



A design flaw that led to a tragedy

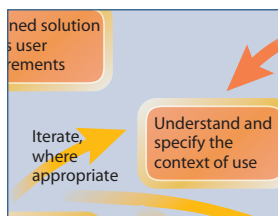
Taking a Human-Centred Approach p3



Ergonomics and Maintainability p4-5



Human limitations in ship design p6



The able seamen Mark and Darren had become firm friends since joining the ship three months previously. They had spent contented off-duty hours together talking about football, films, families and beer until, one stormy Sunday afternoon, they died together.

Mark had been making running repairs to his cabin table with Darren lending a hand. They had ventured out on deck in the rough conditions and made their way forward before entering the forward store and closing the weather-tight door behind them. The chief officer discovered their bodies several hours later while conducting a missing persons search.

The forward store contained a usual mix of tools, spares and equipment for use by the deck department as well as two runs of large diameter galvanised steel vent trunking. The trunking served the single cargo hold and ran, on both port and starboard sides, from the store's after bulkhead, the forward bulkhead of the cargo hold, forward in the store for several metres before turning up 90° and penetrating the main deck to terminate on deck at a mushroom ventilator.

A deckhead mounted vent fan was positioned in the store about midway within each vent trunking run. Ever since the elderly ship's first voyage these cargo vent trunkings had presented maintenance problems. In rough weather the mushroom ventilators, although fitted with fire dampers, could not be sealed watertight and seawater seeped down and into the trunking where it collected in the canvas bellows, which were positioned fore and aft of each cargo vent fan.

Similarly, when extracting air from the cargo hold, cargo residues would be drawn into the trunking to collect in the bellows. Although a bellows piece could be unbolted and removed for maintenance of the adjacent fan, the job entailed

removing 40 bolts, many of which were difficult to access.

A few years before Mark and Darren had joined the ship, an enterprising boatswain, with the permission of the then chief officer, had cut neat holes in the canvas bellows to allow for easy draining and cleaning. This was a pragmatic solution to a problem that had frequently been encountered. The vent fans were rarely used and their efficiency was hardly compromised by the modification. Nobody then or since had considered the risks associated with effectively making the forward store air space common with that of the cargo hold despite the 'do it yourself' modification being widely known.

On Darren and Mark's last voyage the vessel had, unusually, loaded a bulk cargo of ferrous metal turnings in rainy conditions and the vessel had encountered gale force conditions on passage. As was the normal rough sea routine, all the forward ventilators had been closed, including the fire dampers on the cargo hold mushroom vents and the natural and forced ventilation systems serving the forward store. Darren and Mark had been in the forward store the day before the accident to stow mooring ropes which had been led down to them from the forecastle deck. Nobody on board considered the forward store to be an enclosed space for the purpose of the ship's permit to work system.

Two days into the voyage, unbeknown to the master and crew, the damp cargo was self-heating and rapidly depleting the air in the cargo hold of oxygen and, through the holes in the bellows pieces, similarly depleting the air in the forward store. The two able seamen were oblivious of any danger as they descended the familiar steep ladder into the store. By the time they realised what was happening it had been too late to escape or raise the alarm.

The two able seamen were oblivious of any danger...

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w: www.he-alert.org
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Introduction

David Squire, FNI FCMI



The Editor

Alert!

The Nautical Institute

202 Lambeth Road

London SE1 7LQ

United Kingdom

editor@he-alert.org

Our cover story features a sad incident in which two crew members died because of a long-standing design flaw in the ship's cargo hold ventilation trunking which had presented maintenance problems for some time. A 'do it yourself' modification was made without appreciating the risks associated with effectively making the forward store air space common with that of the cargo hold - which had fatal consequences.

In this issue of **Alert!** we are focussing on Ergonomics and Maintainability.

IMO MSC-MEPC.7/Circ.3 - *Framework for consideration of ergonomics and work environment* - provides guidance on the application of ergonomic solutions as a means to reduce personal injuries and incidents or accidents brought on by human error. This is explained further in page 8 of this Issue.

