Research into the effects of fatigue on the cognitive performance of maritime watch-keepers under different watch patterns, using ship's bridge, engine and liquid cargo handling simulators.

Publishable Summary of the Final Report - for the Period 1st June 2009 to 31st January, 2012

Project Number	FP7 234000
Project Acronym	HORIZON
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HORIZON Consortium

		Short name
1	Southampton Solent University - Warsash maritime Academy (Co-ordinator)	WMA
2	Bureau Veritas - Marine Division, Research Dept	BV
3	Chalmers Tekniska Hoegskola AB, Dept of Shipping & Marine Technology	Chalmers
5	European Transport workers Federation - Nautilus UK	ETFN
6	Stockholms Universitet (Stress Research Institute)	SU
7	Charles Taylor & Co - P&I Club	CTPI
8	European Community Shipowners Associations	ECSA
9	European Harbour Masters Committee	EHMC
10	International Association of Independent Tanker Owners - INTERTANKO	INTKO
11	Marine Accident Investigation Branch	MAIB
12	Maritime & Coast Guard Agency	MCA

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4.1 PUBLISHABLE SUMMARY of Final Report (as separately submitted online)

This comprises five parts:

Part I - Executive Summary

HORIZON was conceived to apply science to the serious issues of seafarer fatigue, hitherto much reported but mostly anecdotally. The majority of maritime casualties were due to human error and the great majority of those are attributed to fatigue or sleepiness. The impact of those casualties is felt worldwide, as human, economic or environmental losses. HORIZON set out to research and quantify the causes of fatigue; how it is experienced and observed; and what may be done to avoid or mitigate it.

The Consortium consisted of a core set of 5 research partners and 6 stakeholder partners, representing a range of shipping interests: ship owners, harbour masters, insurers, national regulator and national accident investigation body. The core partners comprised 2 universities engaged in seafarer training, a university expert in stress and sleep issues, a classification society and a ships' officers union. The project ran for 32 months ending in Jan. 2012 and was part funded under FP7.

The project was designed to use real-life seafarers, facing highly realistic seagoing demands but using ships' simulators where every aspect of the research was controlled and no real damage was done. The chosen scenario was for voyages of a coastal tanker, operating in a short sea service in the English Channel/ North Sea, involving port visits for loading/ unloading. The simulators included Bridge, Engine Room and Liquid Cargo control operations. The voyages would be precisely scripted and managed by simulator staff, so that predetermined levels of stress, challenge or disturbance would realistically be encountered and would be measurably comparable in their results. Ninety seafarers, in cells of 10 for statistical robustness, were recruited as if they were going to sea with suitable skills for their roles and were required to be healthy, to ensure valid results. They were volunteers and were properly briefed, prepared and supported but not given any clues as to the realistic challenges the voyages would pose; they were randomly selected for their watches. At times they were wired up to EEG machines for 24 hours and at the start and end of each watch, undertook alertness tests and completed work, wake and sleep logs.

The seafarers served for 7 days continuously on watches of either 4hours on/ 8 off, or 6on/ 6off and lived a shipboard life, were monitored assessed and tested throughout the periods. Other factors were also controlled (limited caffeine and no alcohol); food was provided so diet was managed. The anonymous results were passed to sleep research experts and were analysed for professional competence by the maritime universities. Vast arrays of data were accumulated and provided not only substantial resources for analysis, within HORIZON, but also for future use, beyond.

All the research was completed satisfactorily from the viewpoint of the seafarers, staff and even the equipment, never before used continuously. The last project phase saw the climax of the dissemination activity, resulting in high levels of public awareness and expectation. The outcome was a fatigue management toolkit, comprising briefing material for all users: seafarers; ship operators; national flag regulators; maritime services providers; educators, technologists and researchers. In addition prototype fatigue prediction software was developed and made publically available. All user categories will exploit the research in some way, as will all consortium partners.

The results have been well received; with special attention being called for: risks in passages through difficult waters in combination with the 6/6 watch system; night watches; the last portion of most watches; watches after reduced sleep opportunity; individual susceptibility to fatigue also needs to be considered. Essentially, the quality of sleep is vital giving rise to the focus on sleep hygiene. The fatigue prediction software is already being trialled at sea, following the completion of the project.

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Part II. Summary Description of the Project Context and Objectives

Project HORIZON is a major multi-partner European research study that brought together 11 academic institutions and shipping industry organisations with the agreed aim of delivering empirical data to provide a better understanding of the way in which watchkeeping patterns can affect ships' watchkeepers. The broad spread of the project partners ensured expert objectivity of the project and its results, as well as widening routes for dissemination and exploitation of the findings. The project was established to:

- define and undertake scientific methods for measurement of fatigue in various realistic seagoing scenarios using bridge, engineroom and cargo simulators
- capture empirical data on the cognitive performance of watchkeepers working within those realistic scenarios
- assess the impact of fatigue on decision-making performance
- and determine arrangements for minimising risks to ships and their cargoes, seafarers, passengers and the marine environment

At the heart of the project was the extensive use of ship simulators in Sweden and the UK to examine the decision-making and cognitive performance of officers during a range of real-life, real-time scenarios of voyage, workload and interruptions. A total of 90 experienced deck and engineer officer volunteers participated in rigorous tests at Chalmers University of Technology in Göteberg, and at Warsash Maritime Academy (WMA) at Southampton Solent University to measure their performance during seagoing and port-based operations on bridge, engine and liquid cargo handling simulators.

The project sought to take understanding of the issues to a new level with specialist input from some world-leading transport and stress research experts. Academic experts at WMA, Chalmers with input from the Stress Research Institute at Stockholm University (SU), devised the simulator runs, setting the requirements for fatigue measurement and determining performance degradation measures for watchkeepers, and SU analysed the results from the week-long programmes. In response to the research findings, the Project HORIZON partners have developed a fatigue management toolkit for the industry, which seeks to provide guidance to owners, operators, maritime regulators and seafarers to assist them in organising work patterns at sea in the safest and healthiest way possible.

Shipping is the ultimate 24/7 industry - inherently globalised in its nature, the industry is complex, capital-intensive, increasingly technologically sophisticated and of immense economic and environmental significance. More than 80% of world trade moves by sea, almost 90% of EU external freight trade is seaborne, and some 40% of intra-EU freight is carried by shortsea shipping, with increasing demand to alleviate transport congestion ashore. Around 40% of the world fleet is beneficially controlled in the EEA and EU-registered tonnage accounts for more than 20% of the world total. An average of around four million passengers embark and disembark in EU27 ports every year – the vast majority being carried by ferries (which operate under the conditions replicated within HORIZON).

The increasingly intensive nature of shipping operations means that seafarers frequently work long and irregular hours. Under the International Labour Organisation (ILO) regulations (social provisions), it is permissible for seafarers to work up to 91 hours a week – and, under the International Maritime Organisation's STCW 2010 amendments (safety provisions), a 98-hour working week is allowed for up to two weeks in 'exceptional' circumstances. Noise, vibration, sailing patterns, port calls, cargo handling and other activities can all reduce the ability of the seafarer to gain quality sleep during rest periods.

Fatigue is generally understood to be a state of acute mental and/or physical tiredness, in which there is a progressive decline in performance and alertness. The term is often used interchangeably with 'sleepiness', 'tiredness' and 'drowsiness'. Fatigue is often considered to be a generic term, of which sleepiness is one of the major sub-components. In this project, the emphasis has been placed upon 'sleepiness' as the most effective description of the physical and physiological conditions under examination.

Seafarers are already usually covered by rules (company, sector-specific, flag state or IMO: which prohibit or severely restrict alcohol use at sea. However, studies have shown that around the effect of 22 hours of wakefulness will impair an individual's performance, to the same extent as a blood-alcohol concentration of 0.10% -- double the legal driving limit in most EU member states. Laboratory research and studies in other transport modes have demonstrated that severe sleepiness (and even sleep onset) and performance deterioration are common amongst workers undertaking night shifts. Fatigue is also an important health issue, with significant evidence to show the way in which long-term sleep loss can be a health risk factor, in such conditions as obesity, cardiovascular disease and diabetes.

The issue is also one of great relevance to the recruitment and retention of skilled and experienced seafarers. Reducing excessive working hours is of critical importance in delivering working conditions for maritime professionals that reflect the increasingly high levels of training and qualifications, required to operate modern-day merchant ships safely.

Factors which result in fatigue include:

- the lack of, or poor quality of, sleep,
- working at times of low alertness
- prolonged work periods
- insufficient rest between work periods
- excessive workloads
- noise, vibration, and motion
- medical conditions

The extent to which these factors bear upon the problem, has never been scientifically measured, before the existence of project HORIZON

The project was established in response to growing concern about such issues and the increased evidence of the role of fatigue in maritime accidents. The project, responding to the FP7 Sustainable Surface Transport 2008 RTD-1 call, aims to increase safety and security, and reduced fatalities, with attendant economic and environmental benefits.

Over the past 20 years, the maritime sector, generally, has become increasingly aware of the importance of the 'human factor' in safe shipping operations. Marine insurance statistics have shown 'human error' to be the key contributory factor in around 60% of accidents – with other research suggesting that the figure is as high as 80% to 90%, in the case of collisions and groundings. Such statistics have generated a growing impetus to investigate the nature of the human factors that may contribute to the causal chain in shipping accidents.

The increased complexity of ships' systems and the growing technological sophistication of onboard equipment, have placed greater emphasis on the performance of seafarers – and watchkeepers in particular. The marked increase in the size of passenger ships and cargo vessels has also highlighted the potential for substantial loss of life or pollution in the event of an accident. Extrapolation of UK Marine Accident Investigation Branch statistics on the role of seafarer fatigue in shipping accidents, between 1993 and 2003, suggests that significant economic savings could be made if the number of tiredness-related accidents is reduced.

As awareness of the importance of the human factor in shipping has grown, recognition of the role of fatigue in maritime safety has also increased. There have been a number of high-profile casualties - often costly and damaging - in which seafarer fatigue has been shown as a key causal factor. These include:

- the Exxon Valdez tanker disaster in 1989. the US National Transportation Safety Board found that in the 24 hours prior to the grounding of the ship, the watchkeeper had only had 5 or 6 hours of sleep;

- the grounding of the feeder containership Cita in the Isles of Scilly in March 1997, after the mate fell asleep - the ship sailed on, for two and a half hours, with no one in control;

- the grounding of the general cargoship Jambo in Scotland, in June 2003, after the chief officer fell asleep and missed an intended change of course;

- the grounding of the bulk carrier Pasha Bulker near the port of Newcastle in Australia in June 2007, in which an investigation report stated that 'the master became increasingly overloaded, and affected by fatigue and anxiety';

- the death of a Filipino AB, in a fall onboard the Danish-flagged general cargo ship Thor Gitta in May 2009. Investigators, who used FAID fatigue assessment software, found that the seafarer's 6-on/6-off work pattern was at a score of 111 on the morning before to the accident – a level considered to be in the very high range;

- the grounding of the bulk carrier Shen Neng 1 on the Great Barrier Reef in April 2010. The Australian Transport Safety Bureau investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue. Investigations showed that he had only two and a half hours sleep in the 38.5 hours prior to the casualty.

Concern about such incidents was also mirrored by a growing weight of evidence gathered from surveys among seafarers. It was generally accepted that fatigue at sea had been subjected to considerably less research than in other modes of transport or safety-critical industries, but from the 1980s onwards increasing academic attention was paid to working hours in the maritime sector – with a 1989 UK Medical Research Council report by Professor ID Brown, on hours of work, fatigue and safety at sea, serving as something of a watershed. In 1990, a report on shipboard crew fatigue, safety and reduced manning, by JK Pollard, ED Sussman and M Sterns noted that work at sea is characterised by longer working weeks, more non-standard work days, extensive night operations, and periods of intense effort, preceded by periods of relative inactivity.

