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Workshop Proceedings

ALLIANCE FOR COASTAL TECHNOLOGIES

INTEGRATED SENSOR SYSTEMS FOR VESSELS OF OPPORTUNITY

National Oceanographic Centre, Southampton, UK
October 10-12, 2006

Funded by NOAA's Coastal Services Center through the Alliance for Coastal Technologies (ACT)

An ACT / ECOOT Workshop Report

A Workshop of Developers, Deliverers, and Users of

Technologies for Monitoring Coastal Environments:

Integrated Sensor Systems for Vessels of Opportunity

National Oceanographic Centre, Southampton, UK
October 10-12, 2006

Cosponsored by Alliance for Coastal Technologies (ACT) and the European Coastal and Ocean Observing Technology (ECOOT).

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ACT Workshop: Integrated Sensor Systems for Vessels of Opportunity

Executive Summary

The use of self-contained, low-maintenance sensor systems installed on commercial vessels is becoming an important monitoring and scientific tool in many regions around the world. These systems integrate data from meteorological and water quality sensors with GPS data into a data stream that is automatically transferred from ship to shore. To begin linking some of this developing expertise, the Alliance for Coastal Technologies (ACT) and the European Coastal and Ocean Observing Technology (ECOOT) organized a workshop on this topic in Southampton, United Kingdom, October 10-12, 2006. The participants included technology users, technology developers, and shipping representatives. They collaborated to identify sensors currently employed on integrated systems, users of this data, limitations associated with these systems, and ways to overcome these limitations. The group also identified additional technologies that could be employed on future systems and examined whether standard architectures and data protocols for integrated systems should be established.

Participants at the workshop defined 17 different parameters currently being measured by integrated systems. They identified that diverse user groups utilize information from these systems from resource management agencies, such as the Environmental Protection Agency (EPA), to local tourism groups and educational organizations. Among the limitations identified were instrument compatibility and interoperability, data quality control and quality assurance, and sensor calibration and/or maintenance frequency. Standardization of these integrated systems was viewed to be both advantageous and disadvantageous; while participants believed that standardization could be beneficial on many levels, they also felt that users may be hesitant to purchase a suite of instruments from a single manufacturer; and that a "plug and play" system including sensors from multiple manufactures may be difficult to achieve.

A priority recommendation and conclusion for the general integrated sensor system community was to provide vessel operators with real-time access to relevant data (e.g., ambient temperature and salinity to increase efficiency of water treatment systems and meteorological data for increased vessel safety and operating efficiency) for broader system value. Simplified data displays are also required for education and public outreach/awareness. Other key recommendations were to encourage the use of integrated sensor packages within observing systems such as IOOS and EuroGOOS, identify additional customers of sensor system data, and publish results of previous work in peer-reviewed journals to increase agency and scientific awareness and confidence in the technology.

Priority recommendations and conclusions for ACT entailed highlighting the value of integrated sensor systems for vessels of opportunity through articles in the popular press, and marine science

and technology publications, and the hosting of a technology workshop on data loggers as they relate to integrated sensor suites.

Alliance for Coastal Technologies

The Alliance for Coastal Technologies is a NOAA-funded partnership of research institutions, resource managers, and private sector companies dedicated to fostering the development and adoption of effective and reliable sensors and platforms. ACT is committed to providing the information required to select the most appropriate tools for studying and monitoring coastal environments. Program priorities include transitioning emerging technologies to operational use rapidly and effectively; maintaining a dialogue among technology users, developers, and providers; identifying technology needs and novel technologies; documenting technology performance and potential; and providing the Integrated Ocean Observing System (IOOS) with information required for the deployment of reliable and cost-effective networks.

To accomplish these goals, ACT provides these services to the community:

- Third-party testbed for quantitatively evaluating the performance of new and existing coastal technologies in the laboratory and under diverse environmental conditions.

- Capacity building through technology-specific workshops that review the current state of instrumentation, build consensus on future directions, and enhance communications between users and developers.

- Information clearinghouse through a searchable online database of environmental technologies and community discussion boards.

ACT is organized to ensure geographic and sector involvement:

- Headquarters is located at the UMCES Chesapeake Biological Laboratory, Solomons, MD.

- Board of Directors includes Partner Institutions, a Stakeholders Council, and NOAA/CSC representatives to establish ACT foci and program vision.

- There are currently eight ACT Partner Institutions around the country with coastal technology expertise that represent a broad range of environmental conditions for testing.

