

The International Maritime Human Element Bulletin

Issue No. 3 April 2004



There are many factors that can ultimately affect the ability of the master and his crew to ensure the safe conduct of the ship, and the safe and timely delivery of its cargo. Poor ship design, bad ergonomics, equipment failure, fatigue, stress, boredom, commercial pressures, cultural differences, differing equipment designs, and a lack of proper training in the operation of equipment, all affect the way in which a ship is operated.

The human element is a critical feature of all aspects of ship or system design and operation. For any ship or system to operate safely and effectively, it must be designed to support the people who work it, without detriment to their health, safety and overall performance, particularly in respect of:

- workability
- controllability
- safety and emergency response
- maintainability
- security
- manoeuvrability
- habitability

In this issue of *Alert!*, the focus is on ergonomics - the science of fitting the workplace to the worker. In our central feature - *The A to Z of Ergonomics* - we offer some ergonomic definitions that are relevant to the design and operation of a ship and its systems, together with some pictorial examples of how the lack of attention to ergonomics can affect the mariner.

Comments on any of the articles or other human element issues are always welcome to: editor@he-alert.org

An ergonomic nightmare!

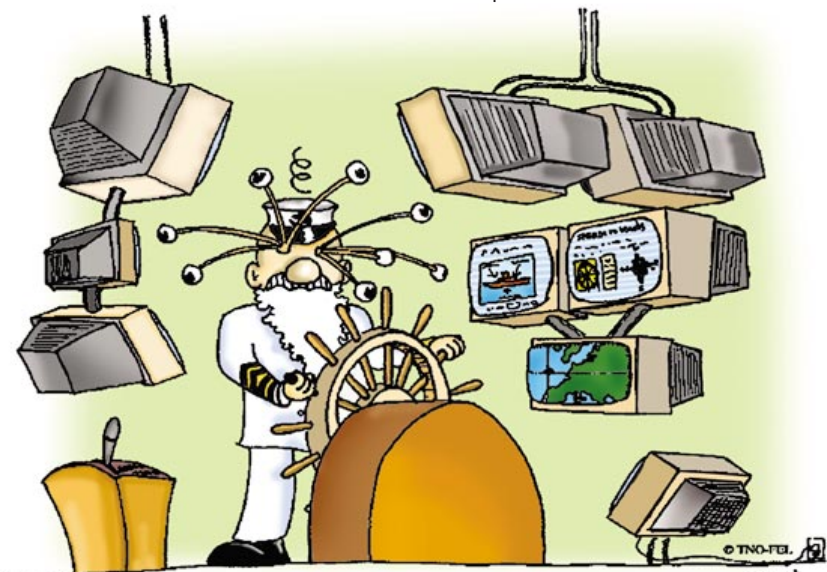
'An ergonomic nightmare' is an expression often to be heard emanating from the mariner, reflecting his opinion on the layout of the ship's bridge, or the engine room. The IMO definition of ergonomics is *the study and design of working environments (e.g., workstation, cockpit, ship bridges) and their components, work practices, and work procedures for the benefit of the worker's productivity, health, comfort, and safety.*

A ship is unique in that it is not only a place of work, within which there are a number of workspaces - the bridge, the machinery control room, the engine room, the cargo control room, cargo holds, galley etc - each of which may have different operational criteria, but also it is a 'home' to those who work onboard. Furthermore, it is a floating platform which can be affected by external and internal environmental conditions such as weather, temperature, humidity, noise, vibration and ship motion (pitching, rolling and slamming), any of which can also be detrimental to the safety and performance of those who work and live onboard.

The mariner is generally a trusting sort of person; he (or she) has implicit faith in those who have conceived, designed and built his ship. Alas, there is no such thing as 'the perfect ship', because the end product is inevitably a compromise between what is needed to satisfy the regulations, what is absolutely necessary to fulfil the operational role, and what is affordable. But, it must be 'fit for purpose' to enable the master and his crew to fulfil their obligations to ensure the safe conduct of the ship and the safe and timely delivery of its cargo. Put simply, for any ship or system to operate safely and effectively, it must be designed to support the people who operate it, without detriment to their health, safety and overall performance.

Ergonomic considerations do not just start at the design stage of a ship and finish at build - they must be applied throughout its lifecycle, especially when updating its role or its manning philosophies or when retro-fitting new systems or equipment.

If you don't get the ergonomics right, overall ship performance may be compromised!



