Project no. **012585**

Project acronym

HISMAR

Project title

Hull Identification System for Marine Autonomous Robotics

Instrument: Specific Targeted Research or Innovation Project

Thematic Priority: Sustainable Surface Transport

Deliverable D7.2: Publishable Final Activity Report

Period covered: from: 1 November 2005 to 30 April 2009

Date of preparation: 30 April 2009

Start date of project: 1 November 2005 Duration: 42 months

Project coordinator name: Professor Tony Roskilly

Project coordinator organisation name: Newcastle University

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AUV	- Autonomous Underwater Vehicle
CI	- Control Interface
CPU	- Central Processing Unit
DBMS	- Database Management System
GIS	- Geographic Information System
HAZ	- Heat Affected Zone
IACS	- International Association of Classification Societies
IMO	- International Maritime Organisation
MFL	- Magnetic Flux Leakage
MLRS	- Magnetic Landmark Recognition System
MMI	- Man-Machine Interface
NDT	- Non-Destructive Testing
ODRS	- Optical Dead Reckoning System
OS	- Operating System
ROV	- Remotely Operated Vehicle
SLAM	- Simultaneous Localization and Mapping
SOLAS	- Safety of Life at Sea
SQL	- Structured Query Language
UN	- United Nations
UUV	- Untethered Underwater Vehicle

1 Project Execution

1.1 Overview of Project Objectives

Mission Statement: To design, develop and build a working self navigating robotic prototype for the purpose of autonomous hull cleaning and inspection of ocean going commercial and military vessels.

The key objectives of the project are:

- To develop a multipurpose robotic platform for mapping a vessels external profile to allow repeatable and safe navigation of its surface.
- To develop optical and magnetic sensing devices for accurate dead reckoning positioning of a robotic platform traversing the surface of a ship's hull.
- To develop platform 'plug in' functional modules to enable surveying of hull structural integrity and to carry out cleaning of the ship hull.
- Reduce greenhouse gas emissions from ships by providing a tool to maintain low hull resistance through continuous in-water cleaning.
- Reduce the likelihood of vessel structure failure by providing a tool to monitor hull structural integrity continuously without dry-docking.

<u>Project Logo</u>

Figure 1: HISMAR logo

1.2 Summary description of objectives:

This project will develop a fully automated self navigation, multi-functional platform hull maintenance robot with an advanced navigation system for marine applications. The device developed will offer a means to undertake hull inspection and maintenance in dry-dock, in port or at anchor thereby improving the potential safety and environmental impact of vessels. The robotic platform will have an innovative navigational system that will be cost effective and be an economically viable product.

Both the global and EU shipping fleet continue to grow and over 3 billion tonnes of goods are handled in the EU as well as the movement of over 300 million people. The sector employs over 2.5 million people in the EU. Whilst shipping is one of the cleanest forms of transportation, the fouling of ships reduces efficiency and increases the consumption of fuel. Vessel safety has improved in recent years, however structural failures continue to occur. Therefore any system which is capable of continuously monitoring the integrity of the vessels hull will provide a valuable operational tool.

1.3 Project Co-ordinator:

Professor Tony Roskilly

Deputy Director and Dean of Research
Sir Joseph Swan Institute for Energy Research
3rd Floor
Devonshire Building
Newcastle University
Newcastle upon Tyne
NE1 7RU

T. 44 (0) 191 2225869
F. 44 (0) 191 2228533
tony.roskilly@newcastle.ac.uk

Project Website:

http://hismar.ncl.ac.uk

Project Consortium:

Organisation Name	Short Name	Contact
Newcastle University	UNEW	Professor Tony Roskilly
Graaltech	GT	Andrea Caffaz
Shipbuilders and Shiprepairers Association	SSA	Ashutosh Sinha
TecnoVeritas Servicos de Engenharia e Sistemas Technologicos	TV	Jorge Antunes
TEPAC Patent and Consulting Eberhard Kuebel	TEPAC	Eberhard Kuebel
Polski Rejestr Statkoro S.A	PRS	Marek Narewski
ROBOSOFT	RB	Joseph Canou
Carnival plc	CNV	Tom Strang and John Drew
Moscow State Technical University 'Stankin'	STK	Ivan Ermolov
Royal Thai Navy	RTN	Capt Monchai

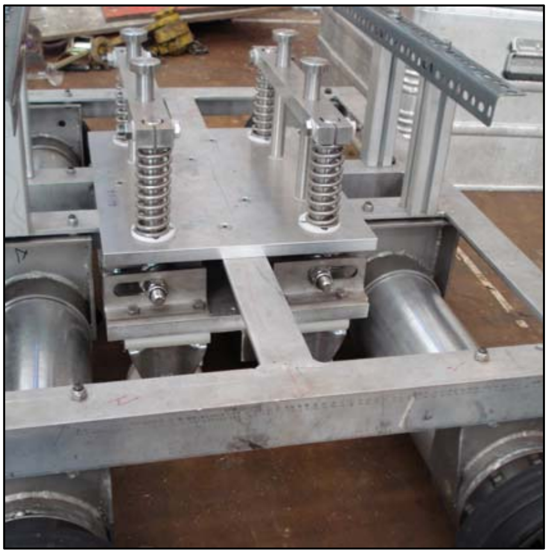
Table 1: Table of HISMAR project consortium partners