- The ACT Stakeholder Council is comprised of resource managers and industry representatives who ensure that ACT focuses on service-oriented activities.

The ACT workshops are designed to aid resource managers, coastal scientists, and private sector companies by identifying and discussing the current status, standardization, potential advancements, and obstacles in the development and use of new sensors and sensor platforms for monitoring, studying, and predicting the state of coastal waters. The workshop's goal is to help build consensus on the steps needed to develop and adopt useful tools, while facilitating critical communication among the various groups of technology developers, manufacturers, and users.

ACT Workshop Reports are summaries of the discussions that take place between participants during the workshops. The Reports also emphasize advantages and limitations of current technologies while making recommendations for both ACT and the broader community on the steps needed for technology advancement in the particular topic area. Workshop organizers draft the individual reports with input from workshop participants.

ACT is committed to exploring the application of new technologies for monitoring coastal ecosystem and studying environmental stressors that are increasingly prevalent worldwide. For more information, please visit www.act-us.info.

Background and Workshop Goals

To better understand and manage our oceans and coastal systems, there is a clear need for higher resolution spatial and temporal environmental data. Efforts, such as the Integrated Ocean Observing System (IOOS) and the Global Ocean Observing System (GOOS) and its regional programs, are evolving to provide international coordination. However, in the field, the critical step of gathering the required information can prove costly. Recent efforts that have shown great promise in reducing this cost is by taking advantage of vessels of opportunity or "volunteer observing ships (VOS's) as mobile platforms for environmental data collection. The installation of self-contained, low-maintenance sensor system modules on commercial vessels has become an important monitoring and scientific tool in many regions. Consequently, ACT, ECOOT, and our colleagues became interested in examining in-depth the current state of technology in this area and building a consensus of recommendations to improve instrument packages to better address user needs and to explore how these systems might be further developed as a key component in ocean observing efforts.

**See http://ocean.tamu.edu/GOOS for more information on the structure of GOOS and www.ocean.us for more information on IOOS.*

The Integrated Sensor Systems for Vessels of Opportunity Workshop examined the following core questions:

1. What suite of instruments (meteorological and surface water) are currently incorporated in integrated sensor systems deployed on vessels of opportunity?

2. Who are the users of the data collected (e.g., scientists, vessel operators, fisherman), and what are their specific parameters/applications of interest (e.g., weather, vessel efficiency, primary productivity)?

3. What are the limitations (e.g., cost, calibration, maintenance, data quality) of current integrated sensor systems for vessels of opportunity?

4. How can the limitations of current systems be addressed or overcome?

Specifically -

4a. Should there be standard architecture and data protocols for integrated sensor systems deployed on vessels of opportunity?

4b. What additional data or new technologies would be valuable to incorporate into these systems, and how can there be wider acceptance/adoption by vessel owners?

5. How best to incorporate these systems into observing programs?

6. What are other potential applications for these integrated sensor systems (e.g., water treatment facilities, fixed platforms)?

Organization of the Workshop

The Workshop was hosted by the National Oceanographic Centre (NOCS) on October 10-12, 2006 in Southampton, UK. The meetings were devoted to small working groups of invited participants to develop consensus about impediments to and opportunities for the future adaptation of integrated sensor systems to vessels of opportunity.

There were 32 invited participants (Appendix A) selected to represent four segments of the community: commercial instrument vendors (those who manufacture the technology), vessel of opportunity representatives (those whose vessels are being outfitted with sensor suites), academic researchers (those who deploy integrated sensor packages), and environmental resource managers (those who utilize the data). Participants were separated into two groups that included each of these communities during two breakout sessions; both groups were then asked to address the aforementioned questions. After each session, all participants reconvened to compare findings and recommendations.

The morning breakout sessions split the attendees into two groups: industry (vessel operators and instrument manufacturers) and research (resource managers and academic scientists). The main objective of this breakout session was to address the workshop questions from different perspectives. Attendees were again divided for the afternoon breakout session, blending managers, manufacturers, academic scientists, and vessel representatives into two groups. They were charged with developing recommendations and action items that would address the findings of the earlier sessions. The final morning of the workshop was devoted to a plenary session where recommendations from the previous day were reviewed, clarified, and finalized for inclusion in the final report. Prior to this, however, question five (which dealt with the incorporation of integrated sensor systems into observing programs) and question six (which dealt with additional applications of these systems) were also addressed. The following is a general description of the breakout session discussions.