In 1995, the UK National Union of Marine Aviation & Shipping Transport Officers (NUMAST - the fore-runner of Nautilus) published the result of a survey of 1,000 officers. Just over three-quarters of those surveyed said they believed that fatigue had increased significantly in the previous three to 10 years. In a further survey of 563 members, NUMAST found 50% reporting that they worked more than 85 hours a week. A 2006 report on one of the most extensive research projects, carried out by the Centre for Occupational and Health Psychology at Cardiff University, UK, found evidence that as many as one in four watchkeepers reported having fallen asleep on watch. As many as 53% of respondents reported having no opportunity to have six hours of uninterrupted sleep. A Swedish survey carried out in 2008 and 2010 showed that about 70% of officers had nodded off on watch one or more times during their career.

Another significant study was published by the UK Marine Accident Investigation Branch (MAIB) in 2004. This analysed the role of fatigue in 66 collisions, near-collisions, groundings and contacts investigated between 1989 and 1999. The study considered fatigue to be a contributory factor 82% of the groundings, which occurred between 0000 and 0600, and was also a major causal factor in the majority of collisions. This latter point was also highlighted in research published by the Karolinska Institute in Sweden in 2004, which found levels of sleepiness to be highest during the 00:00-06:00hrs watch period. In 2005, a report published by TNO in the Netherlands, recommended the setting up of a framework for the development of a fatigue management programme or tool to help shipping companies to take measures to manage fatigue.

Other seafarer fatigue studies have also highlighted such factors as:

- the long working hours experienced by many crew members
- problems in gaining quality sleep
- the impact of watchkeeping patterns: notably six hours-on/six hours-off
- stress and workloads
- frequent port calls and associated cargo work
- tour lengths

The anecdotal evidence was widespread and substantial but, as yet, unquantified or proven scientifically.

Against that background, Project HORIZON sought to address the marked concerns over the increasing human, financial and environmental impact of maritime accidents, which frequently cited fatigue as a contributory cause. It is an issue of critical importance, at a time when the high demand for shipping capacity has led to national and international shortages of well-qualified and experienced seafarers, further adding to maritime safety risks. The project was set up with a short set of clear Objectives:

1. Provide a realistic, high fidelity, voyage scenario in which watch-keeper cognitive performance can be measured.
2. Provide various watch-keeping patterns which will lead to fatigue in the watch-keeping officers;
3. Capture empirical data on the cognitive performance of the watch-keepers undertaking these watch-keeping patterns;
4. Analyse this empirical data to determine the effect of fatigue on the cognitive performance of the watch-keepers;
5. Develop a fatigue management toolkit for use by ship managers, maritime regulators, flag states, port states and the International Maritime Organisation;
6. Derive a set of recommendations that maritime regulators and ship managers can use to improve the safety and reliability of vessels.

All these objectives have been met in the project and its delivery of them led to progressively increasing interest in HORIZON amongst the commercial shipping world, not least due to the extensive promotional activity of the project website, press articles, information leaflets, media releases and briefings. Numerous visits by maritime VIPs took place to view simulation activity and those also added to wider awareness and anticipation of the project and its intended results.

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Part III. Description of the main S&T Results/ Foreground

This section covers HORIZON's S&T activity and achievements, together with the results, as foreground. It comprises the following content:

Foreword

This section presents the Science and Technology in the project that led to the findings of Project HORIZON – the research investigating the impact of watch keeping patterns on the cognitive performance of seafarers. This pioneering research sought to advance understanding of seafarer fatigue through scientific analysis of data drawn from realistic working scenarios using experienced watch keepers on ship simulators. The majority of the S&T was drawn form existing experience and established practice but which had never before been brought together in this way nor undertaken for such periods of time; to the scale undertaken; nor with such a rigorous approach to the experimentation and measurements made.

The project has taken knowledge in this area to a new level, demonstrating conclusively the links between performance degradation and certain patterns of work. The project surpasses previous subjective fatigue studies, delivering validated, scientifically and statistically robust results that can be used to help determine safer working patterns in the interests of the safety of life at sea, the safety and security of the marine transport system and the protection of the marine environment.

In response to the research findings, the Project HORIZON partners have developed a fatigue management toolkit for the industry, which seeks to provide guidance to owners, operators, maritime regulators and seafarers to assist them in organising work patterns at sea in the safest and healthiest way possible.

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Section II. RESEARCH BACKGROUND

Project HORIZON research has been based on very rigorous scientific principles, involving unprecedented and cutting-edge use of deck, engine and cargo handling simulators to create realistic seven-day simulated voyage scenarios for the volunteer officers.

The study was focussed upon two of the most common watch schedules used at sea: six hours on watch followed by six hours off (6/6) and four hours on followed by eight hours off (4/8). The 6/6 pattern is most common on smaller ships, often operating in short sea and coastal trades and often operating with just two officers onboard.

The simulator voyage plans were designed to ensure a high degree of authenticity, including variable workloads, port visits, mandatory reporting points, and passing traffic. The studies were carried out using the simulators at Warsash Maritime Academy in the UK and Chalmers Technical University in Sweden. At Warsash, the effects of the 6/6 schedule were observed for deck and engine watch keepers, whilst at Chalmers the tests examined the effects of 4/8 and 6/6 watches on deck watch keepers only.

A total of 90 officers were recruited to undertake the simulated voyages. All those taking part were appropriately qualified and experienced deck and engineer officers from west and east Europe, Africa and Asia. The mix of nationalities and gender (87 males and three women) provided a representative cross-section from the industry and all participants were required to be in good health, with no sleep disorders. The volunteers were recruited through advertisements and crewing agencies as if they were going to sea and during the tests they lived as close to a shipboard life as possible -- in institutionalstyle cabin accommodation at WMA and onboard an accommodation vessel at Chalmers. During the runs, there were a number of imposed restrictions and participants were allowed up to four cups of coffee a day, and no alcohol was permitted.

The test methodology was rigorous. Cameras tracked and recorded participants' every movement on watch, producing an enormous database of activity, while supervisors were able to observe remotely on CCTV monitors. Instructors were able to oversee the 'voyages', not only monitoring performance but also acting as 'masters' and 'chiefs' during handovers and in cases where intervention has been required to prevent an accident. The policy was one of minimal intervention, but instructors could not allow a collision, grounding or other major incident to occur as this would have prevented the completion of the exercise under experimentally controlled conditions.

The following data were collected:

- Actigraphy – participants wore the Actiwatch, a device that measures acceleration and enables physical activity and sleep duration to be calculated
- Electroencephalogam (EEG), electrooculogram (EOG), and electrocardiogram (ECG) – recordings of brain activity, eye movements and heart rates
- Psychomotor Vigilance Test (PVT) – performed, using standard hand-held equipment, before and after each watch. The test involved participants having to press a button to record when they see a target presented on a screen at random intervals. Each test lasted approximately five minutes and the reaction time, the number of lapses, and the mean reaction time were all recorded and stored on the device
- Karolinska Sleepiness Scale (KSS)
- Karolinska drowsiness test (KDT) – administered at the end of a watch, when participants' EEG measurements were taken as they were asked to stare at a black spot on a wall for five minutes and then to close their eyes for five minutes
- Stress scores
- Stroop Test – in which participants were sat at a laptop computer on which the names of two different colours (green and red) were shown on the screen. Participants had to click on the colour-name as quickly as possible, ignoring the meaning of the word displayed
- Evaluation of general watch keeping performance during navigation, engine room and cargo operations
- Evaluation of performance in "specific" repeatable events
- Demographic data (background questionnaire)
- Sleep and wake diary
- Ship's logbook
- Temperature in simulators and quarters
- Videos in all simulators
- Debriefing interview

Data on participants' alertness and sleepiness was amassed using both subjective and objective research methods. The subjective information was drawn from the three diaries participants were asked to keep: a sleep diary filled in on waking up; a work diary they completed during the watch; and a wake diary completed during the off-watch period. In the watch diary, participants indicated how they felt at various points on duty using the Karolinska Sleepiness Scale. This ranges from 1 for 'extremely alert' to 9 for 'very sleepy, great effort to keep awake, fighting sleep'. This was recorded every hour on watch and on the hour off-watch if the participant was still awake.

At the end of each watch, participants were also asked to record their food intake on watch, how well they thought they had performed and their perceptions of the workload. At two stages of the 'voyage', the participants wore 10 electrodes that measured their brain activity over two watch periods and two sleep periods. Data obtained enabled the research teams to analyse cognitive performance at key stages and to detect instances of 'microsleep'. Data recorded from the off-watch periods was especially valuable, as it enabled an objective picture to be obtained of exactly when participants fell asleep and the quality of the sleep they obtained.

Using simulators allowed the researchers to 're-set' the voyage at the end of each watch, so that the watchkeeper coming on duty repeated the section of the voyage just completed by the previous participant. As 'handovers' were conducted by staff members acting in the role of master or chief engineer, the participants were unaware that the voyage sections were being repeated in this manner. The standard test conditions and replicated situations enabled the researchers to make valid comparisons, under statistically robust conditions, monitoring the way in which the volunteer officers reacted and how their judgement and performance were affected at different times during the week.

Volunteers' performance was also checked by a wide range of indicators – with lecturers monitoring such things as their behaviour, body language and ability to pass on 10 standard items of information at each watch handover. During each bridge watch, participants were observed and rated by the simulator operators. The scoring system covered the general performance over the whole watch, the watch handovers, 'special' events – such as certain close-quarters situations -- and 'unplanned' events – such as unintentional 'near-misses' with other vessels. The evaluation of watch keeping performance was based on both expert rating (for example, how well the collision prevention regulations were followed) and objective scores (for example, the number and timing of positions marked on the chart).

Section III. RESEARCH FINDINGS

In presenting the research findings, variables that were measured once per watch were analysed using repeated measures analysis of variance (Anova) with day (1 to 7) and watch (first or second watch of the day) as 'within subject' factors and watch team (working 00:00 to 06:00 or working 06:00 to 12:00) as 'between subject' factors. Variables measured at the start and end of every watch (PVT) also included those timepoints as 'within subject' factors, and variables measured on an hourly basis (KSS and stress) included hours in watch as a 'within subject' factor.

For the Warsash runs, the analysis was carried out separately for the deck and the engineroom teams. For the Chalmers runs, analysis was carried out separately for the two watch systems (4-on/8-off and 6-on/6-off).

III.1 Karolinska Sleepiness Scale (KSS)

Sleepiness was rated every hour on the KSS self-rating scale, which has been validated against EEG measurements. The KSS scale varies from 1 to 9, with Score 1 representing highest alertness and Score being close to falling asleep. The KSS ratings are:

1. Extremely alert
2. Very alert
3. Alert
4. Rather alert
5. Neither alert nor sleepy
6. Some signs of sleepiness
7. Sleepy, but no effort to keep alert
8. Sleepy, some effort to keep alert
9. Very sleepy, great effort to keep alert, fighting sleep

- **Chalmers 4-on/8-off**

Sleepiness scores were found to differ significantly between the first and the second watch of the day. The difference was highest in the team working 04:00 to 08:00 (4.1 ± 0.3 versus 2.9 ± 0.3) and virtually absent in the team working 08:00 to 12:00 (3.8 ± 0.4 versus 3.7 ± 0.3).

Sleepiness was also found to peak at the end of the watch (4.1 ± 0.2), with the three-way interactions and the pattern of results indicating that maximum sleepiness is reached towards the end of the 00:00-00:04 watch, closely followed by the 04:00-08:00 watch. Lowest sleepiness scores occurred in the afternoon or early evening watches.