1.4 Work Performed and End Results

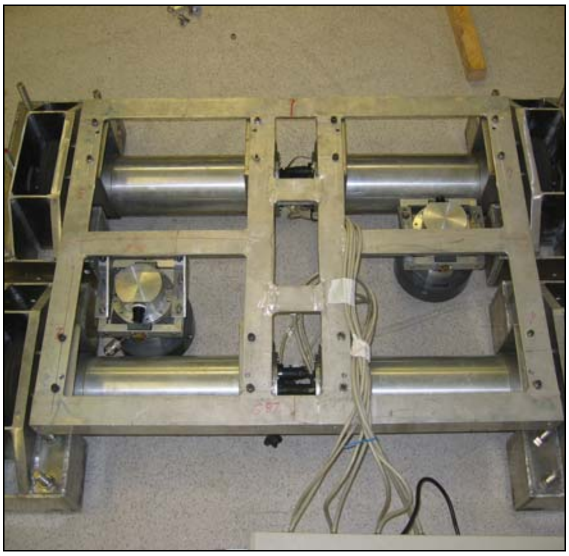
The work performed involved six technical workpackages, one workpackage relating to IPR, dissemination and exploitation and one workpackage relating to project and task management.

The first workpackage provided the consortium with a clear understanding of the technology, equipment and techniques needed for the project. End user requirements were established and a cost benefit analysis undertaken. This was a key achievement for this period of the project as a clear understanding of the technology and the customer needs was essential before any detailed design was undertaken.

The second workpackage involved the design, construction, testing and performance analysis of the navigational sensory system consisting of the magnetic landmark recognition system (MLRS) and the Optical Dead Reckoning System (ODRS).



(a). Mounting of MLRS



(b). Mounting of ODRS

Figure 2: Pictures of the navigation sensor systems mounted on the HISMAR robot frame

The magnetic attachment system and drive system were designed, manufactured and assembled. The control architecture development was also completed. Finally the drive and attachment systems were tested in terms of their individual performance and also their interactions.

Figure 3: Picture of the HISMAR magnetic attachment system

The design and construction of the cleaning module was completed along with the hull structural integrity module. The hull inspection module incorporates cameras to perform the visual inspection of the hull whilst thickness measurements are undertaken by the MLRS using magnetic flux leakage (MFL) readings.

Figure 4: Picture of the HISMAR camera system

Finally, the last technical workpackage involved the integration of the components into a fully operational prototype, followed by laboratory and field testing and performance analysis.

Figure 5: The completed Prototype HISMAR robot attached to a ship during field trials

IPR, dissemination and commercialisation strategies were developed and implemented and opportunities were identified and exploited throughout the project duration.

The project and task management was undertaken utilising a variety of communication strategies and the project was successfully completed.

The project's key achievements and end results were:

- Technical end user requirements of the project were identified and a cost benefit analysis completed.
- Development of the magnetic and optical sensory navigation system
- Intelligent navigational system prototype developed
- Successful construction, testing and integration of the drive and attachment system
- Completion of the cleaning and structural integrity modules
- System testing and performance analysis
- Ongoing exploitation of IPR and opportunities for dissemination and commercialisation
- Successful project and task management in order to ensure successful project delivery

1.5 Methodologies and Approach Employed

The consortium has continued to work towards meeting the needs of the end users through a system which would provide ship operators and ship-repairers with a financial cost benefit and would also lead to an environmental benefit for the European community and society in general. This has been the key objective of the project.

Overall control and facilitation of the project was handled by UNEW, while certain consortium members were responsible for leading the development of elements of the prototype HISMAR robot in particular technical workpackages (WP2, WP3, WP4, WP5 and WP6) and tasks, reflecting their expertise and the experience they brought to the consortium. To aid in the development of components, support in the design and construction of specific elements of the prototype HISMAR robot was provided through the involvement of additional consortium members where required. UNEW facilitated the dissemination of information between consortium partners and managed the resolution of differences of opinion between partners in the design phase.