In Issue No. 3 of **Alert!**, we define *Ergonomics* as *the study and design of working environments, for the benefit of the worker's productivity, health, comfort, and safety*. And, in the same Issue we define *Maintainability* as *designing operational maintenance tasks to be rapid, safe and effective in order to allow equipment and systems to achieve a specified level of performance*.

In laymen's terms, *Ergonomics* is about making the ship and its systems fit for the people who are going to operate them, rather than fitting the people to the ship and its systems, as is often the case, particularly when purchasing 'off the shelf'.

Accidents at sea can manifest themselves in different ways, such as: operator error, through a lack of attention to regulations or instructions, unfamiliarity, or through poor ergonomics; slips, trips and falls, due to poor design and insufficient attention at the design stage to the possibilities of operating in an environment which affects ship motion; or through inadequate maintenance and a lack of attention at the design stage to maintainability – to name but a few.

Human-centred design is the means by which the risks arising from a mismatch between seafarers, their ship, its systems and operational procedures are mitigated. A well-designed ship and its systems should meet the needs of the operator, be easy to use, easy to maintain and, above all, reliable.

Alert! bulletins, issues No. 3 - **Ergonomics**, No. 7 - **Design and usability**, No. 11 – **Integration**, No. 15 - **Automation** and No. 17 - **Slips, trips and falls**, and their associated centrespreads and videos can be downloaded from:

<http://www.he-alert.org/en/all-issues.cfm>

Reports & Studies

The human element in safe shipping

J. Pray, K. McSweeney, C. Tomlinson, ABS, USA

B. Craig, Lamar University, USA

This paper presents information reinforcing the continued need to address human element concerns in maritime systems. ABS human element-related topics include crew habitability, the assessment of safety culture, the identification of potential leading indicators of safety, mariner personal safety, and the application of ergonomics in a maritime environment.

Downloadable from:

www.he-alert.org/docs/published/he01250.pdf

Designing efficient and safe machinery spaces for merchant ships: a human factors approach

Nicolas J. Méry & Jonathan McGregor, Bureau Veritas,

Division Marine, Research Department

This paper outlines the Bureau Veritas approach to the development of design requirements for machinery spaces

and their arrangement onboard merchant ships. An important aspect of the work being carried out is the integration of users' characteristics and requirements in the development of design standards for machinery spaces.

Downloadable from:

www.he-alert.org/docs/published/he01245.pdf

The values of ergonomics in ship design and operation

N A Costa, Chalmers University of Technology, Sweden

M Lützhöft, University of Tasmania, Australia

This study explores and disseminates the success factors of User-centred Design (UCD) from which seafarers believe they can benefit as ship users. The findings represent the importance of UCD for those who operate ships and may serve as an incentive for ship-owners and designers to adopt a UCD approach, as well as for researchers to continue studying this subject further.

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Taking a human-centred approach

Guides for ship designers and equipment manufacturers

Dr Jonathan Earthy, Lloyd's Register

Usability

The popular impression of the Human Element emphasises competence and leadership. These alone are not sufficient. We also need usable ships and systems:

- Getting the design right is a one-time activity. Training and competence to compensate for a bad design are a continuing commitment
- A usable design provides support when it is most needed, e.g. when fatigued or under stress
- Usable equipment can dramatically reduce training requirements - potentially to 'walk up and use'
- The state of the art is such that cheap, simple design changes can have a significant reduction in human error potential.

Usability is particularly important when introducing new technology and functions. It provides support to the seafarer performing an unfamiliar task, particularly in situations where operational use precedes training delivery.