- **Chalmers 6-on/6-off**

Within subjects, sleepiness scores were found to be significantly higher during the first watch of the day than the second (4.6 ± 0.2 versus 4.0 ± 0.2). Sleepiness scores also differed based on the hours in watch - being lowest after one hour in watch (3.7 ± 0.2) and highest at the end of the watch (5.1 ± 0.3). A more complex three-way interaction between watch, hours in watch, and watch team was observed ($F(3.95, 51.40) = 10.88$, $p < 0.001$).

- **Effect of the Off-Watch Disturbance**

In both watch systems, the off-watch disturbance had a profound effect on sleepiness. In the 4-on/8-off system, sleepiness levels were higher during the watch following the disturbance (6.5 ± 0.3) compared with the control watch (4.2 ± 0.2) in the other half of the week. A similar pattern was observed in the 6-on/6-off system, with sleepiness levels being considerably higher following the off-watch disturbance (6.7 ± 0.4) than during the control watch (4.6 ± 0.3. No interactions were observed, indicating that the effect was similar in all watch teams. A higher rate of sleep on watch was discovered amongst participants who had experienced the disturbed off-watch period.

- **4-on/8 off versus 6-on/6-off**

Sleepiness levels differed between the two watch systems, being found to be higher in all watches and for all teams in the 6-on/6-off watch system (4.6 ± 0.2) than in the 4-on/8-off watch system (3.9 ± 0.2). Higher rates of sleep on watch were found in the 6/6 teams than in the 4/8 participants and sleep duration was found to be longer for those on 4/8 than in the 6/6 pattern.

- **Warsash Deck**

Within subjects, sleepiness scores differed significantly across the days of the week, being lowest on day 1 (3.1 ± 0.3) and highest on both days 5 and 6 (4.3 ± 0.4). Sleepiness scores were also found to be higher during the first watch of the day than the second (4.1 ± 0.3 versus 3.6 ± 0.3). Sleepiness scores also differed based on the hours in watch, ranging from 3.3 ± 0.3 at the start to 4.8 ± 0.3 after 5 hours in watch. Sleepiness levels were also shown to have increased during the course of the week. Daily sleep durations were found to total between 6 and 7 hours.

- **Warsash Engineroom**

Sleepiness scores differed significantly across the days of the week, being lowest on day 2 (3.5 ± 0.2) and highest on day 7 (4.3 ± 0.3). Scores were also found to be higher during the first watch of the day than in the second (4.2 ± 0.3 versus 3.5 ± 0.3). Sleepiness was found to increase during the watch period, with scores ranged from 3.3 ± 0.3 at the start to 4.5 ± 0.3 after 5 hours in watch. Sleepiness levels were also shown to increase during the course of the week.

- **Deck versus Engineroom**

Overall sleepiness ratings did not differ between the bridge and the engineroom.

- **Conclusions**

- overall, more sleepiness was recorded during the first watch of the day – especially among deck teams
- sleepiness was found to increase with time in watch
- the off-watch disturbance instantly increased sleepiness
- on the whole, sleepiness levels were higher in the 6-on/6-off system than in the 4-on/8-off system
- sleepiness levels did not significantly differ between deck and engineroom
- sleepiness levels consistently peaked between 0400 and 0800
- alertness levels consistently peaked between 1400 and 1800

III.2 Stress Scale

Stress was rated every hour on a 1 (very low stress – I feel very relaxed and calm) to 9 (very high stress – I feel very tense and under high pressure, on the limit to what I can manage).

- **Chalmers 4-on/8-off**

Stress levels remained fairly low under all circumstances

- **Chalmers 6 on 6 off**

Stress levels remained fairly low under all circumstances

- **Effect of the Off-Watch Disturbance**

In the 4-on/8-off system, stress levels were higher during the watch following the disturbance (3.7 ± 0.3) than in the control watch (2.8 ± 0.2) in the other half of the week. A similar effect was observed in the 6-on/6-off system, with higher stress levels following the disturbance (4.0 ± 0.5) than in the control watch (2.9 ± 0.2). An interaction with hours in watch was observed in the 6-on/6-off system. Following the off-watch disturbance, stress levels increased during the course of the watch, whereas such a trend was not observed during the control watch.

- **4-on/8-off versus 6-on/6-off**

Stress levels did not differ between the 2 watch systems though levels were higher in 6-on/6-off watch system (3.1 ± 0.2) than in 4-on/8-off system (2.7 ± 0.2).

- **Warsash Deck**

Stress scores were found to be higher during the first watch of the day than in the second (2.8 ± 0.2 versus 2.5 ± 0.2). Stress scores also differed based on the hours in watch, ranging from 2.1 ± 0.2 at the start of the watch to 3.1 ± 0.3 after 5 hours in watch. An interaction between day and watch was observed - indicating that the effect of watch was not identical across the days of the week.

- **Warsash Engineroom**

Within subjects, stress scores differed based on the hours in watch, ranging from 3.1 ± 0.3 at the start of the watch to 3.6 ± 0.3 after 2 hours in watch. In addition, an interaction between watch and hours in watch was observed, indicating that the effect of hours in watch was different for the two watches.

- **Bridge Versus Engineroom**

Stress ratings were higher in the engineroom than on the bridge.

- **Conclusions**

- Stress levels were found to vary, but the axis along which it varied differed between the watch systems and between deck and engineroom teams
- Overall, stress levels remained fairly low
- The disturbed off-watch period resulted in an immediate increase in stress levels
- Stress levels were higher in the engineroom than on the bridge
- Stress levels did not differ between the two watch systems

III.3 Wake diary

Participants were asked to provide ratings on a scale of 1 (not at all) to 5 (to a great extent) on whether they had experienced any irritability, tensions, worn-out feelings, exhaustion, anxiety, or persistent fatigue, and to rate their health and whether they had got enough rest and recuperation during the last period of wakefulness.

- **Chalmers 4-on/8-off**

No within or between subjects difference was observed in response to questions about feelings of irritability, being worn out, anxious, exhausted, or feeling persistently fatigued. However, more tensions were reported following the second watch of the day and rest and recuperation was reported to be less sufficient during this period.

- **Chalmers 6-on/6-off**

No within or between subjects difference was observed in response to questions about feelings of irritability, being tense, worn out, anxious, exhausted, feeling persistently fatigued, or on ratings of health during the last period of wakefulness.

However, a significant difference within subjects was observed in response to the question about gaining enough rest and recuperation during the last period of wakefulness – with rest and recuperation reported to be more sufficient during the time off period following the first watch of the day than the second (2.6 ± 0.2 versus 3.2 ± 0.2).

- **Effect of the Off-Watch Disturbance**

Scores on most wake diary parameters indicated a worse state following the off-watch disturbance. For example, the category 'exhausted' obtained a rating of 2.9±.3 after the disturbance vs 1.7±.2 after no disturbance for 6/6. The corresponding values for 4/8 were 1.8±.2 vs 1.2±.1. Both were highly significant, but those on the 6/6 pattern were more affected - presumably because they lost a six-hour free watch, while those on 4/8 'only' lost four hours. Similar effects and ratings were seen for the category 'worn out'.

- **4-on/8-off versus 6-on/6-off**

Two wake diary parameters differed significantly between the two watch systems. Worn out feelings were more substantial in the 6-on/6-off system (2.1 ± 0.2) than in the 4-on/8-off system. The sufficiency of rest and recuperation was reported to be higher in the 4-on/8-off system (2.3 ± 0.1) than in the 6-on/6-off system (3.2 ± 0.3).

- **Warsash Deck**

Wake diaries showed feelings of irritability, tensions, worn out, anxiety, self-rated health and sufficiency of rest and recuperation increased during the course of the week. Tensions were higher following the second watch when rest and recuperation was stated to be less sufficient compared to the first watch.

- **Warsash Engineroom**

No significant differences within or between subjects were observed in responses to questions about irritability, tension, exhaustion, anxiety, or self-ratings of health. But feelings of persistent fatigue and insufficient rest and recuperation increased during the course of the week – being shown to be more abundant during the second watch of the day than the first.

- **Deck Versus Engineroom**

Wake diary parameters did not differ between the bridge and the engine room.

- **Conclusions**

- Wake diary outcomes indicated better time off following the first watch of the day: rest and recuperation was rated as more efficient and less negative symptoms such as tensions occurred
- Outcomes got worse during the course of the week
- The disturbed free watch had adverse effects in both watch systems
- Overall, more negative wake diary outcomes were reported in the 6-on/6-off system than in the 4-on/8-off system
- No differences were observed between the bridge and the engineroom

III.4 Work Diary

Participants were asked whether they had experienced on a scale of 1 (not at all) to 5 (to a great extent): heavy eyelids; 'gravel eyes'; difficulties focussing; irresistible sleepiness; tired eyes; difficulties holding eyes open; impaired performance; effort to stay awake; and to rate difficulty in working; work performance; and workload; and whether they had nodded off during the watch.

- **Chalmers 4-on/8-off**

No within or between subjects differences were observed for the parameters of gravel eyed, difficulties focussing, irresistible sleepiness, impaired performance, effort to stay awake, work performance, and nodding off.

Responses showed that the experience of heavy eyelids differed across the days and between the first and the second watch of the day, while the experience of tired eyes was reported to be higher during the first watch. Within subjects, the experience of having difficulties holding the eyes open was reported as higher during the first watch. Within subjects, self-reported work difficulty and workloads differed across the days.

Overall, the work diary parameters indicated more sleepiness and fatigue during the first watch of the day than in the second.

- **Chalmers 6-on/6-off**

Within subjects, the experience of heavy eyelids, 'gravel eyes', difficulties focussing, irresistible sleepiness, tired eyes, difficulties holding the eyes open, was reported as higher during the first watch than the second. Self-reported nodding off was found to be higher during the first watch.

No within or between subjects difference were observed for the parameters of impaired performance, effort to stay awake, and self-rated work performance.

Within subjects, self-reported work difficulty differed across the days and was reported as being more difficult during the second watch of the day. Within subjects, self-reported workload differed across the days and a three way interaction between day, watch and watch team was observed, indicating that the effect of day was dependent on the watch of the day and that this dependency, in turn, is dependent on the watch team.

Overall, many of the work diary parameters indicated increased levels of sleepiness and fatigue during the first watch of the day compared with the second watch.

- **Effect of the Off-Watch Disturbance**

The effects of the off-watch disturbance compared to the control watch in the other half of the week were evident from a number of ratings. For example, the rating of 'heavy eyelids' was higher during the watch after the disturbed free watch: 2.9±.2 vs 1.8±.2 for 4/8 and 3.3±.3 vs 2.1±.2 for 6/6 - both highly significant. Similar results were seen for the rating 'impaired performance' (2.2±.2 vs 1.5±.1 for 4/8 and 2.9±.2 vs 1.8±.1 for 6/6) as well as 'nodding off' (2.1±.2 vs 1.3±.1 for 4/8 and 2.7±.3 vs 1.6±.1).

Similar variations were seen in the results for a number of other ratings of performance and fatigue. It was evident that using an off-watch period for activity rather than sleep caused major effects on perceived fatigue and performance.

Overall, the work diary parameters indicated increased sleepiness and fatigue following the free watch disturbance in both shift systems and in all watch teams.

- **4-on/8-off versus 6-on/6-off**

Several work diary parameters differed between the two watch systems. Heavy eyelids and gravel eyes were more abundant in the 6-on/6-off system than in the 4-on 8 off system. Participants working in the 6-on/6-off system had more difficulties focussing the eyes and reported a higher incidence of tired eyes. Difficulties holding the eyes open were also more abundant in those working 6-on/6-off and those working this system also reported having to put in more effort to stay awake than those working 4-on/8-off. Subjects in the 6-on/6-off system also nodded off more frequently.

- **Warsash Deck**

Both between and within subjects, the experience of heavy eyelids was reported as higher during the first watch. Between subjects, the watch team working from 00:00 to 06:00 reported more experiences of gravelled eyes than the second watch team. Difficulties focussing the eyes and experiences of near-irresistible sleepiness, tired eyes, difficulties holding the eyes open, impaired performance, effort to stay awake, self-reported work difficulty differed across the days, and were found to be higher during the first watch. More nodding-off was reported for the first watch than during the second watch.

