf seas is getting a better knowledge of the exchange of waters between the oceans and shelf seas. This is important because the exchange process controls the flushing of the shelf sea with respect to contaminants and the flow of plankton species vital to fisheries.

Within the FerryBox project the NERC.NOC route between Portsmouth and Bilbao was chosen so that the exchange of waters across the shelf break into the Celtic Sea could be studied and the progression of these water into the English Channel and then into the North Sea. To the north of the North Sea the MarLab (Marine Laboratory, Aberdeen) will soon be operating a Ferrybox system on a ferry route, Aberdeen to the Shetlands, and is planning a route out to Norway. The recently established Bergen – Newcastle route on which NIVA operates a Ferrybox system crosses the central North Sea. These routes would enable a far better estimation of the flows in and out of the North Sea. Linking the MarLab data of NIVA from the central part, the GKSS line in the southern and NERC.NOC data at the southern boundary establishes the potential of Ferryboxes to fulfil the other meaning of "Box" in the name for a large marginal European sea. This is the idea that areas can be boxed in by ferry data routes providing boundary conditions for models.

The Norwegian Ferrybox systems are intended to be used to quantify long-term transport of particles from the continent to the Norwegian coast which are suspect to cause increased particle concentration on the kelp in Southern Norway. Scientific investigations are started to understand if the particles are long transported or locally introduced.

A key aspect of the Ferrybox concept is that use is made of vessels running regular routes throughout the year. This is critically important in reducing the aliasing that occurs in observations that are made by vessels that can only operate in benign sea states or are restricted to limited periods of observations such as research vessels.

There exist many other 'Ferrybox' type systems that are currently being operated elsewhere on research vessels, but the data obtained from these type of systems is often not from a regular transect. As an example, a system had been set up by the Marine Research Institute in Iceland mainly to analyse the development of phytoplankton biomass with regard to changes in season and salinity. Other Ferrybox type systems have been set up to provide scientific data either fitted to research vessels or other platforms. This includes the General Oceanics SeaKeeper System, which is sponsored by the International SeaKeeper Society. This is a Ferrybox-type system designed for use on recreational vessels such as luxury yachts and large pleasure boats. This has been in operation for several years now, and has been set-up to provide data to the international scientific community. Such data could potentially feed into operational monitoring systems in the future, but it should be recognised that data collected from recreational craft will be of limited value, as these crafts will not be taking regular transects from the same ports and following the same track on a regular basis. It is also still unclear how permanent data quality can be ensured.

A-5.2 Future Scientific Applications, Requirements and Expectations

A-5.2.1 Improved Cyanobacteria Blooms Detection

FIMR realises that research on harmful algae blooms frequently occurring in the Baltic Sea requires improved spatial and temporal resolution in measuring related parameters and precursors. This led to the idea of using ferries and other voluntary ships of opportunity for more automated and less personnel and infrastructure consuming measurements.

Following the development and adaptation of instrumentation as well as of methodologies field work started in the early 1990s. This has now developed into an operational system (see also section A-6.1.2).

Accompanying research also utilises Ferrybox data for process and ecosystem investigations as well as producing advances in the system itself in terms of the instruments used and the processing of data. Notably, standard fluorometers used in Ferrybox systems are not suitable for the detection of cyanobacteria. Chlorophyll in vivo fluorescence is, however, not optimal for the detection of cyanobacteria as for these species fluorescence at the wavelengths specific for chlorophyll is very weak. Instead, these species contain phycobilin pigments that have their own specific wavelengths for excitation and fluorescence emission. FIMR's previous studies with pure phytoplankton cultures and experimental work in field along with testing several devices for detection of phycobilin pigments in cyanobacteria have provided important background for cyanobacterial detection by fluorescence. Bloom forming filamentous species in the Baltic are the main source of phycocyanin related optical signals. Picocyanobacteria (i.e. cells < 2 µm), not forming the blooms, together with some eucaryotic species, is the main source of phycoerythrin signals. Studies with cultures provide us also information on the environmental control of the variability in cellular phycobilin content which is extremely significant information when analysing the field data.

After this intensive research FIMR can now apply operational detection of phycocyanin in the Baltic Sea since summer 2005.

A-5.2.2 Future Scientific Uses

From the perspective of the scientific community the following future applications of Ferrybox systems are feasible:

- Time series for hydrodynamic <u>and</u> biogeochemical changes
- Including better linkage of plankton productivity and variability in productivity in relation to physical and bio-geochemical constraints and eutrophication
- Validation of indicators linking nutrient supply and plankton production
- Development of tools for identifying different plankton types, particularly harmful algae
- Identification of sources of nutrient supply from ocean river and the atmosphere
- Assessment of transport of sediments and associated contaminants over long and short spatial and temporal scales
- Quantification of the stability and transport of water masses in the Mediterranean, Baltic and on and adjacent to the Western European shelf
- Definition of zones of freshwater influence to improve the precise of regulatory tools such as the Water Framework Directive.

A-5.3 Requirements from the Marine Science Community

The overall requirements posed by the scientific community are making the best use of Ferrybox data. The FerryBox project partners have worked towards developing a standard scheme for validating the accuracy and precision of all data gathered in the project.