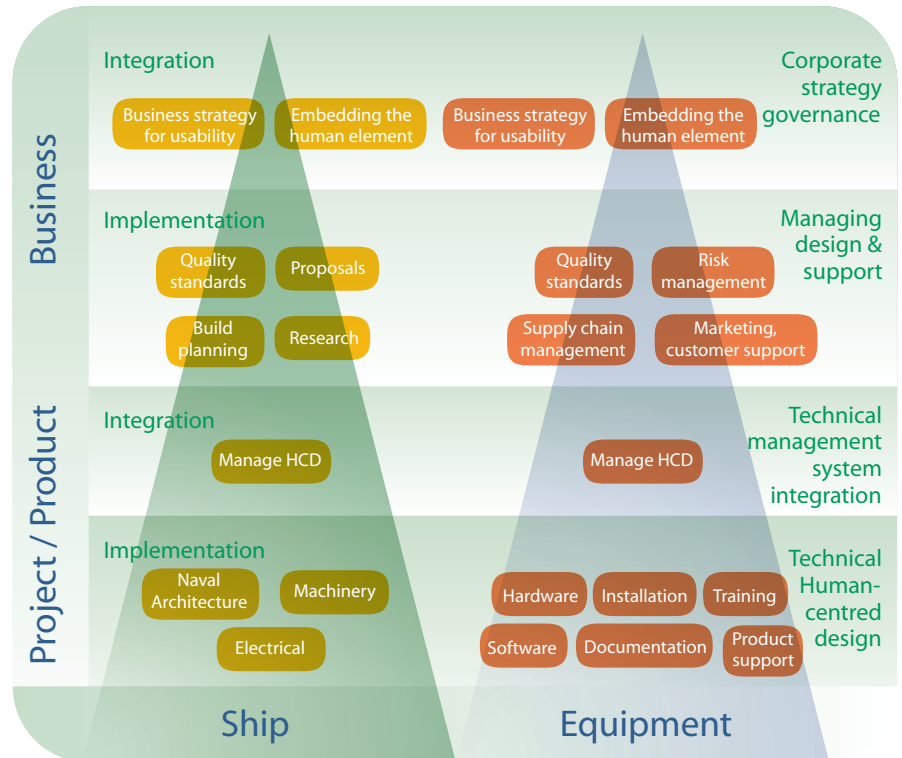
Usability is a result of taking a human-centred approach to design. Lloyd's Register has produced Human-Centred Approach Best Practice Guides (based on International Standards) to help shipyards, equipment manufacturers and Class.

Human-Centred Design (HCD)

The principles of HCD are:

- A clear and explicit understanding of users, tasks and environments (context of use)
- The involvement of users throughout design and development
- Iteration
- Designing for the user experience
- User centred evaluation
- Multi-disciplinary skills and perspectives

Applying these principles requires strategic and managerial, as well technical, changes in an organisation. The Guides describe a staged approach to HCD and enable planning and implementation of an



achievable improvement programme with respect to HCD.

The Guides

The activities set out in the Ship Design Guide are shown in the Figure above. Corporate strategy has activities that align HCD and corporate objectives, and provide the necessary high-level support. The next level is concerned with business management; activities are grouped under well-known functions. At a technical level, the integration of HCD into a project is shown as a single set of activities, since it is likely to be resourced by very small numbers of people. The technical implementation of HCD is split up by technical specialist disciplines.

The structure of the Equipment Manufacturers Guide is similar to that for yards, but with two essential differences at management level:

- The need for product support beyond a guarantee period, with a more extended lifecycle, and less organizational partitioning between stages.

- The likelihood of a greater emphasis on risk management.

At a technical level, the differences reflect the technical specialisms involved.

In conclusion

Shipyards and manufacturers do not benefit directly from usability in the way that a ship operator does. These Guides help to reward efforts made, and to provide incentives to those who are in the early stages of addressing usability. By concentrating on processes within design and manufacturing organizations, they can simplify and promote usage and uptake of good practice. Given this background the aim of the Guides is to offer a scale of benefits to yards and manufactures, and provide assistance with making simple improvements from a basic starting position. Engaging the user community is also an aid to technical innovation. Many major companies in other sectors find that their best ideas come from their users.

For further information go to: www.webstore.lr.org

Ergonomics and maintainability **A rough guide**

Ergonomics and the work environment

Manual valve operation, access, location and orientation

- Guidance Notes for the Application of Ergonomics to Marine Systems, Section 9 - ABS (2013)

Stairs, vertical ladders, ramps, walkways and work platforms

- Guidelines for the Design of the Means of Access for Inspection, Maintenance and Operation of Commercial Ships - Bureau Veritas (2008)
- Human element recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements – IACS Rec. No. 132 Section 4.6 - Access and Egress Design
- Guidance Notes for the Application of Ergonomics to Marine Systems, Section 7 - ABS (2013)