Overall, most work diary parameters indicated increased levels of sleepiness and fatigue during the first watch of the day than in the second. Some parameters also indicated higher rates of sleepiness and fatigue in the team working the 00:00 to 06:00 system.

- **Warsash Engineroom**

Participants reported a higher rate of experiencing heavy eyelids, gravel eyes, difficulties focussing, irresistible sleepiness, tired eyes, difficulties holding the eyes open, impaired performance, and effort to stay awake during the first watch. Self-reported performance satisfaction levels were higher during the second watch and self-reported workload ratings were higher during the first watch. More nodding-off was reported for the first watch.

The work diary parameters indicated increased levels of sleepiness and fatigue during the first watch of the day as compared with the second. Sleepiness and fatigue symptoms also increased during the course of the week.

- **Deck Versus Engineroom**

Sleepiness and fatigue-related parameters of the work diary did not differ between the bridge and the engineroom, although work difficulty and workload was found to be lower in the engineroom than on the bridge.

Overall, more sleepiness and fatigue-related symptoms were recorded during the first watch of the day. Fatigue symptoms were shown to be more abundant in the 6-on/6-off system than the 4-on/8-off system, and participants rated work difficulty and workload levels as higher on the bridge than in the engineroom.

III.5 Sleep Diary

In the sleep diary, participants wrote down details including if and when they slept and how long it took for them to fall asleep (sleep latency). Questions also addressed the quality of the sleep, with subjects asked to rate their feelings at bedtime and at getting up on a scale of 1 (very alert) to 9 (very sleepy). They were also asked to state the number of cups of coffee consumed, as well as the number of sleeping pills, painkillers or any other medication that was taken.

Other questions included:

- Number of awakenings from 0 to 6 or more;
- Was it hard to fall asleep? 5 (not at all) to 1 (very hard)
- Did you wake up too early? 5 (no) to 1 (much too early)
- How have you slept? 5 (very well) to 1 (very bad)
- Was it easy to get up? 5 (very easy) to 1 (very hard)
- Did you have disturbed sleep? 5 (not at all) to 1 (very disturbed)
- Did you spent time awake during the period of sleep? 5 (no) to 1 (> than 1 hour)
- How deep was your sleep? 5 (very deep) to 1 (very light)
- Did you wake up well rested? 5 (completely) to 1 (not at all);
- Did you feel stressed at bedtime? 5 (not at all) to 1 (very);
- Have you slept long enough? 5 (definitely enough) to 1 (definitely too little).

➢ Total Daily Sleep Duration

The total daily sleep duration for each participant was calculated from the start of the first watch on for every 24-hour period. Variations were found between the two watch systems, with sleep duration being considerably longer in the 4/8 system (211 ??8 minutes per free watch) compared with the 6/6 system (162 ??10 minutes per free watch).

The vast majority of participants were found to split their sleep across the two free watches. In the 6/6 system, sleep duration was longest during the free watches from 0000 to 0600 and from 0600 to 1200. In the 4/8 system, sleep duration was longest during the free watches from 0400 to 1200, from 2000 to 0400 and from 0000 to 0800.

Significant differences were also found in the time taken by participants to get to sleep. The delay to bedtime differed significantly across watches – for example, on Chalmers 4/8: after 0000-0400 the delay to bedtime was 42±21 minutes (±standard error), after 0400-0800 it was 60±22 minutes, after 0800-1200 it was 225±23 minutes (and few sleeping), after 1200-1600 it was 237±18 minutes, after 1600-2000 it was 169±20 minutes, after 2000-2400 it was 74±23 minutes. Night watches had the least delay to bedtime.

Similarly, at Warsash, a comparison between the bedtimes between deck and engine room officers on 6/6 reveals that after the 0000-0400 watch, the delay to bedtime was generally about 50 minutes, rising to nearer 100 minutes for the late afternoon and evening watches. These results also show that the delay in getting to sleep after the end of the watch was considerably less on the 6/6 regime than for the 4/8. This relative ease of falling asleep after the end of the watch on 6/6 is explained by the general lack of sleep for those on that more arduous watch.

These results mean that estimates of bed timing need to be adjusted in any estimates of fatigue in models of fatigue regulation.

- **Sleep on duty**

Sleeping on duty poses an immediate and significant threat to safety in any mode of transportation, and shipping is no exception. Through analysis of EEG recordings and visual observation of Project HORIZON participants, researchers were able to identify incidents of sleep – both on the bridge and in the engineroom – as defined by the occurrence of at least one 20 second period of stage 1 sleep whilst on watch.

- **Chalmers 4/8**

The highest proportion of watchkeepers falling asleep was observed between 0000 and 0400hrs -- 40%, or four participants.

McNemar's testing did not reveal any statistically significant differences between watches overall, but between night watches and evening watches. The presence of sleep during day watches (between 1200 and 2000) is unusual and normally not seen, but could be a consequence of working night watches, preventing participants from getting their sleep at the proper time – in the hours of darkness.

- **Chalmers 6/6**

The percentage highest proportion of watchkeepers falling asleep was observed between 0000 and 0400 (more than 40%).

- **Effect of the off-watch disturbance**

Increased rates of participants sleeping were noted in almost all watch teams in both watch systems during the watch following the off-watch disturbance as compared to the control watch in the other half of the week.

- **4/8 versus 6/6**

The results showed more participants sleeping on watch in the 6/6 system than in the 4/8 system, although a level of statistical significance was not reached. At least 50% of participants in both watch teams in the 6/6 system were found to have slept on the bridge, whereas in the 4/8 system such a percentage was only reached by team 1 (working 0000 to 0400 and 1200 to 1600).

- **Warsash bridge**

The highest proportion of watch keepers falling asleep was observed between 1800 and 0000 (more than 20%, or two participants). McNemar's testing did not reveal any statistically significant differences between watches. Researchers suggest that the absence of participants sleeping between 0600 and 1200 may have been the consequence of half of the group participating in cargo-handling simulations (which is rather activating) at that time. Again, sleep during daytime might have been a consequence of the night work involved.

- **Warsash engineroom**

The highest proportion of watch keepers falling asleep was observed between 0000 and 0600 and between 0600 and 1200 (more than 20%, or two participants).

- **Bridge versus engineroom**

The percentage of participants sleeping on watch was found to be relatively similar for both watch teams in the bridge and the engineroom. No statistically significant differences were observed.

- **Conclusions**

- The percentage of participants showing sleep while working on the bridge were unexpectedly high
- More participants fell asleep during the night/morning watches than day-early evening watches
- A disturbed off-watch period was found to result in more sleep during the subsequent watch
- More sleep was found to occur on watch in the 6/6 system than in the 4/8 system
- No significant differences observed between the bridge and the engine room

III.6 Activity/Electrophysiological measurements

- **Chalmers 4-on/8-off**

Reaction time:

Within subjects, the mean reaction time differed across the days and between the first and the second watch of the day, being slower during the first watch. Mean reaction times also differed based on time in watch, being slower at the end of the watch than the start.

Lapses:

Within subjects, the number of lapses was greater during the first watch of the day than the second and lapses were more abundant at the end of the watch than at the start.

- **Chalmers 6-on/6-off**

Reaction time:

Within subjects, the mean reaction time was found to be slower at the end of the watch than at the start, and the number of lapses was greater at the end of the watch than at the start.

- **Effect of the Off-Watch Disturbance**

- In both watch systems, reaction times were slower following the off-watch disturbance. In the 4-on/8-off system, the mean reaction time was considerably slower following the disturbance (306 ± 7 ms) compared with the control watch (283 ± 5 ms). The number of lapses was also higher following the disturbance (2.3 ± 0.4) compared with (0.9 ± 0.2) in the control watch.

- In the 6-on/6-off system, no differences in the rate of lapses were observed between subjects following the free watch disturbance and the control watch. However, the mean reaction time was slower following the disturbance: (339 ± 27 ms) against (289 ± 18 ms) for the control watch.

- **4-on/8-off versus 6-on/6-off**

Reaction times and no. of lapses did not differ between the two watch systems.

- **Warsash Deck**

Within subjects, no significant main effects were observed for reaction times or the rate of lapses.

- **Warsash Engineroom**

Reaction time:

Within subjects, the mean reaction time was found to be slower during the first watch of the day than the second: (339 ± 17 ms versus 329 ± 17 ms).

Lapses:

Within subjects, the number of lapses was found to be more abundant during the 1st watch of the day compared to the 2nd: 6.1 ± 1.6 versus 5.2 ± 1.4. Number of lapses was also more abundant at the end of the watch than at the start: 6.1 ± 1.5 versus 5.2 ± 1.5.

- **Deck Versus Engineroom**

PVT reaction times and number of lapses did not differ between the bridge and the engineroom.

Overall findings:

- Worse PVT performance during the first watch of the day
- Worse PVT performance at the end of the watch compared with the start
- The off-watch disturbance worsened PVT performance
- PVT performance did not differ between the bridge and the engineroom

III.7 Stroop Test

- **Warsash Deck**

The reaction time on control stimuli did not differ within or between subjects. However, within subjects, the mean reaction time on interference stimuli differed significantly across days with a gradual decline in daily means (1103 ± 61 ms on day 1 to 982 ± 58 ms on day 7) which indicated a learning effect over the course of the week.

The number of mistakes on control stimuli did not differ within or between subjects and no mistakes on interference stimuli were observed within subjects. However, the number of mistakes on interference stimuli differed significantly between the two watch teams, with the team working 00:00-06:00 making more mistakes (2.1 ± 0.4) than the other team (0.6 ± 0.3).

Within subjects, absolute interference (the mean reaction time on interference stimuli minus the mean reaction time on control stimuli) differed significantly across days, with the gradual decline in daily means (from 136 ± 18 ms on day 1 to 60 ± 20 ms on day 7) suggesting the presence of a learning effect. Between subjects, no effects were observed.

Within subjects, percentual interference (the relative increase in reaction time on interference stimuli as compared to control stimuli) differed significantly across days and the gradually declining daily means (from 13.8 ± 1.7% on day 1 to 6.3 ± 2.0% on day 7), were a sign of a learning effect. Between subjects, no effects were observed.

- **Warsash Engineroom**

Within subjects, the mean reaction time on control stimuli differed significantly across days and the gradual decline in daily means (909 ± 51 ms on day 1 to 805 ± 37 ms on day 7) indicated a learning effect over the course of the week. The mean reaction time was observed to have differed between the first and the second watch of the day, with slower mean reaction times during the first watch (857 ± 47 ms) than during the second (832 ± 41 ms). Between subjects, no effects were observed.

Within subjects, the mean reaction time on interference stimuli differed significantly across days, with the gradual decline in daily means (1010 ± 69 ms on day 1 to 883 ± 54 ms on day 7) being indicative of a learning effect over the course of the week.

The number of mistakes on control stimuli and interference stimuli did not differ within or between subjects. Within subjects, absolute interference (the mean reaction time on interference stimuli minus the mean reaction time on control stimuli) differed significantly across days and the gradual decline in daily means (from 102 ± 24 ms on day 1 to 79 ± 24 ms on day 7) suggested the presence of a learning effect. Between subjects, no effects were observed. Percentual interference did not differ within or between subjects. Stroop performance was not found to differ depending on the watch.

Conclusion

- **Deck versus engineroom**

None of the Stroop test parameters differed between the bridge and the engineroom. Overall, the tests showed slower reaction times on interference stimuli than on control stimuli. This interference effect declined during the course of the week, probably due to a learning effect.