Workpackage Number	**Workpackage Title**	**Workpackage Leader**
1	Investigation & analysis of technology, equipment & techniques associated with project objectives	UNEW
2	Design, manufacture & testing of the integrated navigational system	GT
3	Design & construction of the hull structure mapping system and intelligent algorithm	UNEW
4	Design, construction and testing of the drive & electromagnetic attachment system	TV
5	Design & construction of the buoyancy outer shell, structural integrity monitoring, cleaning & debris removal 'plug-in' modules	GT
6	Full field trials & analysis of the system performance	UNEW
7	Project management	UNEW
8	Exploitation, dissemination & commercialisation	TEPAC

Table 2: List of consortium partners responsible for specific workpakages

In the design and construction of the prototype HISMAR robot it was important to have the relevant partners' input. Main design ideas and decisions were always discussed during the regular consortium meetings, held every six months at UNEW. Liaison between consortium partners about detailed designs and development of components were held periodically by internet conferencing (Interwise) or telephone conferencing (Skype). Further correspondence between relevant consortium partners about the progress of the design and construction of components were reported to UNEW by email. Occasional technical meetings were arranged by UNEW to resolve or aid the development of specific elements of the prototype HISMAR robot. During the important development of the mapping and navigation systems, representatives of STK and RTN were based at UNEW, to provide them with constant access to the prototype HISMAR robot. Personnel from GT and RB visited UNEW in January 2009 to aid in the final stages of the development of the prototype HISMAR robot before final testing and field trials.

Figure 6: HISMAR laboratory testing team February 2009, from left to right; C. Mullen (UNEW), Dr. R.A. Norman (UNEW), Dr. N. Tunwatta (RTN), J. Heslop (UNEW), A. Turetta (GT) & V. Balashov (STK)

In addition to the above communication routes to disseminate information on the progress of the project, a newsletter was produced after the first year of the project, to provide information to consortium members.

1.6 Achievements of Project to the State of the Art

The project has contributed to the development of new knowledge and state-of-the-art. There are several novel features of the project including the use of magnetic sensors and optical technology in relation to the navigation of a robotic vehicle in an underwater environment for landmark recognition.

Another area of novelty is the intelligent mapping, with the construction of a unique structural map for each vessel and that being stored and used to navigate around the surface of the vessel.

The state of the art knowledge has been protected under a patent and it's exploitation is being managed as part of the exploitation strategy.

1.7 Impact of project on industry

HISMAR is intended to be a multifunctional robotic platform which will offer the option to perform specific inspection or maintenance tasks such as structural integrity monitoring of the ship's hull or carrying out cleaning. The robot offers a means to effectively undertake hull inspection and maintenance thereby ensuring minimal vessel drag and improved propulsion efficiency. The hull navigation dead reckoning position system uses optical technology to track two-dimensional movement over the hull surface. To obtain absolute position measurement, known hull features are used to update the current tracked position using a magnetic sensing system. By saturating the hull with a localised magnetic field, Hall Effect sensors detect subsurface strengthening struts and other hull structural features, which are used as unique landmarks. With a combination of magnetic and optical sensors, a map of the structure of the vessel can be built, stored and recalled to allow navigation over the hull surface. The robotic platform can complete its tasks whilst in port, at anchor or in dry-dock.

It is clear from research performed across the world, especially in the USA and Europe, that regular hull cleaning improves the efficiency of a ship through the water, leading to decreased fuel consumption and overall sailing costs. For example a ship having an average hull roughness (AHR) of 400µm with a profile similar to sandpaper will require an increased power of 27% compared to a newly painted ship. However, if a ship has the same AHR but different distribution and undulating contours, it may only require a power increase of 7% [Jones, 2000]. Milne estimated that costs of $3billion were incurred by the global shipping fleet each year in dealing with fouling, including $720million in increased fuel consumption and $409milion due to shipping delays [Townsin, 2003].

In 1998 the Kyoto Protocol on climate change set out to reduce greenhouse gas emission by 5% of 1990 levels by 2012 and the EU community and most nation states around the world signed up to this. The commitment of the EU to implement global greenhouse gas emission reductions, as laid out in the Kyoto Protocol, saw the introduction of EC directive 96/61/EC (concerning integrated pollution prevention and control). In 2003 the EU passed directive (com(2002)595) on a *European strategy to reduce atmospheric emissions from seagoing ships.* This directive set out strategies for the reporting the magnitude and impact of emissions from ship's, setting out a number of action strategies aimed at reducing the contribution of NOx gas emissions to the atmosphere by shipping.

The study by Milne also showed that by burning less fuel, the greenhouse gas emissions could be reduce by about 10 million tonnes per annum, relating to 3.1-3.2 tonnes of CO_2 per tonne of fuel burnt and 7.36 million tonnes of other green house gases annually. In addition, over the last ten years there has been growing evidence that anti-fouling coatings applied to vessels, traditionally based on biocides such as TBT (tributinyl tin), can be deposited into water systems killing marine life.

The major potential impact of the HISMAR project is to make the EU shipping industries more competitive in the global shipping market, as savings in maintenance and running costs are made by regular cleaning. Greater efficiency of the vessels will contribute to the reduction of greenhouse gas emissions aiding in the EU's compliance to the Kyoto agreement and reduce the use of natural resources (fuel) making them more sustainable.