A common method for data reporting has been achieved. Also some joint ideas on post-processing approaches and related quality controls which, however, call for further refinement. This next stage is a major one for the full realisation of marine monitoring around Europe beyond the collection of meta-data. Although the GMES exists, its focus is on the global ocean and deep water. An improved will is needed to get the national agencies responsible for data collection relevant to the Waters and Marine Directives to work more closely together to set up the required exchange of data. This can be done on the basis of data portals using semantic web technology which needs to be developed (cf. Berners-Lee et al. (2001), “The semantic web” in Scientific American).

In the FerryBox project much of the work towards readily exchangeable data was already achieved through the documentation of data collection and quality control procedures and the use of a standard parameter dictionary for describing data base entries (BODC Parameter Dictionary).

A-6 Present and Future Application Potential for the Operational Oceanography Community

During the FerryBox project the perspectives for operational oceanography applications advanced amazingly and have in some countries reached almost full operational stage. In other countries strong interest was raised which at the end of the project lead to definition of Ferrybox test trails and pilot applications at several agencies and institutions concerned with marine monitoring.

A-6.1 Present Operational and Pre-operational Ferrybox Applications

A-6.1.1 Applications in Routine Meteorological Observation Programmes

A serious hindrance to understanding and forecasting the state of marine systems is the lack of monitoring systems that provide on-line data. Observations mostly lack the spatial coverage and temporal resolution required to determine a true view of the state of the marine environment and changes within it. The FerryBox project has provided a practical demonstration of how effective the use of ships of opportunity can be in contributing to our ability to set up local, regional and global monitoring systems. This allows considerable progress to be made in achieving some of the aims of GOOS (Global Ocean Observing System) and in Europe by EuroGOOS, in a cost effective manner.

Systems of ships of opportunity observation do already exist round the world which are well organized and co-ordinated and are funded round by local meteorological agencies. This meteorological SOO work is already conducted under three main programmes:

1. The Voluntary Observing Ships (VOS) Programme (Surface meteorology, typically reports in 6, 3 hour or 1 hour intervals).
2. The Ship Of Opportunity (SOOP)Program (XBTs on a network of lines as defined by OOPC)
3. The Automated Shipboard Aerological (ASAP) Programme uses radiosondes and requires installation of a instrument container on the ship.

The international body that oversees data collected in support of weather forecasting and climate research is the JCOMM Ship Observations Team (http://www.jcommops.org/sot/) which supervises these programmes. All data are transmitted to the GTS (Global Telecommunications System). They are then freely available in real time for forecasting to meteorological agencies round the world. Delayed mode data is also collected (e.g. higher resolution atmospheric and ocean profiles).

The only other global SOO programme that exists and this much less formalised than the met data collections is the linkage various scientific efforts collecting data round the world relevant to the air-sea exchange of carbon dioxide by the IOCPP International Ocean Carbon Coordination Project (http://ioc.unesco.org/ioccp/) which is sponsored by the IOC and run on a voluntary basis by the contributing scientific groups.

A-6.1.2 Alg@line – Operational Information on the Northern Baltic Sea

FIMR coordinates the Alg@line project, and the regional environment centres of Uusimaa (UUS), West Finland (LSU), Southwest Finland (LOS) and Southeast Finland (KAS) as well as the Helsinki City Environment Centre (HKI) are the domestic partners. EMI and the Estonian Maritime Academy (EMA) are active foreign partners. The responsibility and maintenance work of the Alg@line-ships is divided as follows:

- FIMR: Finnpartner, Serenaden, Silja Opera and a coast guard vessel Merikarhu
- UUS and HKI: Silja Serenade
- KAS and HKI: Kristina Brahe
- EMI and EMA: Romantika
- LOS: coast guard vessel Telkkä
- LSU: coast guard vessel Turva

Alg@line conducts a state-of-the-art environmental monitoring campaign in terms of spatial and temporal coverage of data. This is the result of a unique cooperation with Finnish and foreign research institutes and scientific communities.

The measurement results of the ships are disseminated through the Baltic Sea Portal, and on an annual basis, through each institute's annual reports.

A-6.1.3 Ferrybox Monitoring of Norwegian Coastal Waters

Already during the lifetime of the FerryBox project the interest from other ferry companies led to the development of two new Ferrybox implementations. Together with the existing ones these cover now most of the Norwegian coastal waters as well as the Skagerrak area with two and the central North Sea with one line. In addition the old system on the coastal steamer MS Vesterålen operated by the Institute of Marine Research (IMR) will be upgraded. This increases the frequency of measurements at the Norwegian west and northern coast line.

In summary the Norwegian Ferrybox observation systems consists of the following lines and operators:

- Color Festival. Oslo (NO) – Hirtshals (DK), in 2006 – change to Fredrikshavn (DK)
- FjordNorway. Bergen (NO) – Hanstholm (DK).
- FjordNorway. Bergen (NO) – Newcastle(UK)
- MS Trollfjord. Bergen (NO) – Kirkenes (NO)
- MS Vesterålen. Bergen (NO) – Kirkenes (NO) – operated by IMR

The data are used in algal monitoring, in the coastal monitoring programmes, for the ESA validation project VAMP and in the national satellite programme SATOCEAN. The data are available on-line through satellite links to the ships and in a new GIS/WMS portal together with satellite data (http://www.ferrybox.no).