Current State of Integrated Sensor Systems

1) *What suite of instruments (meteorological and surface water) are currently incorporated in integrated sensor systems deployed on vessels of opportunity?*

There was general consensus among participants that most integrated sensor systems consisted of both meteorological and subsurface sensors. Within the meteorological suite, the following sensors/parameters were believed to be most prevalent:

- Wind speed / direction
- Temperature
- Relative humidity
- Barometric pressure
- GPS positioning
- Solar radiation (short & long wave)
- Ceilometry

Within the subsurface suite, the following sensors/parameters were found to be most prevalent on integrated systems:

- Sea surface temperature (SST)
- Sea surface salinity (SSS)
- Chlorophyll
- Dissolved oxygen (DO)
- pH
- Partial pressure of carbon dioxide
- Nutrient sensors (nitrate & phosphate)
- Blue green pigment
- Silicate
- Turbidity

Additional sensors mentioned for future consideration included:

- Discreet samples for use in quality control
- Colored dissolved organic matter (CDOM)
- Waves
  - Shipboard WR
  - Radar
- Current
- Biomass acoustic doppler current profiling
- Plankton (flow-cam, fast repetition rate fluorometer)
- Continuous plankton recorder (CPR, see www.**sahfos**.ac.uk)
- Towed sensors
- Expendable probes

While several research groups around the world have developed custom integrated sensor packages, there are currently three commercially available systems in use: 4H Jena Engineering, Chelsea Technologies Group, and The International Seakeepers Society. For summaries of these three commercial systems see Appendix B, which briefly describes the individual systems (to be added).

2) *Who are the users of the data collected, and what are their specific parameters/applications of interest (e.g., weather, vessel efficiency, primary productivity)?*

With respect to the identification of users of integrated sensor system data, both groups came up with similar findings. Among the most frequently cited users were the following (listed in no particular order):

- Transportation agencies
- Health-related agencies (e.g., Environmental Protection Agency (EPA))
- Marine and climate forecasters and modelers
- Coastal resource managers (e.g., National Marine Fisheries Service (NMFS))
- Commercial and recreational fishermen
- Private sector companies (e.g., petrochemical industry)
- Education and outreach organizations
- Tourism-related entities
- Industrial and recreational vessel operators
- Value-added resellers of data
- Academic researchers
- Defense agencies

3) *What are the limitations (e.g., cost, calibration, maintenance, data quality) of current integrated sensor systems for vessels of opportunity?*

There were several limitations associated with the use / current configurations of integrated sensor systems. Among the major limitations identified by both groups were the following:

- System Maintenance
- Initial installation / retrofit cost
- Downtime
- Calibration frequency / cost
- Sensor reliability
- Biofouling
- Debubbling (residence times, sampling intervals)
- Compatibility / interoperability
- Access to sensors
- Vertical / horizontal scale profiling
- Sustained funding
- QA/QC of data

Other limitations and pertinent issues identified by both groups included the creation of incentives for ship owners, labor, socioeconomics, and sensor / technology maturity as it relates to some sensors being more advanced than others. Along these same lines, the groups reviewed the various technology types being employed on vessels of opportunity and identified each as being mature and operational, experimental (limited use and reliability), or developmental (not yet reliable or operational). Table 1 identifies the different technologies that fall within each category:

TECH STATUS DATA SOURCE	PARAMETER (ACT/NOCS)	INSTRUMENT/METHOD (ACT/NOCS)	RANGE (DESIRED)	ACCURACY (IGOS)	ACC. MIN (IGOS)	ACCURACY (DESIRED)	RES/PREC (DESIRED)	CAL. INTERVAL (DESIRED)
MATURE								
	Sea Surface Temp. (SST)	Pt100	-2 to 45 †	0.2'C	0.5'C	0.01 †	0.001 †	1 year †
		Ir		0.1 †			0.1 †	
	Sea Surface Salinity (SSS)	Cond	0 to 45 †	0.1psu	0.3psu	0.01 †	0.001 †	0.5 year †
	Currents	adcp		3cm/s	10cm/s	3cm/s †		0.5 year †
	Scatterer Density	adcp						
	Wind Speed and Direction	mechanical/ultra sonic	0 to 70 m/sec †	1m/s 10'	2 m/s 20'	± 1.0 m/s †	0.1 m/s †	1 year †
	Air Temperature	Pt100	-50 to 60'C (ACT)		±0.5'C (ACT)	± 0.3 C †	0.1 deg C †	1 year †
	Barometer	digital	600 to 1100 hPa †			± 0.3 hPa †	0.1 hPa †	1 year †
	Relative Humidity (RH)		10 to 100 90% (ACT)		±3% (ACT)	± 3% †	1 % RH †	1 year †
TRANSITIONAL								
	Turbidity/Absorption/TSM	backscatter		30%	40%			1 year †
	O_2 and pCO_2 (IGOS)	equilibrium/gas tension		10%	30%			0.5 year †
	Dissolved Oxygen	clarke	10%			10%†		0.5 year †
		optode						1 year †
	Primary Production	variable fluorometry †						1 year †
	pH	electrode						0.5 year †
	Chlorophyll	fluorometer	10% †	30%	40%	0.01 ug/l †	0.001 ug/l †	1 year †
	CDOM	Uv fluorometer	10%	30%	40%	0.01 ug/l †	0.001 ug/l †	1 year †
	Nitrate (optical)	Uv spectrometer	10%					0.5 year †
EXPERIMENTAL								
	Nutrients (wet chemistry)	wet chemistry	10% †	10%	30%			0.5 year †
	Shapes	optical cytometry						
	Blue Green Algae	fluorometer	10% †			0.01 ug/l †	0.001 ug/l †	1 year †
	Harmful Algal Blooms (HAB)	hyper spectrometer						0.5 year †
	pH	optical	10% †					0.5 year †
DEVELOPMENTAL								
	Bio Chemical Sensors	lab on chip/analyzer						
	Biochemical DNA	lab on chip/analyzer						
	Laser Induced Fluorometery	fluorometer						
	Atomic Mass Molecules	UW mass spectrometry						
	Waves	radar/ship wave recorder						

EXPLANATION	
Data source	*Refers to the origin of the information*
(ACT)	*Refers to the minimum requirements determined at the ACT Workshop on Meteorological Buoy Sensors, 2006*
†	*Refers to data that was contributed by participants at the ACT/NOCS Workshop on Integrated Sensor Systems for Vessels of Opportunity, 2006*
IGOS	*Refers to data taken from the Integrated Global Observing Strategy Coastal Theme Report, 2006 (All data not identified as ACT or ACT/NOS was taken from IGOS)*
Parameter	*The variable being measured*
Accuracy (IGOS)	*Accuracy as outlined in the IGOS Coastal Theme Report, 2006 (Reference Figures)*
Acc. Min (IGOS)	*Minimum accepted accuracy as outlined in the IGOS Coastal Theme Report, 2006 (Reference Figures)*
Accuracy Desired	*The desired accuracy determined by participants at the ACT/NOCS Workshop, 2006*
Res/Prec (Desired)	*The desired resolution/precision determined by participants at the ACT/NOCS Workshop, 2006*
Cal. Interval	*The desired calibration interval of an instrument/technology determined by participants at the ACT/NOCS Workshop, 2006*

4a) *Should there be standard architecture and data protocols for integrated sensor systems deployed on vessels of opportunity?*

Both groups believed a hardware interface issue was a major hurdle further complicated by the issue of proprietary technology that prevents companies from integrating their connections and software. The concept of "plug and play" arose and was seen as an ideal adaptation to these integrated systems. However, it was also thought to be costly with respect to developing unifying programs that are able to standardize the input displayed by the various integrated sensors contained in one package. It was concluded that it would be difficult to standardize the interfacing of all instruments due to the multitude of manufacturers involved. The other issue concerning this standardization approach to integrated sensor systems was that users may prefer a particular instrument that may not be adaptable for an integrated suite due to software or power requirements.

It was considered that standard protocols for monitoring are welcomed by many agencies and are, in some cases, a basic requirement. Most of the VOS systems that are currently operated are being done so by academic or research institutions rather than operational agencies, such as EPA in the USA or CEFAS in the UK. As a consequence, strict protocols have yet to be developed. However, in Europe, the European Union funded project "FerryBox" has developed standard data reporting procedures and produced a coordinated review of the procedures employed by the eight different organizations running VOS lines within the project. (See www.ferrybox.org.)

One obstacle associated with the implementation of standard protocols is that many countries do not readily grant permission to monitor in restricted waters due to defense and/or natural resource (including artifacts and fisheries) protection issues. Participants pointed out that, in some countries, it could take up to six months before being granted permission into these restricted areas.