Inspection and maintenance

- Guidance Notes for the Application of Ergonomics to Marine Systems, Section 10 - ABS (2013)
- A guide to managing maintenance in accordance with the requirements of the ISM Code – IACS Rec. No. 74

Working environment

- Code on noise levels on board ships – IMO Resolution MSC.337(91)
- Ships and marine technology -- Ship's bridge layout and associated equipment - Requirements and guidelines - ISO 8468:2007
- Guidelines for engine-room layout, design and arrangement - IMO MSC/Circ.834
- Guidelines on ergonomic criteria for bridge equipment and layout – IMO MSC/Circ.982
- Guidelines on the application of SOLAS Regulation V/15 to INS, IBS and bridge design – IMO SN.1/ Circ.265
- Human element recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements – IACS Rec. No. 132
- Recommendation for the application of SOLAS Regulation V/15 bridge design, equipment arrangement and procedures – IACS Rec. No.95
- Provisions on occupational accidents, injuries and diseases – ILO MLC Guideline B4.3.1

The application of ergonomics to design

- Ergonomic principles in the design of work systems - ISO 6385:2004
- Guidance Notes for the Application of Ergonomics to Marine Systems, Appendix 2 - ABS (2013)
- The Human-Centred Approach - A Best Practice Guide for Ship Designers and Builders – Lloyd's Register (2013)

Human-centred Design best practice

1. Understand and specify context of use

- Establish, clarify and communicate the characteristics of the users, their tasks and the technical, organisational and physical environment in which the system will operate
- Document the characteristics of the intended users and their tasks, including user interaction with other users and other systems
- Describe the real operational environment of the system, including the factors that affect the performance of users

2. Specify the user requirements

- Establish, clarify and communicate the requirements of the users of the system
- Identify and analyse relevant groups of users, and their task needs
- Define the requirements of the users of the system
- State the user criteria for the performance of the system of work against operational and functional objectives
- Address user requirements in the system design

3. Produce design solutions

- Allow the design options for the product system of work to take account of the human element
- Consider human element issues in the trade-off between design options
- Trade-off usability against other design criteria
- Design all user aspects of the system, e.g. jobs, roles, documentation & staffing
- Incorporate user input direct and/or as feedback from evaluations in the design

4. Evaluate

- Provide design information, new risks and issues, i.e. feedback on how to improve the system
- Demonstrate the fulfilment of user requirements, i.e. inform decisions on whether the system is adequate
- Inform the organisation's decisions regarding one or more human element issues
- Test the design with real users



To download this centrespread with links scan the QR code.

Habitability

- ILO MLC 2006, Title 3 - Accommodation, recreational facilities, food and catering
- Alert! Issue No. 34, January 2014 centrespread and page 8

Fatigue mitigation

- IMO MSC/Circ.1014 - Guidance on fatigue mitigation and management
- Module 7 - Shipboard fatigue and the naval architect/ship designer