A-6.1.4 Ferrybox Integration into the Greek POSEIDON System

Greece has plans to integrate Ferrybox observations between Athens and Crete in their national operational marine monitoring system POSEIDON. This is operated by a separate unit hosted by the institute and consists presently of several fixed monitoring buoys, operational models and related information processing and distribution modules.

A-6.1.5 Ferrybox Integration into the POL Coastal Observatory

The Ferrybox measurements across the Irish Sea will become a component of the operational POL Coastal Observing System consisting of a variety of fixes monitoring and measurement stations and a series of numerical models. This system provides real- and quasi-real-time observations in the Irish Sea and Liverpool Bay both from fixed monitoring stations as well as from the ferry connecting Liverpool and Belfast. The data are used for routine forecasting of regional marine conditions and is also utilised in larger scale oceanic and meteorological information and forecasting activities covering the North-West European Shelf. This network is operated by a partnership which the UK DEFRA funded CEFAS Laboratory Centre for Environment Fisheries and Aquaculture Science and the UK Environment Agency, who provide information on river discharges. Other partners directly involved in environmental monitoring include the UK Met Office and the Department of Agriculture and Rural Development of Northern Ireland.

A-6.1.6 Ferrybox Applications by Iceland

Iceland has plans to improve monitoring of their waters and EEZ with a Ferrybox system which is also of particular importance for managing and monitoring fish stocks.

A-6.1.7 Ferrybox Inclusion into the IBIROOS System

IEO has endorsed Ferrybox applications to become a component of the Iberian-Biscay-Irish Regional Ocean Observing System (IBIROOS). Plans have been presented on constituting and ICES Science meetings and were further endorsed at the EuroGOOS Conference 2005.

A-6.1.8 Improved Coverage in the Baltic Sea

Intentions and already advanced project preparation in Russia (together with Estonia and Finland), Sweden and Poland endorse Ferrybox measurements on additional routes across the Baltic Sea and along the Gulf of Finland which will enhance the coverage and observation possibilities in the Central and Northern Baltic Sea.

A-6.1.9 Improved Coverage in the North Sea

Complementary to the above mentioned activities in Norway the Netherlands have installed a Ferrybox system on one of their public survey vessels. Also BSH in Germany prepares a project for testing Ferrybox applications on one of their Hydrographic vessels. Scottish environment authorities and the UK NERC have advanced plans to operate a Ferrybox system for monitoring purposes in the Northern North Sea. Sweden (SMHI) considers operation of a Ferrybox on a vessel running through from the Belt Sea across the Central North Sea to UK.

A-6.1.10 Application on German Research Vessels

GKSS already operates a Ferrybox system on their coastal research vessel Ludwig Prandtl. A Ferrybox test was recently conducted on the German research vessel and icebreaker FS Polarstern to demonstrate applicability on large research vessels. A proposal was submitted to the German Research Foundation to successively fit most of the German research fleet with Ferryboxes. Applications on research vessels will also increase coverage and measurements in remote areas which are usually not covered by ferry and commercial freight lines.

A-6.1.11 Additional applications of Ferrybox/SOO

Additional applications all over the world including among others the activities carried out in the Ferrymon project, with the Alaska Ferries and within the Cavassoo project.

A-7 Supplementary Information

A-7.1 Further FerryBox Results, Literature and Data

For further literature and information one is referred to the FerryBox project, with their Deliverables and network website (http://www.ferrybox.org) on which publicly available reports and results are published. Here also further literature lists and publications are provided for download. This website facilitates also as a portal to websites and online Ferrybox data services of the project partners. It will be maintained and, if possible, enhanced, to an European FerryBox Portal within post-project exploitation and networking activities of the partners plus interested scientific institutes, agencies and companies.

A-7.2 Abbreviations

ADCP	Acoustic Doppler current profiler (trademark)
ADP	Acoustic Doppler current profiling instrument (general)
ARGOS	a satellite data collection and relay system
COTS	Commercial off-the-shelve
CSR	Corporate social responsibility
EC	European Commission
EU	European Union
EuroGOOS	European initiative to implement the GOOS in Europe
FerryBox	Underway measurement activities from ferries in direct relation to the European FerryBox Project
Ferrybox	Underway measurement systems from ferries and SOOP in general relation (e.g. with sensors, systems, data)
GOOS	Global Ocean Observing System
ICES	International Council for Exploration of the Sea
Inmarsat	a marine communication system with satellites in geostationary orbit
NERC	National Environment Research Council of the UK
ORBCOMM	a communication system using low earth orbit (LEO) satellites
SME	Small and Medium Enterprise
SOOP	Ship of opportunity
WFD	European Water Framework Directive
UK	United Kingdom
XBT	Expandable bathy-thermograph (temperature profiler)
XCTD	Expandable conductivity temperature-depth-profiler

Note: Other institution and company abbreviations are explained in the text or listed in the preceding table of FerryBox project partners.