III.8 Naturalistic Performance

- **Chalmers 4-on/8-off**

Subjects were observed responding to a range of 'events' and sub-tasks, including:

- collision course
- compliance to collision regulations
- the presence of fishing boats
- object adrift
- communication task
- close encounter
- high-speed ferry

Whole watch performance was assessed and if nodding-off was observed by simulator instructors and/or researchers, the watch was scored as 1. If not, it was scored as zero. No differences within or between subjects were observed.

Performance during the two sessions in the liquid cargo operations simulators was expressed on a 0 to 100 scale. Performance did not differ within or between subjects. Comparative analysis was not possible for a number of events and sub-tasks but, overall and in particular in relation to the 'close encounter' event, a limited performance increase was noted during the course of the week and this was indicative of a learning effect.

- **Chalmers 6-on/6-off**

Comparative analysis was not possible for a number of events and sub-tasks but, overall performance in the 'close encounter' event was higher in the team working 00:00 to 06:00 watch (7.1 ± 0.5 versus 3.8 ± 0.5).

No differences within or between subjects were observed in relation to nodding-off or performance during the two sessions in the liquid cargo operations simulators.

- **Effect of the free watch disturbance**

Limited and somewhat bi-directional effects were observed. The off-watch disturbance only affected sub-task 1 on the whole watch performance rating. In the 4-on/8-off system, a significant difference was observed on this sub-task between the control watch and the watch following the off-watch disturbance, with performance being worse following the disturbed off-watch period (2.8 ± 0.2) than in the control watch (3.2 ± 0.2). This effect was not seen in the 6-on/6-off system, but an interaction between day and watch team was observed.

Comparing the free watch following the disturbance with the control watch, performance increased in team working 00:00 to 06:00, but decreased in the other team.

In the 4-on/8-off system, more nodding offs were observed after the free watch disturbance than in the control watch: 0.3 ± 0.1, against none during the control watch.

- **4-on/8-off versus 6-on/6-off**

Limited differences between the two watch systems were noted from all sub-tasks of all events. Performance on sub-task 3 (detection range) of event 3 (communication event) was seen to be higher in the 6-on/6-off system (4.0 ± 0.3 versus 2.2 ± 0.2). Sub=task 1 (position taking) of the whole watch performance was found to be higher in the 4-on/8-off system (2.9 ± 0.1 versus 2.6 ± 0.1)

- **Warsash Deck**

Adherence to the collision prevention regulations was scored during the first and second watch of days 2, 4, and 7 and rated on a 0 to 10 scale. No within or between subjects effects were observed.

The standard of communications with the engineroom was measured in the second watch on days 4 and 7. Limited differences were noted and only accuracy differed between the days, with higher accuracy being observed on day 4 than on day 7 (4.8 ± 0.2 versus 4.1 ± 0.3). The effect of day was only present in the team working 00:00 to 06:00.

Accuracy and completeness of watch handover was rated on a 0 to 10 scale during both watches on days 2, 4, and 7. No within or between subjects effects were observed. Overall log keeping was rated on a 1 to 10 scale on days 2, 4, and 7 during both watches and was found to be rated higher during the second watch of the day than the first (6.3 ± 0.6 versus 5.8 ± 0.6).

No within or between subject effects were observed in standard alteration of course and determination of position tasks.

However, several LICOS performance scores decreased during the course of the week, including: adherence to standard watchkeeping tasks (from 4.5 ± 0.3 on day 1 to 4.2 ± 0.2 on day 3 to 3.7 ± 0.3 on day 6) and completeness of the handover (from 4.4 ± 0.3 on day 1 to 4.3 ± 0.3 on day 3 to 3.3 ± 0.3 on day 6). The decline in the completeness of the watch handover over the three days was much more pronounced in the team working 00:00 to 06:00 (from 5.2 ± 0.5 to 3.1 ± 0.4 versus 3.5 ± 0.5 to 3.5 ± 0.4).

- **Warsash Engineroom**

No differences between or within subjects were noted on a range of tasks, including professional discussion, providing current status information and acknowledgement of information received.

The team working the 00:00 to 06:00 watch scored higher in requesting information when coming on watch (4.1 ± 0.2 versus 3.5 ± 0.2) and higher on one of the problem-solving tasks(2.5 ± 0.3 versus 1.6 ± 0.3) when responding to a high scavenge air temperature on the main engine.

Performance ratings for a range of speed and accuracy tasks varied – with some decreasing during the week, others improving and no differences within or between subjects being noted on others.

Adherence to standing orders was found to be greater in the second watch of the day than the first (4.8 ± 0.5 versus 4.6 ± 0.1). The quality of the watch handover was found to have gone from 6.7 ± 0.4 on day 3 to 7.8 ± 0.2 on day 5 and overall watch performance ranged from 6.8 ± 0.4 on day 3 to 7.7 ± 0.2 on day 5.

Overall, the team working 00:00 to 06:00 performed slightly better. Performance on some tasks increased during the week, while performance on other tasks decreased.

III.9 Audio and Video Capture of Experiments

- **Warsash Deck and Engineroom**

Capture of audio and video data was achieved at Warsash for all 10 experimental runs. As the video footage was to be used for qualitative retrospection of the research, there was no impact on the project results themselves, of only doing this work at Warsash and not at Chalmers, where for reasons of logistics (with five deck operations carried out in parallel) such capture was impractical. The data capture involved equipment which allowed video and audio recordings of the bridge and engine control room simultaneously, and an independent set-up for the cargo control room. Subjects were videoed by fixed cameras that recorded the principal places of work within the simulators. Subjects had given their permission to be recorded beforehand for the purposes of the research. The subjects could not see the cameras which, in any case, did not move or otherwise draw attention to their presence. Early efforts revealed that additional camera positions were needed on the bridge to cover "hidden" areas. The only other technical problems encountered in the early stages was the over-writing of the hard disc, thus the records are not 100% complete.

However, the results of this procedure has been to provide immense volumes of data enabling post-simulation study and analysis. It was not known at the outset how advantageous this aspect might be but two main benefits have emerged: firstly, it is possible to revisit the circumstances of the simulation, when subsequent fatigue results indicate a point of significance, for example, subjects actually falling asleep on watch. For the mainstream HORIZON research, the video records and the ability to return precisely to a point in time, enabled researchers to view the demeanour of the subject, when evidence is found of occasions of micro sleep or other discontinuity of alertness appears. This then enables self-awareness of fatigue and sleepiness to be observed visually.

Secondly, the footage also provides macro evidence of the spatial movements of the subjects, which is valuable for human factor analysis of the man-machine interfaces. In this latter case, BV has produced some ground breaking methods for interpreting such data: Terabytes of recordings have been passed to BV who are observing and analysing them, as activity outside the project contract. Initial findings show how the subjects either remain in one place or move around, as the different levels of sleepiness develop and mitigation activity is undertaken. The ease (or in some cases the beneficial difficulty) of having all instrumentation or controls within easy reach of the workstation become apparent. Once fully analysed and assessed, this material will be the subject of further study by BV with potential application to ships' compartment design and equipment layout. No such extensive records have hitherto existed.

The recordings have also allowed the research team at Warsash to build a vast archive of material to begin internal research aimed at studying some of the problems of communication between watch keepers. The simultaneous recording of bridge, cargo and engine room watch keepers has allowed an innovative and unprecedented set of data to be provided for examples of miscommunication, cultural differences between watchkeepers, and social interactions, both good and bad, to be the subject of potential future studies. Furthermore, because Warsash also deployed the engine and cargo control room simulators, this has allowed comparison between constant-light scenarios, with the diurnal variations of the bridge operation.

The consortium had foreseen in its bid that HORIZON would provide the material suitable for the creation of a video on the project but that this would be beyond its resources to produce one. However in addition to the video recording referred to above, WMA also produced two project videos during the contract: one presenting the process of the simulation activity and the other expanding that to include presentation of the results. Both videos are available on the project website.

Section IV. CONCLUSIONS

Project HORIZON has undoubtedly succeeded in its core of aim of delivering a more informed and scientifically rigorous understanding of the way different watchkeeping patterns at sea affect the performance of ships' officers. The range of measurements and the high degree of realism gained through the use of simulators have provided detailed and robust data on which to assess and analyse effects. Data gained from the research is sufficiently robust to provide input to marine-validated mathematical fatigue prediction models within a fatigue risk management system.

Overall, it is clear that much of the data gained from the research supports the 'circadian theory' of diurnal performance peaks and troughs and clear evidence of 'sleepiness' risk periods:

- watchkeepers were found to be most tired at night and in the afternoon
- sleepiness levels were found to peak towards the end of night watches

- slowest reaction times were found at the end of night watches
- sleep incidence on watch mainly occurred during night and early morning watches
- the 6/6 regime was found to be more tiring than 4-on/8-off
- the onset of tiredness on 6/6 occurred over a shorter timeframe than predicted
- 'disturbed' off-watch periods produce significantly high levels of tiredness
- participants on 6/6 were found to get markedly less sleep than those on 4/8
- all groups reported relatively high levels of subjective sleepiness on KSS scale

EEG data demonstrated that a large proportion of the watchkeepers showed actual sleep on the bridge, particularly following 'disturbed off-watch' periods. In the Chalmers 4/8 pattern, the figures varied between 0% for the 1200-1600 and 2000-0000 watches to almost 40% on the 0000-0400 watch. In the Chalmers 6/6 rotas, the figures varied between almost 10% for the 1800 to 0000 watch to more than 40% for the 0000-0600 period. The disturbed off-watch period was also found to have a strong impact on sleepiness.

These results are significant because they demonstrate the increased probability of the risk of falling asleep under different circumstances. Clearly, the 6/6 watch is generally more likely to produce sleep occurrences than the 4/8 watch: The most difficult watch is the 0000-0600 when four times as many people are likely to fall asleep than during the afternoon watch (1600-2000) on the 4/8 system. If the 6/6 watch is disturbed, this figure can rise to at least 5 times the number of people likely to fall asleep during the night watch on 6/6.

The records of the watch keepers using the KSS scales also demonstrate some significant findings related to the risk probabilities of falling asleep. At the beginning of watches, and at the beginning of the week, typical figures may be scores of 2 or 3, but by the end of a single watch they have climbed to 6 or 7. By the end of a week, these figures are typically 4-5 and exceeding 7 by the end of the watch, especially for a demanding watch like the 6/6. Derived from road accident statistics, if it is assumed that KSS scores of less than 7, give a 1 in 10 (10%) chance of an accident, and scores of 8 increase the likelihood of an accident to a 1 in 2 chance of an accident (50%), then it can be seen that for seafaring watch keepers, the risk of falling asleep is increasing noticeably. Of course, other parameters such as the proximity of other hazards and the susceptibility of individuals will also affect the risk probabilities of falling asleep considerably.

Total daily sleep duration was measured for all participants over each 24-hour period and marked differences were detected between the different watchkeeping patterns. The differences were particularly apparent amongst those working the 6/6 schedules – where data showed less sleep and a clear 'split' sleeping pattern in which daily sleep was divided into two periods, one of between three to four hours and the other averaging between two to three hours. In contrast, the sleep patterns for those working the 4/8 schedule at Chalmers were found to be relatively normal – varying between around 7 to 7.5 hours for Team 1 to around 6 hours for the second team.

Another important observation on sleep was discovered through the use of the EEG recordings during the off watch periods of the watch keepers. This has provided new data, on the length of time it takes for watch keepers to fall asleep after they are relieved from watch duties. This phenomenon has not been observed before in seafarer watch keepers, and provides novel data to be input into software models which predict fatigue and the risk probabilities of falling asleep. The results from the EEG recordings showed that sleep was not initiated almost immediately after ending a night watch, but there was a delay averaging about 50 minutes. This is important information for estimating the recuperative effect of sleep. Off-watch periods starting in the forenoon to evening were found to have very long delays to the onset of sleep and often no sleep was taken, particularly on the 4/8 pattern. This clearly reduces the amount of recuperative sleep that watch keepers are actually getting, and confirms both the importance of the circadian effect, and also the importance of the "split" sleep strategy adopted by 6/6 watch keepers.