Issue No.3 - Definitions



Issue No.17 - Mitigating slip, trip and fall hazards



Issue No.7 - Human-centred design



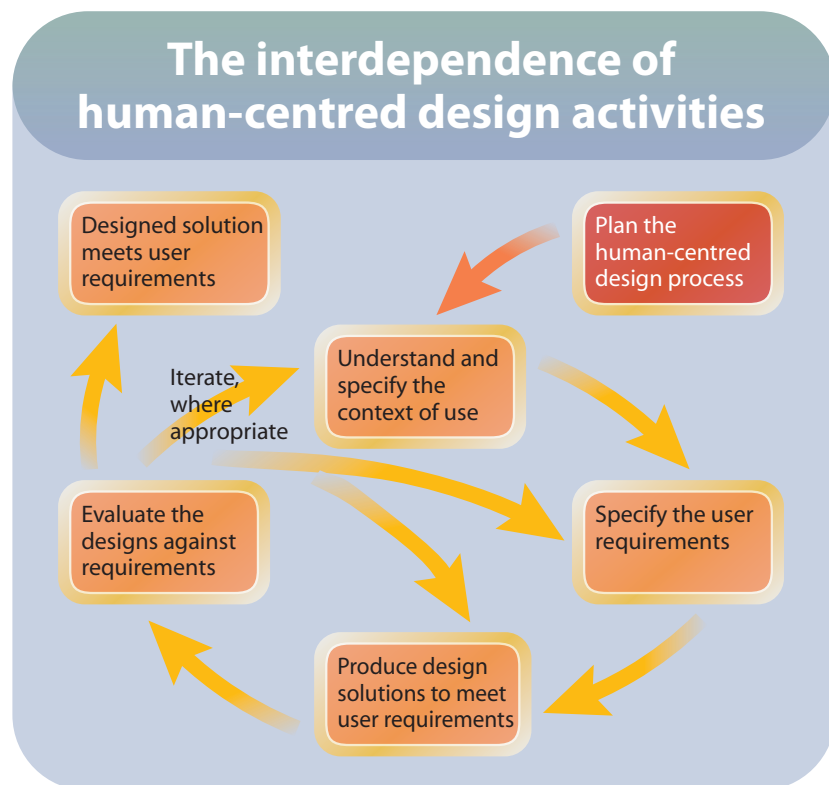
Issue No.15 - Automation



Taking into account human limitations in ship design

Nikolaos P. Ventikos & Georgios V. Lykos

National Technical University of Athens, School of Naval Architecture and Marine Engineering



There are several design improvements that can minimize the possibility of human fatigue and stress

Providing, supporting and enhancing safety in the maritime domain has always been one of the greatest challenges for ship operators. Time pressure, dynamic environment, uncertainty, stress, and organizational shortcomings all contribute to a demanding task environment which promotes good decisions as the decisive factor for successful operations.

The capacity of seafarers to master these challenges requires more than technical skills and expertise. A set of cognitive, social and interpersonal skills - Non-Technical Skills (NTS) - or Soft Skills, is required. NTS complement technical skills and contribute to safe and efficient task performance and comprise: situational awareness; decision making; communication; teamwork; leadership; managing stress; and coping with fatigue.

Human errors are rooted in systemic causes which are embedded in the structure of operations within the maritime domain. Near-miss and accident analysis, and NTS surveys by the National Technical University of Athens (NTUA) have shown the inability of seafarers to cope effectively with both technical and non-technical skills. To date, safety in the maritime domain is mainly restricted to ensuring that 'as few things

as possible go wrong' (*Safety-I*). The next step is *Safety-II* in which the focus is on how to redesign the ship and onboard operations to ensure that 'as many things as possible go right'.

In the context of *Safety-II*, naval architects and marine engineers should reconsider ship design in a holistic way according to the impact of NTS to safety; situational awareness and fatigue are almost always present in major maritime catastrophes. If stressful conditions are combined with significant human fatigue then situational awareness is highly impaired and the consequences have been proven to be more than often, dramatic.

There are several design improvements that can minimize the possibility of human fatigue and stress, while at the same time they contribute to the increase of situational awareness. Designers should adapt their approach so as to minimize the impact of physical environment, fatigue, and stress factors against ship safety. In the context of Human-Centred Design (HCD) these fatigue and stress-related factors can include:

- Level of automation;
- Physical comfort in accommodation and work spaces;
- Location and distance of quarters;
- Lighting;
- Noise;
- Vibrations;
- Ventilation;
- Temperature;
- Ship motions.

By focusing on these factors the designer can improve the ship design by providing an upgraded working and living environment. While most of these factors can be assessed by various areas of engineering, others like vibrations and ship motions are material for naval architects as they rest upon specific ship design elements.

To date, the integration of HCD in the overall ship design is derived by class society guidelines that address the human element on a voluntary basis. However, the maritime sector seems now to be more mature than ever to integrate HCD principles into a holistic ship design framework.

The time has come; all the signs are there, but will the shipping industry meet our expectations?

Do current design standards cater for safety?

Dr Romanas Puisa, Gemma Innes-Jones, Dr Jesus Mediavilla Varas - Project FAROS

We know that human error is often the primary contributing factor to maritime accidents. According to studies by the US Coast Guard, insufficient cognitive functions (e.g. situation awareness and decision-making) as opposed to physiological performance are the primary cause of human errors that contribute to risk at sea. So, how does ship design contribute to human error? And how well do the current design rules and standards cater for safe human performance?