4b) *What additional data or new technologies would be valuable to incorporate into these systems, and how can there be wider acceptance/adoption by vessel owners?*

The participants adamantly believed that more continuous monitoring with a wider range of sensors is and will be of great value. However, there was a desire to make it clear that developments and expansions of systems have to be progressive, with each sensor being evaluated with respect to the quality and utility of the data being returned. For example, although nutrient sensors are being used in some systems, there still exists a lack of confidence in the data being returned; this is a key area in which development is still needed.

It was suggested that initial integrated sensor systems be robust and able to withstand the elements, rather than include instruments still in the developmental phase that require frequent calibration and cleaning. It was agreed that initial systems should start off with more established instruments, such as temperature and salinity, and then expand to monitor other parameters as their technology improves. Standardized, mobile, cost effective systems were viewed as being very favorable to the adoption of these integrated sensor systems by regional managers.

Aside from this, little resistance existed outside the concern that, as monitoring moves towards more automated analysis, hands-on jobs could be lost. Along these lines, one participant noted that, due to budgetary cuts, he was forced to replace observers with automated systems. However, another participant believed the transition to automated systems to be beneficial, noting that with the emergence of more automated vessels, there would be less demand for labor-intensive data acquisition systems. While these systems will require fewer personnel to operate them on a daily basis, there could be an increased demand for field technicians to maintain and service these sensor suites. A larger concern was the funding (initial purchase and operating costs) of these continuous monitoring systems, which was foreseen as a potential hurdle. However, it was noted that even some of the more expensive systems that have been installed have been done so at costs that are small in comparison to the running costs of research ships.

Several participants noted that, to date, the outfitting of vessels with integrated sensor system packages has been welcomed by vessel owners, even with the mechanical and physical alterations required to house the integrated systems. Technical support has often been provided, and in exceptional circumstances, two operators have even provided financial support. One case was mentioned in which a vessel operator went so far as to modify the design of the vessel in order to provide a moon pool for scientific work. Promotion of sensor integration systems to observing system managers was seen to be the key to facilitating the adoption of sensor systems onto platforms of opportunity.

Encouraging manufacturers to package instruments adapted for a flow-through environment is more efficient than having each agency adapt an *in situ* profiling instrument to do the same job. Furthermore, the original equipment manufacturers need to be made aware of critical factors involved in undertaking such an adaptation.

The shipping industry representatives were keen to make the scientists aware of their interest in accessing the data being monitored, as this information could potentially benefit vessel operators. Real-time access to sea surface temperature, sea surface salinity, and meteorological data can improve vessel safety and operating efficiency, as well as the efficiency of water making systems and ballast water monitoring. In addition to these benefits, there was also great interest in the passenger display systems developed in the FerryBox project.

Another means of facilitating the acceptance of these integrated systems was believed to be through the publication of papers by the scientific community and articles by the popular press, both outlining the efficacy of integrated sensor systems.

Additional improvements that could lead to the wider adoption of integrated sensor systems were also identified. These included more robust nutrient sensor technologies, the implementation of more pCO2 and primary production assessment sensors, the addition of acoustic doppler current profilers, cost-effective packaging of sensors, and the increased use of satellite "sea-truthing" whereby one can ensure that data collected from satellites is correct by comparing it to data collected with properly calibrated and maintained integrated sensor systems. Stricter enforcement from monitoring agencies, such as the Environmental Protection Agency (EPA) and European Environmental Agency (EEA), could also provide the stimulus needed to facilitate the adoption of these integrated systems on vessels of opportunity.

The seven major additional parameters/sensor types that the participants felt would be valuable to include on integrated sensor systems entailed:

- Taxonomic identifiers of phytoplankton/HAB's
- pH
- Optical nitrate
- Flow cytometry
- Bio-chemical sensors
- Genetic sensors
- Mass spectrometry

Data Transmission and Communication:

Several different methods are currently employed to send data automatically from ship to shore – GSM phone links, the ORBCOM and IRIDIUM data satellite systems, and other satellite-based systems that are part of the ships' own communications systems. In some cases, the ships have a continuously open broadband link to shore (for the processing of credit card transactions), and this can be used for two-way communications with the scientific instruments on the ship, allowing them to be remotely controlled. The advantage of continuous satellite communications is that data can be displayed on shore in real time. From an engineering point of view, this allows problems to be identified before the ship docks and remedial action to be planned in advance of docking.