Dry-dock cleaning and surveying of the hull can take several weeks and is very labour intensive. The shipping industry is thus reluctant to put the vessel in for a dry-dock service until it is completely necessary, approximately every 5 years for new vessels and 2.5 years for vessels over 12 years in service. Cleaning and surveying with the HISMAR system can be performed more regularly while the ship is in port or at anchor. Surveying the vessel while it is being cleaned would provide regular information on the state of the hull recognising changes to the hull over time due to accidental damage or corrosion and this information would be made available, making dry-dock maintenance more efficient and reducing the time that the vessel spends out of service. By providing ship operators with a product which can avoid unnecessary and expensive dry-dockings (both the cost of dry-docking itself and lost revenue whilst the vessel is inactive) or alternatively allow well planned dry-docking operations, the project would have a very positive impact on the competitiveness of ship operators.

Any savings in fuel costs or more efficient dry-dockings would be beneficial to the European Merchant shipping fleet making them more competitive in the world market and extending the sustainability of the vessel's working life through regular hull maintenance.

The HISMAR project has the potential to impact employment in the areas of manufacturing, marine servicing and construction industries. In the servicing industry, the HISMAR system will not be seen to affect the dry-dock maintenance industry a great deal, as regular dry-docking is still necessary for the vessel to gain sea worthiness certification. Cleaning and surveying of the ship's hull will still be performed, although less frequently and/or more efficiently, enabling better use of the maintenance time and workforce for other repairs. The main impact is seen in the underwater cleaning industry, traditionally employing divers and support crew, but this effect is limited as many harbour authorities are banning or limiting these ship maintenance practices due to their environmental impact on harbours and waterways. The underwater hull maintenance industry can employ the HISMAR system, retraining most of its staff in the safe operation of the cleaning and surveying robot, reducing its impact for this industry.

Jobs will be created in the electronic and robotic industries, in the manufacture of the HISMAR robotic platform and specifically designed 'plug-in' modules. These are not seen as one-off products, but have the potential to be a mass produced item.

From the response to dissemination activities of associated marine and technology development industries, it is clear that there is a desire and demand for a commercial version of the HISMAR hull cleaning robot. The novel aspect of a commercially available autonomous hull cleaning and inspection robot would have an impact on the marine maintenance industry. Since the banning of TBT, there has been a major desire from the marine industry to extend dry-docking periods from every 5 years up to 10 years. This has been facilitated by the development of longer lasting hull coatings, such as hard coatings like EcoSpeed, and the development of new underwater robotic hull inspection systems. However, the new generation of hull coatings will require regular cleaning to maintain their performance. A commercially available version of the HISMAR robot would be ideally placed to exploit any changes in legislation and/or maintenance strategies.

2 Dissemination and Use: Final Plan for Using and Disseminating the Knowledge

2.1 Exploitable Knowledge and its Use

Overview Table

Exploitable Knowledge	Exploitable product or measure	Sectors of application	Timetable for commercial use	Patents or other IPR protection	Owner and other partners involved
Optical Dead Reckoning Sensory System (ODRS)	As part of a navigation tool for robotic or mobile systems	Any industrial robotic application, particular applicable to shipping, oil and chemical industries	2011	National (UK), European, Singapore and United Arad Emirates Patent Applications	UNEW & RTN
Method of 2D Mapping Surface & Subsurface Features of Large Steel Structures	Navigation and inspect tool for robotic or mobile systems for large steel structures	Applicable to shipping, oil and petrol chemical industries	2011	National (UK), European, Singapore and United Arad Emirates Patent Applications	UNEW, STK, GT & RTN
Method of Autonomous Robotic Navigation of Large Steel Structures	Navigation and inspect tool for robotic or mobile systems for large steel structures	Applicable to shipping, oil and petrol chemical industries	2011	National (UK), European, Singapore and United Arad Emirates Patent Applications	UNEW, STK, GT & RTN
An Autonomous General Maintenance Robot for Large Steel Structures	A series of maintenance robots for large steel structures or standalone unit.	Any industrial robotic application, particular applicable to shipping, oil and chemical industries	2012	N/A	UNEW, STK, GT, RB, TV and RTN
A Device for the Cleaning & Waste Extraction System for Maintaining Large Steel Structures	As part of a series of cleaning robots or devises.	Any industrial robotic application, particular applicable to shipping, oil and chemical industries	2012	N/A	UNEW, TV and RTN
A Dedicated Robotic Maintenance System for the Cleaning & Inspection of Ships' Hulls	A series of maintenance robots for large steel structures or standalone unit.	Applicable to shipping, oil and petrol chemical industries	2012	N/A	UNEW, STK, GT, RB, TV and RTN