In summary, we can state the following in terms of risk of a bridge officer falling asleep:

In the 6/6 system, the risk was:

35% regardless of watch
44% for the night watch (and similar for the morning watch)
10% for the evening watch

The risk was increased towards the end of the week. It was also increased when the prior free watch was used for work instead of sleep. With respect to individual differences the proportion that fell asleep on at least one watch was 48%. Individual vulnerability was considerable but could not be related to any clear predictor.

The EEG-based risk above was clearly supported by the subjective ratings of sleepiness which were highest on the night watches, towards the end of week, and after a free watch used for work instead of sleep.

For the 4/8 system the risks were similar but somewhat lower.

Section V. OUTCOMES

There can be no doubt that Project HORIZON has achieved its principal objective of gaining a deeper and more scientifically rigorous understanding of the way in which sleepiness affects watchkeepers at sea. The results have taken knowledge of the issues to a new level and have demonstrated the multiple and complex effects of some of the most common working patterns for seafarers.

It should be noted, however, that Project HORIZON was a simulator-based study that was designed to study some basic aspects of the effects of standard maritime watch schedules on sleepiness and fatigue. Whilst the simulator setting can present a limitation, it does provide better control of the test conditions and offered researchers opportunities for in-depth comparative analysis of participants at different times and on different working patterns in near-identical situations. Whilst every effort was made to design realistic simulated working conditions, the practical limitations must be recognised – such as timescales and working environment. There are many other factors may have an important impact on watchkeepers' sleep and rest – such as bad weather conditions, onboard noise, the effects of long periods at sea, skills and competence of the crew, and varying rules on the use of chairs on the bridge. All these are influences that need to be considered in future studies of fatigue at sea.

Nevertheless, Project HORIZON has delivered an unprecedented level of remarkably detailed data that enables the achievement of the core objective of using the findings to assist the development of 'best practice' standards for the shipping industry. The results also provide reliable and validated source material for input into policy discussions at national, regional and international level – with the potential for appropriate bodies to take forward plans for improved regulation of seafarers' working hours, safe manning and fatigue mitigation.

Analysis and assessment of this data has enabled researchers to develop a lasting legacy, in the form of a proposed fatigue management toolkit. This package is intended to provide practical guidance for key stakeholders covering:

- the nature of fatigue or sleepiness at sea
- pointers to aid recognition of such conditions
- measures by which mitigation of them might be achieved
- concrete indications how the conditions might be avoided at source and the findings of the project might be applied – in particular to the key stakeholders: seafarers; ship owners/managers; classification societies; policymakers/regulatory authorities; training establishments; equipment providers

V.1 Fatigue Management Toolkit

Sleepiness is an acknowledged risk factor in safety-critical industries and in all modes of transport. It is recognised, however, that shipping differs from some other transport modes, in that the nature of risk exposure and the capacity to act is extremely variable and depends on many factors. The characteristics of working at sea – and especially in the deep-sea trades – mean that the coincidence of exposure to risk and absence of capacity to deal with it will be a relatively rare event. It is probable that the level of risk will be much lower than that for road transport, for example, and most likely to be more similar to that in aviation.

In fact, the data from Project HORIZON indicates that the probability of danger at sea will be highest when night watches are combined with prior reduction of sleep opportunities, and exacerbated by passages through narrow or very densely travelled waters, or during reduced visibility.

The Project HORIZON findings suggest that owners, regulators, seafarers and others should pay special attention to the potential risks in difficult waters in combination with the 6/6 watch system (because of sleep loss), night watches, the last portion of most watches (especially night watches), and watches after reduced sleep opportunity. There is also some evidence from the research to suggest that individual susceptibility to fatigue probably also needs to be considered.

A variety of methods (some of which are already commonly deployed) may be used to address this potential risk, including alarm systems to alert crew before important waypoints, encouragement not to use chairs on the bridge during night watches, additional crew, training crew to recognise symptoms of fatigue, and special protection of sleep periods for watchkeepers.

Another way of reducing fatigue-related risk is to train seafarers in understanding the causes and consequences of fatigue, how to detect it, how to prevent it and how to report it. The latter requires a level of acceptance of fatigue reporting without reprisals from those in authority. Personal fatigue countermeasures include caffeine, strategic napping and physical or mental activity. Judicial use of countermeasures against fatigue should be part of the job description for all personnel on watch duty.

The toolkit takes these precautions a step further, by using scientifically verified data to build mathematical models which can be used to predict which portions of a particular voyage may be critical from a fatigue point of view, thus allowing mitigating action to be planned ahead of time.

V.2 MARTHA

It is well known that working hours which deviate from conventional patterns (shift work, roster work, and irregular watch schedules) always entail a high probability of reduced sleep and of increased fatigue, with an ensuing accident risk. In recent years, scientists have developed mathematical models for alertness or performance prediction – and these have most notably been applied in the aviation industry. An example of the recognition of the value of such systems can be seen from the US National Transportation Safety Board's 'Most Wanted List' and the associated 2011 recommendation stating: 'The Safety Board continues to call for the development of fatigue management systems, which take a comprehensive approach to reducing fatigue-related risk. These systems should be based on empirical and scientific evidence and should include a methodology to continually assess their effectiveness.'

It is against this background that the Project HORIZON researchers have been able to use the robustness of the results of their work to develop a maritime alertness regulation version of these models – 'MARTHA': an acronym derived from 'a maritime alertness' regulation tool based on hours of work.

Mathematical models for alertness or performance prediction have been developed mainly as tools for evaluating the effects on sleepiness or fatigue of work schedules or sleep/wake patterns that deviate from the pattern of daytime activity and night time sleep. Early models were based on the effects of time awake and amount of prior sleep as well as a circadian component representing the effect of the biological clock. As scientific understanding has increased, models have become more sophisticated, incorporating a wider range of factors that influence sleepiness and alertness and expanding to include predictions of sleep latency and sleep duration.

The detailed information obtained in Project HORIZON has enabled the model to be validated against the empirical sleepiness data. Apparently, there has been no prior knowledge of the way in which sleep is distributed across sleep opportunities on sea schedules. An important new development from Project HORIZON has been the use of the empirical sleep data (bedtimes and rise times) obtained from the research to create a new function of the model to predict sleep on sea watches. The model also incorporates a third process reflecting the effects of time on-watch.

These functions were combined and, using a computer-based system, will provide a maritime interface with selectable watch schedules and a 'do-it-yourself' watch system facility. Users will be able to enter their working schedules over a six-week time window and receive predicted estimates of the most risky times and the times of highest potential sleepiness for each watch and for the whole watch schedule, as well as for time outside watch duty.

The major display contains estimates for each 24-hour period, with a second display to describe each 24-hour period with sleep periods and a continuous estimate of sleepiness. This information may also be displayed as miniatures in the main display.

MARTHA can be used onboard during voyage planning to develop watch systems that are efficient and that minimise risk. Shipping companies can use the system when planning the size and competence of the crew. The tool could also yield important

International Safety Management Code benefits, and might be used for insurance and classification purposes.

MARTHA could also assist flag states and port state control authorities, enabling solid documentation if, for example, a ship is to be detained in order to let the crew rest before the voyage is resumed. It could also be used for the prevention and investigation of accidents. The HORIZON consortium recognises, and Project HORIZON itself, has become recognised as a project that will be more for public benefit, than having commercially exploitable outputs. It fulfils a need that could not economically be sustained by any individual, or even a group of, actors, without the essential ingredient of public funding, by courtesy of the EU. It will achieve its success through exploitation, in a variety of ways: widely and generally on the world stage of maritime safety, as well as individually through the benefits attained and appreciated by the project partners themselves.

From the more scientifically innovative aspects, Project HORIZON has produced a number of results of practical importance and MARTHA has been developed as a practical tool to predict sleepiness and to evaluate the risk involved in watch schedules. While of considerable practical importance there is also the advance of scientific knowledge. HORIZON is a one-shot study of a specific problem. The possibility to build scientific knowledge and integrate the new knowledge with the established one has been at the core of the project and MARTHA is the tool for this function. This tool has its origins in the Two-process model for sleep regulation put forward by Borbély et al (2002). This model showed how circadian (time of day) and homeostatic factors would determine when individuals would choose to go to bed and when to rise.

This thinking was later transferred to sleepiness/alertness by Folkard and Akerstedt (1992) and called the Three-process model of alertness regulation. In further developments sleep onset and offset functions were added, based on empirical data (Akerstedt and Folkard, 1996). The model was also validated against sleepiness ratings in shift workers (Akerstedt and Folkard, 1995; Akerstedt et al (2007) and road accidents (Akerstedt et al 2008). MARTHA'S contribution of storage and integration of new knowledge, involved:

1. The validation of the original model in a context of sea watches. This presents a unique problem since there simply was no knowledge available on how mariners would place there sleep in relation to the off-duty time. It was assumed that there may be more cognitive strategy decision than what is normally seen in a shift worker, for example. The latter would go to bed within an hour after finishing a night shift. The pattern seen in the mariners may also be characteristic for other groups with very irregular work hours.

2. The work-start effect. Comparing off duty with on duty time, there was an apparent increase in alertness during the latter. Switching to the activities and social interaction at work apparently raised alertness. This knowledge is now added to the generic model.

3. Time on task was a third piece of knowledge, to be built into the model. The effects of time on task have seldom been studied before and the present results

indicate a slow increase, as time passes on a watch. It is highly likely that similar factors play a role also in traditional shift work.

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Section VI. RECOMMENDATIONS

The overall results from Project HORIZON may be transferred into different types of recommendations. However, these need to acknowledge the total risk situation --the convergence of risk exposure and capacity to act. In road transport the risk exposure is present 100% of the time. In seafaring risk exposure may mainly occur in manoeuvring in narrow or otherwise difficult waters or with poor visibility. The incidence of such exposure will vary greatly depending on many factors, but must be very much lower than that for road transport -- probably more similar to that in aviation.

One of the strongest factors influencing the capacity to act is sleep, when performance is absent. However, such states during work are relatively sparse and sporadic - even during night work - but they occur for most operators on each difficult watch or shift.

The coincidence of exposure to risk and absence of capacity to deal with it will be a relatively rare event. The probability of danger will be highest when night watches are combined with prior reduction of sleep opportunities, together with passages through narrow or very densely travelled waters, or during reduced visibility.

Considering the results of the present study, special attention needs to be paid to:

- the risks in passages through difficult waters in combination with the 6/6 watch system (because of sleep loss)
- night watches
- the last portion of most watches (especially night watches)
- watches after reduced sleep opportunity
- individual susceptibility to fatigue also needs to be considered

The suggested 'special attention' may involve alarm systems to alert crew before important changes of course, alerting devices, encouragement not to use chairs on the bridge during night watches, additional crew, special protection of sleep periods for watchkeepers, or no work apart from watchkeeping.

In addition, mathematical models (MARTHA) can be used to predict which portions of a particular voyage may be critical from a fatigue point of view and thereby mitigating action can be planned ahead of time.

One way of reducing risks related to fatigue may also be to train the crew in the causes and prediction of fatigue, its risks, how to detect it, how to prevent it and how to report it. The latter requires a level of acceptance of fatigue report without reprisals for those in authority. Personal fatigue countermeasures include caffeine, strategic napping and physical or mental activity. Judicial use of countermeasures against fatigue should be part of the job description for all personnel on watch duty. Most of the general points discussed above are part of what is called 'Fatigue Risk Management', and which is presently being implemented in aviation worldwide. A similar development seems called for in marine operations.

A final recommendation concerns future research. Project HORIZON is the first detailed and experimental study of fatigue at sea. As explained previously, it has limitations, one of which is that the data has been obtained in a simulator. This makes good experimental control possible, but also detracts from the possibility to generalise. There is a clear need for replicating the present research at sea and to validate this research and to carry out studies of long periods at sea, to identify fatigue causes that may derive from boredom, isolation, ship motion and other factors.