One area that participants felt should be developed more strongly by all operators of VOS systems is the packaging of integrated sensor data for educational / outreach groups. It was felt that expansion of these types of services could increase public awareness and help develop the acceptance of the benefits of VOS systems, which would then drive demand for the implementation of new systems. This can easily be done on the basis of the existing knowledge that VOS operators have.

5) *How best to incorporate these systems into observing programs?*

Within Europe, the FerryBox-VOS concept has been strongly encouraged by EuroGOOS for over a decade. EuroGOOS coined the FerryBox name recognizing that, if a box of sensors could be outfitted on some of the 800 ferries working in European waters, important data sets could be collected. These would provide data for assimilation in management models, as well as boundary condition data "boxing in" different areas. It is this requirement for regular data that is driving the development of VOS systems. This kind of data cannot be collected in any other way, as research ships are far too few and much too expensive. There were several suggestions pertaining to the issue of how to incorporate integrated sensor systems into observing programs. Key steps were seen in:

(1) Promotion of these systems and their potential with national and regional environmental agencies, academia, and industry.

(2) Provision of the evidence that chemical and biological parameters can be measured as part of these integrated sensor packages and that researchers must verify their reliability and effectiveness both through scientific publications and the development of effective working practices

(3) Good quality control procedures developed alongside the automated processing and transfer of data to users.

6) *What are other potential applications for these integrated sensor systems?*

The concept of housing integrated sensor systems on buoys was discussed, as both VOS and buoy activities have the same demand for robust, low maintenance, long duration measurement systems. The key difference is that, currently, VOS systems have almost unlimited amounts of electrical power available to them, while most buoy systems are and will be critically limited by the amount of power available from batteries. Many felt that management of power generation and consumption would be key to developing systems for use on different types of platforms. Instrument manufacturers who generally have a lot of experience working with buoys and less with VOS systems need to understand that power restrictions in VOS systems are not a limiting factor.

Another application for integrated sensor packages is their potential use in mariculture and aquaculture. A low cost, highly sensitive sensor suite would seem to have great appeal to those seeking to obtain critical water quality data and/or control feeding. The balancing of these two critical parameters could be monitored through the use of integrated sensor systems. As previously mentioned, the use of integrated sensor systems is also believed to have potential use in ballast water monitoring applications.

Recommendations

Priority recommendations and conclusions stemming from the workshop were divided into two categories: those dealing with actions to be taken by the general integrated sensor community (manufacturers, resource managers, etc.) and those dealing with actions to be carried out by ACT and ECOOT. The following actions were suggested:

- Providing vessel operators with real-time access to relevant integrated sensor system data (sea surface temperature, sea surface salinity, meteorological conditions) that could improve efficiency of water making systems, as well as vessel safety and operating efficiency.
- Providing simplified data displays and an explanation of their societal relevance for education and public outreach/awareness.
- Publishing results of experiences with integrated sensor suites in peer-reviewed journals and the popular press in an effort to increase agency and scientific awareness and facilitate the utilization of more integrated sensor suites within coastal/ocean observing systems.
- Encouraging the acceptance of integrated sensor systems among larger "umbrella" agencies such as EuroGOOS and USGOOS. It was recommended that smaller regional and sub-regional components comprising these larger observing systems first employ the use of integrated sensor systems in order to demonstrate their effectiveness and, ultimately, initiate a large-scale adoption. To the extent that all these groups will be making measurements with a variety of sensors, we should be presenting them with a solution to integrating data collected from multiple sources without each user group needing to "reinvent the wheel." In this case, standardization should be embraced by manufacturers as a single solution.
- Identifying potential user groups of sensor system data and modifying our acquisition systems to better suit their requirements. One recommended user group was insurance agencies interested in determining regional risk assessments based on sensor suite data relating to meteorological patterns and global warming effects.

Specific recommendations for ACT entailed:

- Highlighting the value of integrated sensor systems for vessels of opportunity through articles in marine science, maritime, and technology publications, as well as the popular press.
- Given the significance of data logging for integrated sensor packages as well as routine coastal monitoring, it was recommended that ACT host a technology workshop addressing these instruments, with an emphasis on their use with integrated sensor systems.