2.2 Dissemination of Knowledge

Overview Table

Date	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
Feb 06	Project website	General public	Worldwide	--	UNEW
Sept 06	Visit to Shipbuilding Machinery and Marine Technology International Trade Fair Hamburg	Suppliers and users of equipment associated with the shipping industry	Worldwide	1600 exhibitors and 45000 visitors	TEPAC
Nov 06	Ship Repair and Conversion Event, Amsterdam	Suppliers and clients associated with ship repair or conversion activities	Worldwide	800 exhibitors	TEPAC
Nov 06	German Standards Association	Working group 'Environmental Aspects in Shipping Industry'	Germany	30	TEPAC
2007	Development of marketing working group within HISMAR project	Internal group	--	--	TEPAC to establish. Include number of partners
June 07	Subsea North East Event Newcastle, UK	Suppliers and clients in the subsea market	UK	150 attendees	UNEW
Oct 07	Port Authority Bremen		Germany	--	TEPAC
Oct 07	Gauss: Society for applied Environmental Protection and Safety in Sea Traffics	Experts	Germany	--	TEPAC
Oct 07	Port Authority Hamburg		Germany	--	TEPAC
Nov 07	INSTI innovation Consulting Network	Innovation experts	Germany	--	TEPAC
April 08	Extreme Robotics	Robotics experts	Russia		Stankin
Sept 08	SMM 23rd Shipbuilding, Machinery and Marine Technology Trade Fair Hamburg	Suppliers and users of equipment associated with the shipping industry	Germany	45000 visitors	TEPAC SSA UNEW PRS
Sept 08	HISMAR News Report Number 2	General public and industry	Any	--	TEPAC
Sept 08	General Flyer	General public and industry	Any	--	UNEW / TEPAC
Sept 08	Animation DVD	General public and industry	Any	--	UNEW
Entire duration	Project Website	All	Any	2337 page loads in 2008	UNEW
Sept 08	Press Release	Industry and general public	Any	--	UNEW
Sept 08 – April 09	Articles in newspapers or magazines	Trade specific and general public	Any	--	UNEW
Sept 08 – April 09	Radio interviews	General public	New Zealand and Sweden	--	UNEW
Dec 08	Academic paper in Sensors & Actuators Journal	Specialist audience interested in robotic development	Any	worldwide	UNEW & RTN

Date	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
Submitted	Academic paper in Journal of Engineering for the Marine Environment	Specialist marine audience	Any	worldwide	UNEW & RTN
To be submitted	Academic paper in Polish Hyperbaric Research	Specialist marine audience	Any	--	PRS

Project Website: The project website was set up in early 2006. It was set up and is managed by the project team at UNEW. The website has general information on the project which is accessible to the general public and has generated enquiries from different sources. The website also includes a password protected area which is accessible to project partners only. Deliverable reports and other confidential information are hosted in this protected part of the website. In 2008 the website experienced 873 unique visitors and 2337 page loads.

Visits to trade fairs/exhibitions: For further exploration of the existing competition and to disseminate information about the project, visits to different fairs and conferences took place. 50 exhibitors were contacted during the international fair in Hamburg in September 06 and 30 exhibitors were contacted during the 'Ship Repair Ex' in Amsterdam in November 06. Following the exhibitions, closer contacts have been established with different companies including ECOSPEED/SUBSEA Industries (Belgium), German Standards Association (Germany), port authorities across Europe and Lloyds Maritime Intelligence Unit (UK). TEPAC also met with Lloyds Register of Shipping during this period. Several conference/events were attended in 2008 but the key event for the project was the 23rd SMM Trade Fair in Hamburg which has thousands of visitors associated with the marine industry. The HISMAR project had a joint stand with SSA, discussed the project with interested parties and showed it's animation DVD during the fair. Personnel attended from UNEW, SSA and TEPAC.

Marketing Working Group: The development of a marketing working group was established. The group has prepared a strategy and discussed the development of a marketable product. TEPAC has coordinated this work by organising a constant flux of information and discussion among the group by e-mail, internet and phone/skype.

Trademarking: Following careful research it was identified that it was not appropriate to trademark the name HISMAR.

Publicity Material: A range of publicity material was produced during the project, along with a general press release and publication of academic journal papers during the last period of the project.

1. An animation DVD was developed at UNEW and is available on the website at http://hismar.ncl.ac.uk/publicdoc.htm It provides an overview of the project, partners and the technology.

2. A press release was issued on behalf of the consortium by Newcastle University on 17 September 2008. The content of the press release can be found at : http://www.ncl.ac.uk/press.office/press.release/item/robotic-vacuum-offers-shipping-industry-a-cleaner-solution1

3. As a result of this press release, articles have been published in a number of key trade and general publications including Lloyd's List, Tanker Operator, TryEngineering Today, Ship Repair and Conversion Technology Magazine. In

addition, radio interviews have been given with radio stations in New Zealand and Sweden.

To date three scientific journal paper has been produced relating to the activities of the HISMAR project.