Project FAROS (www.faros-project.eu) is a European research project, which has been investigating the relationship between ship design and human performance.

Amongst all contributors to insufficient human performance, the effect of ship motions, noise, whole body vibration, deck layout, equipment arrangement and other *global design factors* (GDFs) controlled by design are, perhaps, the most speculative and anecdotal.

Evidence suggests that exposure to GDFs impacts crew performance, acts as a stressor and affects the underlying human capabilities required to perform tasks successfully. However, humans are often able to maintain performance despite considerable stress by redirecting cognitive resources to the primary task, albeit potentially at the expense of secondary task performance. Task performance is only expected to become insufficient when this compensatory mechanism is no longer able to cope.

Current design rules and international standards specify maximum allowable limits on noise, vibration and motion levels on-board vessels. These limits assume that exposure above these levels would have detrimental effects on both physiological and cognitive performance of crew members. However, FAROS challenges the validity of this assumption.

Modern vessels are indeed quiet, have low vibration levels, and perform well in waves. The study showed that some design standards and requirements are indeed linked to physiological functions, for example, walking and how GDF exposure impacts the probability of being knocked off your feet and sea sickness. Therefore we can say, with some certainty, that some basic physiological performance of crew members can be improved by design. But what about safety critical cognitive functions such as working memory, comprehending and producing language, calculating, reasoning, problem solving, and decision making?

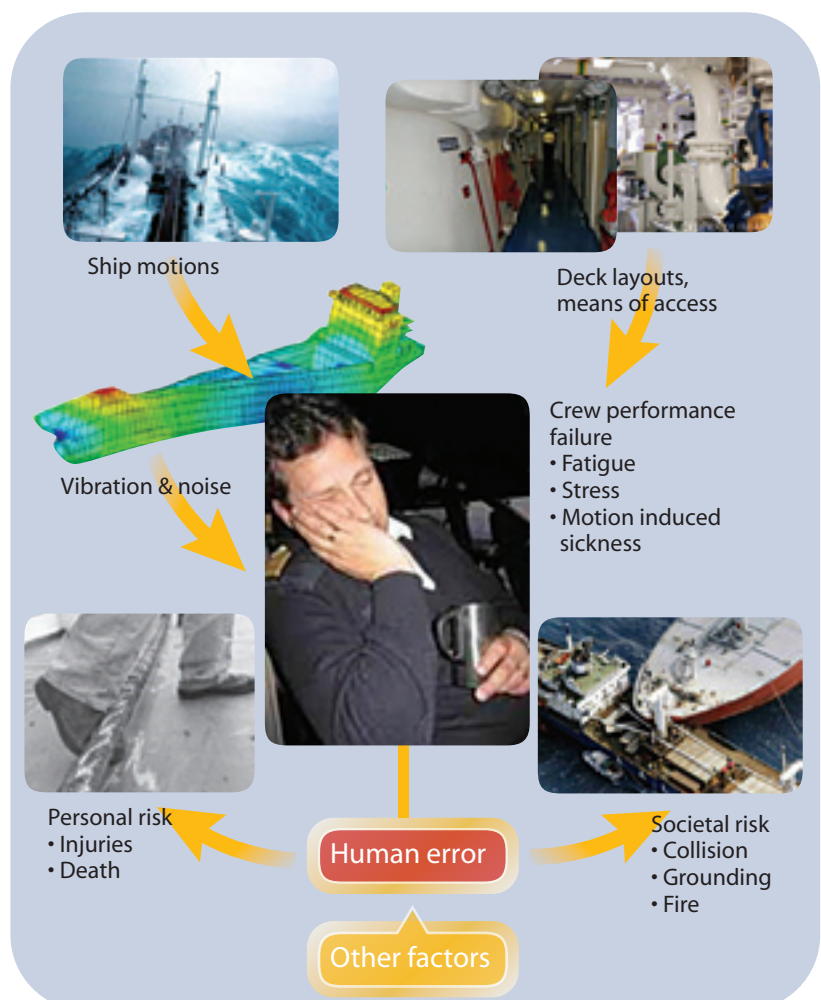
No evidence was found to support the assumption

that cognitive functions were considered when maximum allowable limits on noise, vibration and motion levels were selected. These limits seem arbitrary in this respect and do not cater for some of the most safety critical vessel tasks. This observation is further reinforced by the fact that maximum limits on noise and whole body vibration significantly vary from class to class (e.g. noise limits in the wheelhouse range from 55dB, according to ABS, to 65 dB, according to LR).