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Appendix A. List of Attendees (continued)

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Appendix A. List otf Attendees (continued)

Appendix B. Integrated Package System Descriptions

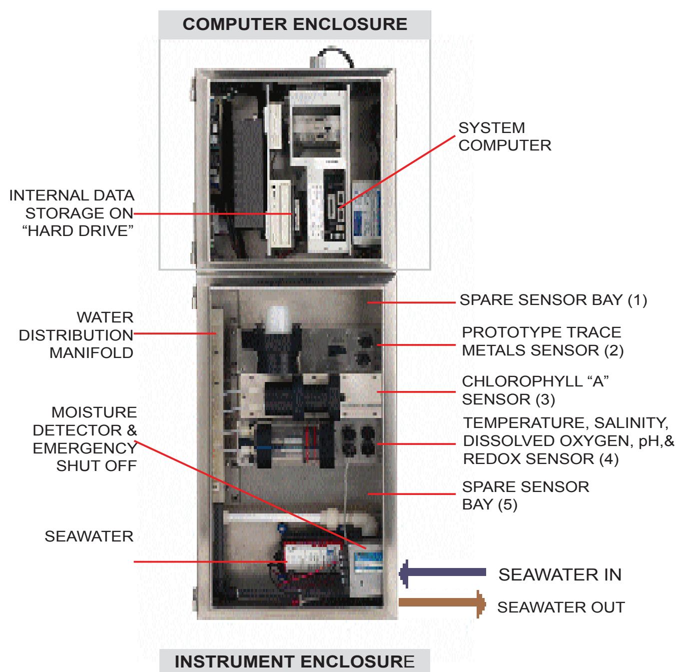
International SeaKeepers Society

The award winning SeaKeeper 1000(r) oceanographic and meteorological monitoring system was developed to fill a need for an automated, economical, and unmanned water and weather monitoring device. The SeaKeeper 1000 needs very little supervision or human intervention. The design criteria aimed to require service calls only a few times a year; since its first deployment, this goal has not only been met, but often exceeded. Compared to conventional oceanographic monitoring instruments, agencies using these autonomous systems save significantly on labor costs.

There are currently four design features that have made the SeaKeeper 1000 especially noteworthy. The following features have earned it the prestigious Tech Museum Intel Award for International Environmental Technology:

- By converting traditional "in situ" sensors into flow-through designs housed in a cabinet, these sometimes delicate sensors are less vulnerable to being damaged by the ocean environment, and do not require deployment by divers.
- The bio-fouling typical of "in situ" ocean instrumentation is dramatically reduced due to the sensors being in a dark environment. Additionally, there is a daily antifouling cycle where a chlorine gas is electrically generated by the SeaKeeper 1000 system at its seawater inlet.
- The interchangeable, modular sensors are a completely new innovation. It is a "plug and work" design for interchangeable sensors including a physical mount, as well as connectors for water flow, electrical power, and data.
- The self-contained "packaged" design, from the through-hull water intake and the flow-through sensors to the data archiving and data transmission, is a revolutionary improvement in the cost, size, and convenience of near-surface ocean monitoring.

The International SeaKeepers Society is a non-profit marine environmental organization. The Society recently decided to make its sensor interface and overall architecture available pro bono. SeaKeepers is now actively soliciting commercial firms to adapt to its standardized sensor interface. By encouraging the use of the freely licensed SeaKeeper system as a standard for the ocean-monitoring community, SeaKeepers hopes to make this kind of data collection less expensive, expand the market for new sensors, and contribute to the greater good of an enhanced global ocean-observing system.



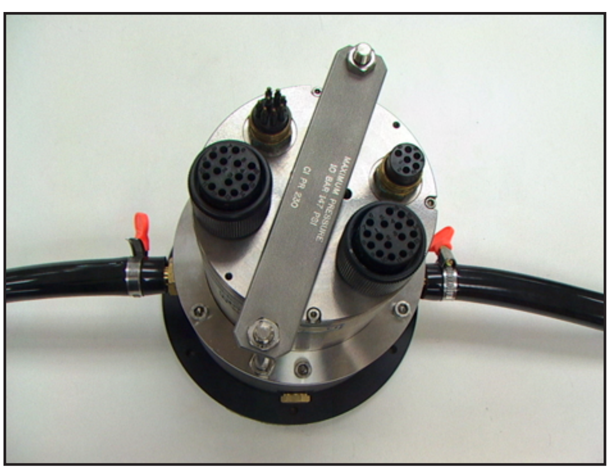
Appendix B. Integrated Package System Descriptions (continued)