Sensor and Actuators Journal (Elsevier Press) ***"Investigation into the effects of illumination and acceleration on optical mouse sensors as contact free 2D measurement".*** Authors: N. Tunwattana (RTN), A. Roskilly (UNEW) and R. Norman (UNEW). Sensors and Actuators A: Physical, 149 (2009), pp.87-92.

Proceedings of the Institution of Mechanical Engineers, Part M, Journal of Engineering for the Maritime Environment ***"Design of an underwater positioning sensor for crawling ship hull maintenance robots"*** Authors: N. Tunwattana (RTN), R. Norman (UNEW), A. Roskilly (UNEW). submitted for publication

Polish Hyperbaric Research (ISSN 1734-7009, www.phr.net.pl) Paper for publication titled ***"Application of the remotely controlled crawling devices for underwater cleaning and inspection of ship hulls"*** – Author M. Narewski (PRS) – to be submitted for publication

Other papers have been planned, with a number currently being edited for submission for publication in relevant technical and scientific journals.

2.3 Publishable Results.

2.3.1 Exploitable Result: Optical Dead Reckoning Sensory System (ODRS)

Result description: The principal aim of the Optical Dead Reckoning System (ODRS) provides up to date information on position, speed and orientation to the central processor of the HISMAR robot. The ODRS is also used to detect slippage of the robot from the intended direction of travel. Wheeled robots traditionally use wheel or motor shaft encoders to provide position information, however, these arrangements are prone to inaccuracy in the event of wheel slippage or sideways slippage.

Possible market applications: The ODRS has been primarily developed for the robotics market. The ODRS has been developed to be used on robots or mobile systems where conventional motion tracking systems are not applicable, due to environmental and operational conditions.

Stage of development: A functioning prototype system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the ODRS to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have shown an interest in the further development of the ODRS. This includes a number of industrial manufacturers of robotic technology. The HISMAR consortium is seeking an industrial partner who would provide the infrastructure and the knowledge to take to market and aid in the manufacturing of a commercial version of ODRS.

Patent pending

2.3.2 Exploitable Result: Method of 2D Mapping Surface & Subsurface Features of Large Steel Structures

Result description: Within the any large steel structure there are a number of fixed features, such as internal structures and surface welds, which can be used to identify the location of an object on the surface, with respect to a given origin. These features are identified and used as landmarks by which the robotic platform can navigate a given maintenance path. To record the location of these landmarks as specific points on the hull, an accurate measurement of the distance travelled by the robot from a fixed starting point was required.

The data gathered during the mapping operation, is then used in combination with basic information on the large steel structure, such as position of obstacles and dimensions, to create a map for later use. The map shows the detect features, operational boundaries and obstacles in the maintenance area. The map will be updated on subsequent operations as new features are detected over time.

Possible market applications: The mapping system has been primarily developed for the robotics market. The mapping system has been developed to be used on robots or mobile systems to map features to aid navigation or to monitor changes of the large steel structures.

Stage of development: A functioning prototype system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the mapping system to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have been interest in the further development of the HISMAR robot. This includes a number of marine service companies, ship builders and industrial manufacturers of robotic technology.

Patent pending

2.3.3 Exploitable Result: Method of Autonomous Robotic Navigation of Large Steel Structures

Result description: The navigation of a robotic platform around a large steel structure was carried out in two stages, (1) the mapping of the hull and (2) retracing the maintenance path. Mapping of the hull involves an operator remotely guiding the robot through a given path on the large steel structure. The primary navigation sensors will create a virtual map of the robots path through the detection of landmarks, monitoring its motion and accurately measuring the distance travelled.

Possible market applications: The navigation system has been primarily developed for the robotics market. The navigation system has been developed to be used on autonomous robotic or mobile systems where conventional motion tracking systems are not applicable, due to environmental and operational conditions.

Stage of development: A functioning prototype system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the navigation system to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have been interest in the further development of the prototype navigation system. This includes a number of marine service companies, ship builders and industrial manufacturers of robotic technology.

Patent pending

2.3.4 Exploitable Result: An Autonomous General Maintenance Robot for Large Steel Structures

Result description: The central HISMAR robotic platform houses the drive, navigation, attachment and control systems. The central HISMAR robotic platform was designed as independent unit, segmenting the robot into separate drive/navigation and tooling modules. Tooling modules can be attached to the front and/or back of the drive unit by a single flexible joint, building greater flexibility into the robot's design. Different tooling modules can be developed and used onboard the central robotic platform to perform a range of maintenance tasks.

Possible market applications: This prototype has been developed primarily for the marine industry, to be used to clean and inspect a ship's hull. However, with some minor modification it is believed that this product, once commercialised could be used by the petrochemical, chemical and nuclear industries for the maintenance of large steel structures.

Stage of development: A functioning prototype robotic system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the generic autonomous robotic system to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have been interest in the further development of the HISMAR robot. This includes a large shipping company, a number of marine service companies, ship builders and industrial manufacturers of robotic technology.