Part IV. Potential Impact and Dissemination & Exploitation of Results

I. DESCRIPTION OF THE POTENTIAL IMPACT

Project HORIZON will have a significant impact on the future of seafarers' welfare, as well as working conditions, in the wider context of work, especially where shift patterns are concerned. The scientific experiments conducted during the project, and the data it has produced, have demonstrated that, as with similar situations in the transport sector, if workers are left alone during the night, with little to stimulate them, it is likely that they will fall asleep. The biological drives of the Circadian rhythms are such that, in the absence of particular stimulants, such as caffeine, or high workload, workers will naturally succumb to an irresistible desire to sleep. In addition to actually falling asleep when on duty, the data from HORIZON clearly demonstrates high levels of tiredness, especially when periods off watch are disturbed, and deterioration in performance.

In themselves, these findings do confirm, scientifically, both laboratory experiments on shift working patterns at night and, more importantly, they demonstrate that the working conditions on board ships do not in any way make seafarers immune to these natural drives. The experiments have also shown that there is no distinction between different types of workers on board, for example, engineers are not different from deck officers, nor is working in a cargo control room apparently less likely to cause sleeping than standing a watch on the bridge. This is particularly interesting, in the context of different light levels in both engine and cargo control rooms. The findings from HORIZON will contribute to the future debate on artificial lighting and the benefits or otherwise of this for the vigilance of workers.

However, perhaps the most significant impact that Project HORIZON will have, in the world of work, is its contribution to the development of fatigue prediction models. In the case of HORIZON, the prototype model builds on findings in aviation but is specific to the maritime setting, as a result of the HORIZON data. MARTHA as the software is known, is dedicated to marine operations, but the principles remain the same for other industry sectors. The dissemination record (over 170 entries: some examples accompany this report) demonstrates that the findings of HORIZON are arousing great interest amongst maritime activities. In addition to the shipping industry, offshore sectors and marine pilots' associations are taking a great deal of interest in the application of the, as well as those organisations involved in loss prevention and accident claims.

The consortium is confident that HORIZON will have a lasting legacy: it may well be one of the landmark projects which demonstrated that the subject of worker fatigue needs to be taken more seriously by individuals and companies. In the future, workers will need to be encouraged to record their hours of work more faithfully and conduct themselves with due recognition of the dangers of lack of proper sleep. In addition, in order to avoid accidents, both to individuals and to capital assets, companies will need to ensure that their operational planning takes full account of potential fatigue amongst their workforce, and that monitoring of hours at work needs to be done in an honest and ethical manner. Similarly, national and international organisations will now have the benefit of the HORIZON fatigue Management Toolkit in making future assessment in changes to maritime legislation, tasking into account seafarer fatigue. That process, through dissemination and increased awareness, has already been started by HORIZON.

All these requirements will need a considerable change in culture, both at sea, and one anticipates, in industry generally. Such cultural changes may take a generation or more, but Project HORIZON will have played an important part in that change.

II. EXPLOITATION OF THE RESULTS

Exploitation of HORIZON is principally done altruistically, with little opportunity for commercial or patent developments. In due course, a commercial undertaking may take on MARTHA, and develop and distribute the prototype software, but that would merely be to cover the cost of its presentation and continuous support.

The effective exploitation of results will be the use within the maritime sector of the new knowledge generated and validated by HORIZON, as embodied in the project's Fatigue Management Toolkit (FMT). This is in addition to, and by means of, the exploitation of each of the partners in their respective roles and areas. The actions of individual partners in exploitation, focus primarily on their own spheres of activity. All partners have exploitation plans, whether they are the five who form the core group of research partners, or the six from the stakeholder community. The core partners comprise: Universities; Officers' Trade Union; a Classification Society; whilst the stakeholder partners cover: Protection And Indemnity Insurance; Ship-owners' Association; Harbour Masters' Association; Tanker Owners' Association; National Accident Investigators; and a National (Flag) Regulator.

Project HORIZON has fulfilled a need that could not economically be sustained by any individual, or even a group of actors, without the essential ingredient of public funding, by courtesy of the EU. Over the years to come, it will go on to achieve its success through exploitation, in a variety of ways: widely and generally on the world stage of maritime safety, as well as individually through the benefits attained and appreciated by the project partners themselves.

The central legacy of the project is the Fatigue Management Toolkit (FMT), where real impacts are already being seen, and this comprises:

1. Practical guidance for seafarers, shipowners & operators, port-state & flag authorities and regulators: covering the nature of fatigue or sleepiness at sea; pointers to aid recognition of such conditions; measures by which mitigation of them might be achieved; and concrete indications of how the conditions might be avoided at source and the findings of the project might be applied. This comprehensive guidance has taken the format of a table which indicates a number of recommendations, appropriate to the target audience. It contains a description of the advice and explanation, as well to whom the advice is targeted. It represents the most up to date thinking on sleep "hygiene" for individual seafarers, as well as recommendations to corporate bodies on planning and implementation of fatigue risk mechanisms for their fleet;
2. To provide quotable, validated input into policy discussions, at national and international levels, with potential for appropriate bodies to take forward plans for legislation, derived and supported by the results of the project;
3. A substantial public document to report on the whole of the project but in a readable and appropriate form for the widest use, including potential follow-on research or inclusion in other such studies of the subject. This report is now uploaded on to the project website, alongside other publications, videos and a downloadable prototype fatigue prediction model. The number of downloads are being counted and the aim, now, includes an evaluation of the model by interested parties.

In the light of reactions, both inside and outside the project, it is confidently foreseen that there will be exploitation through application of the project results in the development of standards and policies, which will grow, as third parties take up and use the results. In addition, MARTHA, the publically available prototype fatigue prediction model allows interested parties to evaluate it, as part of their operations, which would lead to a beta version, capable of full commercial exploitation. More details of the content of the FMT and its application are set out below:

Element of Toolkit	Potential usage	Potential User
Report & Conclusions	To inform discussions about fatigue mitigation using a variety of measures. To inform IMO debates on safe manning	Shipping companies, maritime organisations & associations. Seafarers. IMO. National regulatory agencies. P&I clubs. Training Establishments
MARTHA software	To provide the basic data for the production of software-based fatigue management tools. The tools will help predict fatigue levels in different work conditions and watch patterns.	Shipping companies, maritime organisations and associations. Seafarers. IMO. National regulatory agencies. P&I clubs. Seafarer Training Establishments
Practical Guidelines for Reducing the Incidence and Effects of Fatigue during Maritime Watch keeping Operations	To provide practical advice on maritime watch-keeping operations to reduce the incidence and effects of fatigue. To support self-diagnosis (rating scales and observable factors)	Shipping companies, maritime organisations and associations. Seafarers. IMO. National Regulatory Agencies. P&I Clubs.
Policy documents by stakeholders	To inform Human Element debates on fatigue and safe manning at IMO and European levels	Stakeholders, such as UK MCA, MAIB, ETFN, and ECSA, INTERTANKO through IMO Sub-Committees
Fatigue management training	To provide material for workshops, seminars and short courses on fatigue management	Shipping companies, maritime training colleges and universities for seafarer and shore-staff manager training

Exploitation beyond the Project Consortium

The consortium is made up of academic and technical research bodies and representatives of an EU merchant navy officers union, together with a range of stakeholders, including those responsible for setting and enforcing regulations for ships and seafarers and those who suffer loss and damage, arising from marine casualties. This broad and comprehensive range of project partners therefore has an equally diverse range of interests and opportunities for applying the results of the project, as follows.

Contributions to Standards

This is achieved through the adoption and practical application of the best practice elements, arising from the project results. The project output, covered by the Fatigue Management Toolkit, will be issued for use, as described in deliverable D16. It is anticipated that stakeholders such as MCA will disseminate this information as a Marine Guidance Note (MGN) publications, which will reach shipping companies and organisations on a world-wide basis. Other stakeholders will draw the attention of the report to their members, through presentations at their regular members' meetings. Such stakeholders as INTERTANKO, P&I clubs and the Classification Society, as well as other shipping associations, have an interest in raising the standards of the industry. In this way, the project results will be disseminated to influential sectors of the shipping community. Verification and validation that members of these stakeholder groups (e.g. shipowners, inter alia) are taking up the toolkit findings, will be established through feedback from their members. For example, UK MCA hold regular Human Element Advisory Group (HEAG) meetings and other stakeholders also have specific human element working groups or sub-committees. It is to be noted that the end-of-project event, at which the results were released and at which the MARTHA software (as the FMT software has been named) was demonstrated, was achieved as a HEAG meeting at Warsash.

Contribution to Policy Developments

Policy documents, created as a result of adopting fatigue management toolkit will allow stakeholders, such as the UK MCA and INTERTANKO, to submit information for debate at IMO Human Element sub-committees and working groups on the Human Element. This information will therefore be presented and discussed at international level and would form the basis of contributions to international conventions such as IMO's STCW and ILO's Marine Labour Convention (MLC). Other stakeholders, would also present such material to inform policy at a European level.

Availability of Project Material

In order for third parties to access the outcomes of HORIZON, the public material is now available on the Project Website indefinitely. This includes all the public research deliverables as well as the MARTHA software, complete with its instructions for use. Interested parties will be encouraged to download the software, evaluate it, and report back, so that in time, improvements may be made for future exploitation. Two project videos, explaining how the research was undertaken and describing the results, are also on the website. The deliverables include 10,000 copies of the glossy, hard-copy of the Report of Findings of the project: i.e. the Final Report in its public version (also repeated on the website for wider access).

III. DISSEMINATION ACTIVITY

Dissemination was a major aspect of the project, given the high profile of the topic; the key task was to inform of the existence the project and its aims. Widespread, regular communication reported on the work and progress of the project. The final aim was to publish the findings, and stimulate debate and follow-up. This work was led by ETF-Nautilus (ETFN), the maritime officers' trade union, who had intimate knowledge of the issues as well as extensive networks and facilities for publicity and communication.

The dissemination strategy was developed to reflect the importance of the issues addressed by the research; the varied and complex audiences for the research findings and the broad spread of stakeholders involved. Throughout, efforts were made to focus on the special features of the project that were of particular relevance to certain groups or decision-makers. At an early stage, plans were developed to roll out the news of progress, in a controlled and phased manner, with presentations tailored for different audiences and different organisations. Project partners identified the most effective means by which these audiences were to be reached, together with the particular form and content of message to be disseminated by.

In addition to the global activity on behalf of the project as a whole, specific reaction to external enquiries was undertaken by the Project Coordinator, involving ETFN as media expert, where appropriate. At local level and within their own specialised networks of contacts, individual Partners were encouraged to engage in dissemination programme, by means of their professional links and activities – such as attending conferences, contributing to newsletters, delivering papers, etc.

An extensive record of dissemination activity has been accumulated and accompanies this report, where the total number of actions listed, exceeds 170. Many of these actions and the results of dissemination, are also attached to this report, in the form of media material and press cuttings.