Chelsea Technologies Group
AquaLine FerryBox System

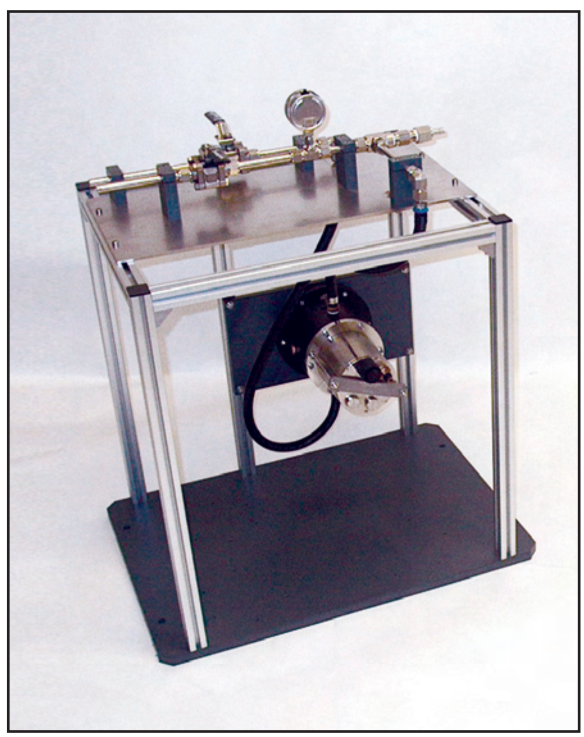
Chelsea Technologies Group supplies complete FerryBox systems throughout the world, including bespoke sensors contained in a flow through system. These systems are plumbed into the ferry's seawater intake to provide reliable, low cost monitoring of the oceans surface layers. Recent customers include Polar Research Institute of Marine Fisheries and Oceanography PNIRO, Murmansk, Russia, and the Marine Fisheries Laboratory, UK.

The systems are based upon the MINIpack CTD-Fluorimeter and a MINItracka II turbidity sensor. Both these instruments are fitted with a flow through manifold specifically designed for ship installation, offering a safety pressure of 10 Bar. The use of the MINIpack CTD-F allows easy integration of additional sensors for future requirements. The system also includes a de-aerator for removal of any bubbles formed within the ship's coolant water intake.

In 2006 the AquaLine FerryBox was launched. This generic robust monitoring system enables sea surface temperature, salinity, chlorophyll-a, and turbidity to be monitored along with a vessel's geographical position. Data is logged onboard and then transmitted to shore by GSM phone links and satellite systems. Already proven internationally, it is an exciting new system, which provides information for operators, passengers, and environmental managers. Long-term scientific quality data sets can be gathered and integrated into operational monitoring networks. Benefits for Vessel Operators include enhanced passenger information, real-time display of sea surface data and position, non-intrusive installation, and low maintenance. Benefits for Environmental Managers include proven scientific equipment expandable to include other parameters, and ship and shore network enabled capability.



Flowthrough Minipack



Frame and GPS

Appendix B. Integrated Package System Descriptions (continued)

4H JENA

FerryBox

A new automated monitoring equipment ("4H FerryBox") has been developed by the 4H- JENA engineering GmbH in Cooperation with the GKSS Research Centre, Institute for Coastal Research. This 4H FerryBox system is a new operational tool using ferries and other "Ships of Opportunity" as carriers and platforms for automated monitoring equipment. The experiences within the EU project demonstrate clearly that such systems can cost-effectively deliver reliable high frequency data and thereby improve, supplement, and even optimize (in terms of reduction of maintenance efforts and running costs) conventional monitoring strategies. The 4H FerryBox system consists of a seawater intake, a debubbling device, a main loop with sensors for temperature, salinity, pH, oxygen, turbidity, and algae abundance. The water of another loop is filtered for analysis of ammonium, nitrate/nitrite, o-phosphate, and silicate. A main feature of the system is the implemented self-cleaning procedure: critical sensors are automatically cleaned with acidified water and rinsed with tap water in order to avoid biofouling and to keep the sensors clean and stable over a long time. For applications in tropical waters, an additional chlorination is available. Such systems will be an important topic within the GOOS (Global Ocean Observing System) and EuroGOOS Framework.

4H JENA Ferrybox

4H Ferrybox with data-logging and data display

Appendix B. Integrated Package System Descriptions (continued)

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