2.3.5 Exploitable Result: A Device for the Cleaning & Waste Extraction System for Maintaining Large Steel Structures

Result description: In the design of an effective and efficient cleaning system, it was important to clarify the desired cleaning process. In the case of HISMAR, the robot is required to remove the fouling while causing minimal damage to coating layers. This is not only to maintain the expected working life of the coating, but to prevent the possible introduction of paint particles into the water.

Possible market applications: This prototype has been developed primarily for the marine industry, to be used to clean and inspect a ship's hull. However, with some minor modification it is believed that this product, once commercialised could be used by the petrochemical, chemical and nuclear industries for the maintenance of large steel structures.

Stage of development: A functioning prototype robotic system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the cleaning and extraction system to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have been interest in the further development of the HISMAR robot. This includes a large shipping company, a number of marine service companies, ship builders and industrial manufacturers of robotic technology.

2.3.6 Exploitable Result: A Dedicated Robotic Maintenance System for the Cleaning & Inspection of Ships' Hulls

Result description: HISMAR offers a fully automated self-navigating, multi-functional underwater hull maintenance robot with the primary objectives of structural inspection and cleaning of marine vessels. The robotic platform was equipped with an innovative navigational system that will be cost effective compared to existing systems. The robotic platform was designed for easy and quick deployment/recovery for speedy and efficient operation of its duties during normal loading or unloading schedules. HISMAR is a unique self-navigating robotic platform that will work in and out of the water.

Possible market applications: This prototype has been developed primarily for the marine industry, to be used to clean and inspect a ship's hull. However, with some minor modification it is believed that this product, once commercialised could be used by the petrochemical, chemical and nuclear industries for the maintenance of large steel structures.

Stage of development: A functioning prototype robotic system.

Collaboration sought or offered: The HISMAR consortium have been and are seeking further financial support from a number of industrial, private, local and government funding bodies. One model being explored is, in return for financial assistance in the development of the HISMAR robot to a commercial level, equity in the rights to knowledge or exclusivity to technology will be allocated depending on the level of financial assistance given.

Collaborator details: During and after the HISMAR project was complete a number of interested marine, industrial and governmental bodies from around the world have been interest in the further development of the HISMAR robot. This includes a large shipping company, a number of marine service companies, ship builders and industrial manufacturers of robotic technology.

3 Future of HISMAR – Plans for Commercialisation

During the last year of the HISMAR project greater emphasis was give to the dissemination of information to the broader marine industry and interested bodies. This initially used the tools described in the previous chapter to promote the idea and cultivate interest in the HISMAR project. The interest generated in the HISMAR project was surprisingly high, especially after the promotional activities of attending the SMM maritime fair 2008, the general press release and the creation of a promotional video in the latter part of 2008.

The majority of inquiries about the HISMAR project were from marine related organisation looking for either greater information on the HISMAR robot and the availability of a commercial version or interest in collaboration in further development of the prototype to create a commercial version of the robot. In light of this interest it was decided that greater effort and emphasis would be placed on cultivating potential funding opportunities for the future development of the HISMAR robot.

This involved the following steps:-

- Seeking future funding opportunities for the future development of the HISMAR robot
- Creating renewed interest through further and future dissemination of information about the HISMAR robot
- Continued development and testing to refine the prototype HISMAR robot
- Cultivation of and seeking new industrial and other interested contacts
- Development of a business and future development plan for the HISMAR robot

3.1 Seeking Future Funding Opportunities

There are several avenues of funding that the HISMAR group plan to approach for future development funding of the robot. Among these are European, national and region funding bodies that could support additional development and the establishment of a company to exploit the knowledge of the HISMAR group associated with the robot. Plans are in place to exploring what aid these funding bodies can provide for the development and exploitation of the HISMAR robot and the knowledge gained during this project. Some of these bodies have already been approached by members of the consortium on a regional, national and European level, to explore the opportunity of and investigate the requirements for future funding.

Another avenue of future funding to explore is private or commercial investment from interested groups or companies. This would involve the creation of a company with a comprehensive business plan for the future exploitation of the HISMAR project's technology. Discussions and meetings with interested organisations and companies have been arranged to promote the idea of collaboration and investment in the future developments and exploitation of the HISMAR robot concept. Great interest was generated in these meeting with the hope of future collaboration once a solid business plan has been developed.

3.2 Future Dissemination & Cultivations of Industrial Contacts

It was realised that the success of the commercial exploitation of the HISMAR robot and technology would depend on providing relevant information, which would spark the interest of the marine industry and potential investors. Early dissemination and promotion activities created a great deal of interest in the HISMAR project.

These activities are continuing with further dissemination of development and test results and the promotion of the HISMAR robot at relevant trade fairs, meeting with interested organisations, regular updating of the HISMAR website, general press releases and technical paper publications planned. This is seen as important to maintain existing and cultivate new interest in the progress of the HISMAR robot. However, this will depend on further development and testing of the prototype HISMAR robot beyond the end of this project.