The findings by project FAROS highlight the need for more research into how GDFs impact the cognitive performance of crew members.

The research has to involve large scale experiments on bridge simulators, virtual reality environments simulating engine and other rooms, as well as on-board measurement. The ultimate objective would be to determine optimal conditions for human performance in normal operation, and compare them to corresponding design rules and guidelines.

Project FAROS is a European research project, which has been investigating the relationship between ship design and human performance



Onboard work and habitability environments

IMO MSC-MEPC.7/Circ.3 - *Framework for consideration of ergonomics and work environment* - provides guidance on the application of ergonomic solutions as a means to reduce personal injuries or accidents brought on by human error. It suggests that, when addressing ergonomics onboard ship, there are five key areas that should be considered; following each we offer a list of sources of information to assist with the application of these solutions:

- 1. Manual valve operation, access, location and orientation**, in order to better access and operate manual valves aboard ship.
 - *Guidance Notes for the Application of Ergonomics to Marine Systems*, Section 9 - ABS (2013)
- 2. Stairs, vertical ladders, ramps, walkways and work platforms.** The application of ergonomic design principles for ladders, ramps, walkways and work platforms.
 - *Guidelines for the Design of the Means of Access for Inspection, Maintenance and Operation of Commercial Ships* - Bureau Veritas (2008)
 - *Human element recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements* - IACS Rec. No. 132 Section 4.6 - Access and Egress Design
 - *Guidance Notes for the Application of Ergonomics to Marine Systems*, Section 7 - ABS (2013)
- 3. Inspection and maintenance considerations**, to ensure the accessibility, inspectability and maintainability of the ship's hull, machinery, lifesaving and fire-fighting appliances.
 - *Guidance Notes for the Application of Ergonomics to Marine Systems*, Section 10 - ABS (2013)

- *A guide to managing maintenance in accordance with the requirements of the ISM Code* - IACS Rec. No. 74
- 4. Working environment**, including: the layout of spaces; the ambient environmental characteristics of human whole-body vibration; noise; indoor climate; and vibration.
 - *Code on noise levels on board ships* - IMO Resolution MSC.337(91)
 - *Ships and marine technology -- Ship's bridge layout and associated equipment -- Requirements and guidelines* - ISO 8468:2007
 - *Guidelines for engine-room layout, design and arrangement* - IMO MSC/Circ.834
 - *Guidelines on ergonomic criteria for bridge equipment and layout* - IMO MSC/Circ.982
 - *Guidelines on the application of SOLAS Regulation V/15 to INS, IBS and bridge design* - IMO SN.1/ Circ.265
 - *Human element recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements* - IACS Rec. No. 132
 - *Recommendation for the application of SOLAS Regulation V/15 bridge design, equipment arrangement and procedures* - IACS Rec. No.95
 - 5. The application of ergonomics to design** how ergonomics can be considered during design for changes after construction.
 - *Ergonomic principles in the design of work systems* - ISO 6385:2004
 - *Guidance Notes for the Application of Ergonomics to Marine Systems*, Appendix 2 - ABS (2013)
 - *The Human-Centred Approach - A Best Practice Guide for Ship Designers and*

Builders - Lloyd's Register (2013)

IMO MSC-MEPC.7/Circ.3 does not cover Habitability, but this is now adequately covered by ILO MLC 2006 (see **Alert!** Issue No. 34, January 2014 centrespread and page 8).

IMO MSC/Circ.1014 - *Guidance on fatigue mitigation and management* - recognises a number of ship design features and environmental factors that can cause fatigue, or have an effect on workload and the crew's ability to sleep.

Those who are involved in the design of ships and their systems should be familiar with Module 7 of MSC/Circ.1014.

For further information, scan the QR code.



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