Challenges and Opportunities

The dissemination programme sought to ensure that flag states, coastal states, port authorities, regulators, accident investigators, seafarers, and the operators and managers of ships and ports, were made fully aware of Project HORIZON and the results of its work. It was recognised at an early stage that dissemination of the information would be a complex matter, with a varied set of stakeholders involved in the project and a diverse range of organisations and individuals for which the results would have relevance. The shipping industry is highly globalised, with many different stakeholders that often lack shared visions; it was therefore essential that the project communications strategy delivered the information in as clear and simple a means as possible, and used available networks and channels in an innovative way. To that end, a number of important issues were identified, including:

Initial challenges in relation to the communications programme, such as:

- Diverse, distinct sectors within the industry
- Diverse maritime community
- Lack of a initial HORIZON 'brand'
- Varied stakeholders
- Lack of a single point of access and impact on messages

A number of opportunities, including:

- Good contacts with maritime media
- Publication of initial findings
- Forthcoming national/regional events
- IMO/ILO/EC receptions
- A stakeholder relationship programme that can be built upon
- Existence of partners' well-established communications channels
- Local events and initiatives to raise the profile of the project
- Use of the digital network to improve communications between key groups

The planning identified further ways in which this work could be most effective:

- Programme of external stakeholder events
- Launch of the findings
- Website development
- Stakeholder engagement
- Single point of access for information
- Digital communications
- Support materials for partners
- Pilot toolkit
- Developing team members as advocates
- Working with partners to develop their capacity
- Developing a programme of local/national/regional events
- Developing research outcome reports in different formats
- Releasing press releases at key stages of the work programme
- Media related activities – events/launches, announcements
- Targeted media announcements on significant national initiatives

- Placement of relevant stories in existing publications
- Identifying programme of relevant events and conferences
- Developing a digital communications programme

Distinct Sectors

The key communications issue was how to address the diverse sectors and ensure that information provided was relevant and useful. It was identified at an early stage that there was a need for initial dissemination of information within the group of project stakeholders. Beyond this, a second level of 'interested parties' was identified: individuals or organisations with a close and relevant interest in the work and the general target audience of shipping industry interests. The strategy also recognised the need to raise awareness and interest, through media and PR activities - including the public arena.

Public Identity/ Logo

Work was undertaken from the start of the project, to create a project logo and "brand identity", which has been used on all internal and external publications, from website, leaflets, and reports to press releases. Project partners' logos have also been used on external material, so that stakeholder involvement was clearly visible. As required by the contract, the EU and FP7 logos were also displayed.

Opportunities

Project HORIZON addresses one of the most important maritime safety issues of the present day. There have been repeated examples of fatigue-related accidents in the shipping industry over the past 20 years. During the course of the project there were a number of high-profile shipping casualties in which fatigue was identified as a major factor. The research was therefore acutely topical, reflecting increasing industry concern and among regulators, over the consequence of accidents: serious losses; death and injury; and environmental damage. The dissemination strategy therefore highlighted the fact that the results of the research were of immense relevance to the industry and to those who control it. The work of HORIZON was publicised, whenever the results of accident investigations identifying seafarer sleepiness appeared.

The project was of particular importance to discussions at the IMO in 2010, when it reassessed the global regulatory regime for seafarers' hours of work and rest as part of the Standards of Training, Certification and Watchkeeping Convention 'Manila amendments'. The project's results were also of great relevance to the forthcoming introduction of the International Labour Organisation's Maritime Labour Convention 2006, which also deals with the living and working conditions of seafarers. The IMO and ILO would clearly be a major targets for project dissemination.

Stakeholder Engagement

Project HORIZON had an impressive list of stakeholder partners, which, together with the core research partners, represented a wide and influential spread of interests; this outreach made best use of their credibility and expertise. It was accepted early on that building awareness and increasing understanding amongst all stakeholders was of critical importance. Partner involvement maximised these dissemination opportunities by:

- talking to others would raise the profile of Project HORIZON and the maritime organisations who had not known of its existence

- partner participation in debates and conferences would establish the Project as a 'key player' in the wider debate about policy and practice

Partners had an extensive existing network of communications channels that was utilised to promote the work of the project and very make-up of the consortium itself, having high profile and respected partners, already lent a substantial profile to the project.

To ensure consistency of message and dissemination discipline, a publicity procedure was agreed, and the ETFN in-house press and PR resources served as the 'clearing house' for media contacts. Specialist questions and more focussed contact was successfully handled by consulting by partners for full and expert responses.

Existing Communications Channels

In drawing up the dissemination strategy, one of the first stages was identifying the wide range of communication channels that existed via partners and their associated organisations, including CESMA, IFSMA, EMPA, ITF/ETF, MIF, ESPO, ECSA, Intertanko, IACS, IMarEST, and the Nautical Institute. All these organisations have a number of communication channels that are well-established, and include websites, regular newsletters, magazines and journals that a widely circulated within the industry. Partners were encouraged to use material provided by ETFN as a key platform for initial dissemination through these mediums, and work to that end was launched immediately after the inaugural meeting.

'Interested Parties' Group

As awareness of the spread from the initial stages outlined above, a number of organisations expressed interest in being involved with HORIZON. Some even wished to become partners, but accepted that this was not possible after the Consortium had already been formed. To satisfy such interest and to recognise that many worthwhile bodies existed, which could not become engaged in the research itself, an Interested Parties Group was formed, to keep them in touch with progress and to invite them to the public events to be held under the project. The Project Co-ordinator managed what became an extensive list of such contacts (over 60), who were sent media releases, reports and other public statements issued by the project, as these were developed.

Activities - Aim

The overall aim of the dissemination strategy was clear and simple: to raise awareness of the project and its findings. To achieve this, the team identified the many distinct target audiences, including:

- IMO/ILO
- National regulatory agencies
- Classification societies
- Shipping companies
- Professional bodies
- The media
- European bodies
- P&I clubs
- Academic institutions
- Seafarers
- Non-maritime organisations

Activities - Dissemination

Press releases were issued at regular intervals, particularly as milestones were reached. A peak in the publicity campaign was achieved, following the results of the research, when it was demonstrated how it had contributed to meeting the problems of fatigue and the challenges faced by policy and decision makers. Similar material had been used earlier on, to publicise the work on the design of the experimental scenarios for the bridge, engine room and liquid cargo handling simulators, and the development of the fatigue measurement toolkit - all seeking to lend credibility to the project and its aims.

Anticipating media interest in the actual simulations, the team organised a media access facility to enable journalists to witness some of the simulations and to report on the 'human interest' angle of the research. This was during the phase when visits of maritime VIPs were set up at Warsash to enable the work of the simulation to be observed. In all, over 40 such people attended these important events.

Journalists attended the industry launch of the results and FMT and a subsequent press conference in London, was attended by representatives from all the major maritime publications, at which the findings were again presented and discussed with researchers.

Activities - Media

The media programme was designed to focus on established journals and specialist publications. It sought to target maritime, general and a range of media within the EU. Key publications and media who were sent press releases and briefings included:

- Lloyd's List
- Fairplay
- Seaways
- Royal Inst. of Navigation News
- Maritime Journal
- Ships Monthly
- Shipping World
- Tradewinds
- Safety at Sea
- MER Review
- Seatrade
- The Seafarer
- BYM News
- Sea Breezes

To seek broader, non-specialist coverage, other outlets that were sent publicity material included: European National newspapers; Radio and TV stations; News agencies

Activities - Targeted Announcements

Dissemination was built around a series of media announcements throughout the project, all closely linked to key stages of the work packages, to maintain the profile of the project and raise awareness of the work being done. At each stage this work involved:

- press releases to specialist and general media
- follow-up information being sent to all partners for publicising the project
- guidance to partners on how to get the best out of the opportunity

Activities - Use of Specialist Publications

It was agreed in the planning stage of that an effective communications strategy should be more than just a series of announcements or events and should be reinforced with consistent promotion of the Project HORIZON 'story' through existing channels. This objective was achieved through close personal contact with key journalists, resulting in features in industry magazines and newspapers, as well as supportive editorial leaders in such publications as Lloyd's List. There was also strong support from associated partner organisations, resulting in extremely positive coverage of the project through newsletters, websites and other media. ETFN enhanced these initiatives with a regular flow of reports and features on Project HORIZON in the Telegraph, a monthly newspaper for maritime professionals with an international circulation of more than 35,000 copies.

Activities - Digital Communications

The HORIZON website provided a core focal point for this work and member organisations were encouraged to set up links between their websites so that users were directed to the HORIZON site.

Contact with previous seafarer fatigue researchers was used to build mutual links to respective work outcomes. This resulted in innovative use of film and social media (YouTube, Facebook and Twitter) to ensure that the project was given broad exposure through as many means as possible.

The HORIZON website, hosted by WMA, provided not only a tool for communication and data-sharing within the project, amongst partners, but its dissemination role cannot be overstated. As well as hosting in its public area all the unrestricted documents and other output from the project, it is also the repository of the various videos and presentations made by the project and ultimately, is host (and will remain so indefinitely) to the prototype fatigue prediction software (MARTHA) and its associated guidance and feedback documents.

Activities - Local, National and Regional Events

Dissemination planning identified that there were many shipping industry conferences and forums to provide partners with a ready-made opportunity to raise awareness amongst key target audiences. These included: local events/conferences; meetings with politicians; national initiatives with a seafaring/maritime theme, such as International Maritime Day, EU Maritime Day and National Maritime Days. These also provided an opportunity to raise the profile of the project and get the results of the research across. The dissemination strategy required partners to:

- identify and use relevant conferences and events as a networking opportunity
- take stands at major conferences and events
- seek platforms at appropriate events for Project HORIZON leaders to speak
- organise round-table discussions with associated organisations to explore ways of promoting/advancing the findings

Amongst others, the project presented its initial findings to: Members of the European Parliament's Transport and Tourism Committee and to the European Maritime Safety Agency, at both of which Commission Services staff were also present. These were successful events in themselves and served to add to the profile of the project.

Culmination of the Project

From the outset, project partners identified the need for a major event at the conclusion of the work, to present the findings, remind all of the origin and purpose of the project and how the FMT could be used to mitigate the effects of fatigue. In addition to the central project event, partners were encouraged to use their own contacts to ensure that a broad range of outlets could be reached. To ensure that these objectives could be met, a range of material was developed, to stimulate interest, including:

- small folded A4 leaflets to publicise initial findings as they emerged
- an eight-page summary report, written simply, for media and public use
- a full and detailed 32-page report, including all the key research findings and methodology (produced in 10,000 copies), that has also been published online

In the run-up to the launch event, WMA, Chalmers and SU were able to utilise their professional and academic links to present the initial results to conference audiences in many parts of the world. Other partners who also have global outreach have disseminated the HORIZON message during events attended, worldwide. Stakeholder partners have been provided with a package of materials to publicise the project within their sectors, including a draft press release for targeted use and PDF versions of the interim and final reports to put on their websites.

In the long-term, Project HORIZON dissemination process will have a lifespan that will extend well beyond the project itself. It is recognised that the complex nature of shipping industry regulation – exemplified by the inherently conflicting nature of the IMO and ILO work and rest hour rules – presents considerable challenges for any process of change. The regulatory regime is one that is determined by national, regional and international authorities and therefore the work to influence the decision-making forums is multi-tiered. The process that started with presentations at the European Parliament, the EMSA headquarters has continued at the IMO.

HORIZON has been acknowledged to have made a step change in understanding of the many complex factors influencing seafarer sleepiness and the way in which performance and behaviour is affected by current common working patterns within the shipping industry. As such, it will have immense long-term influence upon education and research, and the development of future measures to identify improvements in watchkeeping arrangements. The dialogue that is now underway, initiated by partners through the dissemination programme, means that the results of the project are firmly embedded in academic and regulatory agendas. The use of the dissemination material by partners representing shipowners, seafarers and P&I interests will ensure that the research results will influence considerations in such areas as operational policies, safety management and training packages. In addition, the commitment of the MCA and MAIB to the project means that the findings will get further exposure through associated organisations across the world.

In conclusion, the extensive dissemination activities have already succeeded in taking the project's findings to key target audiences and to a vast global audience. But it is clear that the work to promote the adoption of its outcomes will have to be maintained on a long-term basis, and the materials that have been developed will enable this sustained process to continue for many years to come.

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Part V. Address of Project Public Website and Contact Details

Project HORIZON public website address: www.project-HORIZON.eu

(hosted by Warsash Maritime Academy at Southampton Solent University)

Post-project contact point: mike.barnett@solent.ac.uk

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