3.3 Further Development & Testing

Although many technical questions have been answered and a number of technical developments have been made during the building of the prototype HISMAR robot further development is required to take the knowledge gained during the project to a commercial level. Plans are already being implemented at UNEW, with support from some of the other consortium members, to improve the performance of the working prototype and to carry out further testing. This is seen as an important step in the promotion of the HISMAR robot as a commercial product. It is also seen as necessary in the collection of information and test results for dissemination purposes. The extent and range of the testing and modifications that can be made will depend on the success of acquiring further funding, as the amount of time that can be spent in further development and testing is dependent on the resources available. This would include:-

- Improvement in reliability of the sensory systems
- Development of a waste water treatment system
- Development of a HISMAR launch and recovery system
- Extensive testing of the robot on different coatings
- Further testing of HISMAR on ships, in and out of the water.

If enough funding could be secured, a second HISMAR robot would be built and tested. This would build on the lessons learnt during the project to create a commercially viable version of the robot.

3.4 Business Plan

As part of Task 8.3 a business plan was developed to aid in the commercialisation of the HISMAR robot, as reported in Deliverable 8.3. Part of this plan involves the establishment of a company to promote and exploit the HISMAR robot and the associated technology developments.

This plan will be developed by UNEW with the help of other consortium members, who wished to be involved in the further development and exploitation of the HISMAR robot concept. It is hoped that this business plan will be completed by the end of July in order to then exploit future funding opportunities.

References

Jones, D.F. (2000), *The Impact of Underwater Ship's Husbandry on the Marine Environment,* ENSUS 2000: 1st International Conference Marine Science & Technology for Environmental Sustainability, pp.96-102

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Annex

Annex A: Press Release Issued by UNEW, 17th Sept. 2008

Robotic 'vacuum' offers shipping industry a cleaner solution

Designed to reduce the carbon footprint of the world's shipping industry, the robot offers a solution to spiralling fuel costs and marine related pollution while removing harmful, non-indigenous species that could be transferred to local waters.

Operating in a similar way to the automatic carpet cleaner, the robot has been developed out of an EU-funded project called HISMAR (Hull Identification System for Marine Autonomous Robotics) and is able to navigate its own way across the ship's hull.

First a map of the hull is automatically charted, recording the location of every weld, thickness change, rivet and indentation on the ship's surface.

The robot is magnetically attached to the ship's side and sent off on its journey of the hull, following a planned route and cleaning as it goes.

Adjustable jets of pressurised sea water blast the marine growth off the surface of the ship which is then sucked up into the main chamber. Here, 150 litres of water a minute is filtered and the bio-fouling removed and rendered harmless to the local environment.

In this way, the ship's robotic 'vacuum' can continuously roam the ship's hull, preventing the build up of slime and allowing it to travel through the water efficiently by cutting down on drag.

This significantly reduces fuel consumption and also pollution such as the greenhouse gas carbon dioxide.

Newcastle University's Professor Tony Roskilly, leading the project, said: 'Marine growth on ships is a huge environmental and financial problem for the marine industry and HISMAR offers a unique solution to both of these – and more.

'What we have created is a system that works totally independently – in or out of the water – and not only keeps the ship clean but also feeds back vital information about the hull's condition.

'Because the map it follows is so detailed, if there is a change to its path caused by corrosion or a crack in the steel then it feeds this information back. This means it can be used as an additional check on the seaworthiness of the ship's hull or highlight potential future problems.

'And because the drive module and navigational system are separate to the cleaning tools we hope that ultimately we will be able to fit it with different tools to carry out different tasks – such as stripping and painting the hull.

Led by Newcastle University, the international team of experts will present a prototype of the robot at the largest marine maintenance fair in the world - Shipbuilding, Machinery and Marine Technology in Hamburg - on September 23rd.

Until the beginning of this year, ships used antifouling paints to protect them from the corrosive environment, with Tributyltin (TBT) added as a biocide to also prevent marine growth.

However, it was found to contaminate the surrounding water – having a serious detrimental impact on other marine life - and this summer it became illegal worldwide to use TBT antifouling coatings.

Newcastle University’s Jonathan Heslop, a researcher on the project, explains: 'All other developed cleaning or inspection systems currently available are remotely controlled during their operation, requiring highly skilled and experienced operators to effectively clean the hull, while the ship is out of operation and usually out of the water.

'The advantage of the HISMAR robot is that it is an autonomous system so it can continue cleaning with the ship remaining in service – feeding back hull information as it does so – resulting in very little build up of slime, reduced fuel costs and much less pollution.'

The HISMAR robot uses a novel optical dead-reckoning system in conjunction with a magnetic system to identify the location of surface and sub-surface features to build up a detailed map of the ship’s hull. It is this navigation system which allows the robot to operate above and below the waterline whilst the ship is in port or at anchor.