A is for ... Attention

Improving the awareness of the human element in the maritime industry

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Harald Fotland
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Human error - a fragile chain of contributing elements

It is commonly agreed in the shipping industry that close to 80% of accidents are rooted in human error. The trend also indicates that there are fewer accidents caused by technical failure of a piece of equipment, and an increasing number that can be explained by human error. The problem is complex; human error may very well be due to an error in design, improper follow-up of the building process, or lack of proper routines on board. Some studies also indicate that a majority of the accidents due to human error may be traced back to factors where the ship's management has a strong influence, and in some cases direct control.

When establishing the cause of an accident, any approach focusing solely on the personnel on board will reduce the possibility of identifying the underlying cause. There must also be some focus on errors in design, poor ergonomics and technical solutions, and routines and procedures incorrectly implemented.

It is at the design and build stages that future accidents can be prevented with the least costs involved, and with the most long-lasting solutions. Gard believes that a

strong focus on design and optimal technical solutions, and on ergonomic solutions during the building phase, is fundamental in the prevention of future accidents. Some ship owners out-source construction management completely, whilst others believe in in-house site teams, close cooperation with the shipbuilder, and a continuous improvement of the design. The latter approach is probably the natural follow-up to a carefully organised design phase.

Ships and ship operations are becoming more and more sophisticated. New and advanced equipment is introduced on board, vessel speed and size is increasing, and advanced methods of operation are developed. In this context, selection of crew, familiarisation, advanced training, and a continuous focus on the correct implementation of procedures becomes vital for the safe operation of the vessel, as well as for the company's competitive edge. Gard has therefore supported a number of projects where new and advanced training methods have been developed, and will continue to do so in the future.

Alert!

The International Maritime
Human Element Bulletin

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SHIPBOARD MAINTENANCE - a top management responsibility



Ugo Salerno
Chairman IACS

The International Association of Classification Societies (IACS), comprising of ten member societies and two Associates, covers some 90% of the world's cargo carrying tonnage. Here, the important issue of shipboard maintenance is discussed.

While concern over ship casualties tends to focus largely on the age of a vessel, the quality and organization of maintenance remains a central issue. Shipboard maintenance is still the least-developed and weakest element in many of even the most well-intentioned companies. Indeed, maintenance tends to be regarded as the exclusive responsibility of technical staff, rather than the rightful concern of safety managers and Designated Persons.

The IACS Guide to Managing Maintenance may be downloaded from:

http://www.iacs.org.uk/document/public/Publications/Guidelines_and_recommendations/PDF/REC_74_pdf214.pdf

One of the prime responsibilities of a shipowner and ship management company is that the ship's hull structure, machinery and equipment are maintained and operated in accordance with applicable rules and regulations and any relevant additional requirements, procedures and standards established by the company. That responsibility starts from the top managers of the company, who should be committed to direct efforts, resources and investments in order to ensure that their ships are properly maintained and operated by qualified and competent crew. It is all too easy to lose sight of the fact that the fundamental responsibility for a ship's condition rests squarely with the owner of the vessel.

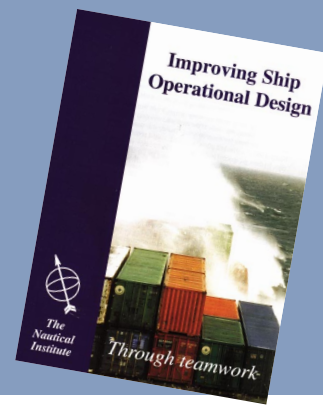
Ugo Salerno, the Chairman of IACS comments: *'Poor maintenance increases the risk of casualty, pollution and damage to property. Of all the Port State Control detentions attributed to failures in shipboard safety management systems, more have referred to maintenance than to any other clause of the ISM Code.'*

Improving Ship Operational Design

Operational design is a collective responsibility and should be shared between owners, mariners, designers and builders. The Nautical Institute publication *Improving Ship Operational Design* sets out to examine the problems found at sea due

to inattention to detail at the design stage. The Human element is addressed through expert advice on plan approval, design project management, through-life costings, the application of ergonomics and conflict resolution.

Further information can be found at: www.nautinst.org/en/Publications/index.cfm



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The Case for a Decent Design

Given that ships in various forms have been with us since the dawn of time, the perennial lament from end-users, namely the seafarers, about the incongruity of ship designs with respect to safety, security, practicality, functionality and operability, still goes on today.

Most seafarers are aware and accept that the underlying factor is 'economics' - the builder, the shipowner, the legislators and the designers are governed by it. However there is a fine line between commercial profitability and exploitation - the trick is in knowing where the compromise lies.

Thankfully, when it comes to safety and security issues, Flag Administrations and Classification Societies are continually introducing improvements for safer designs through regulations - often otherwise known as 'minimum requirements or standards'. The term 'standard', though, is subjective and can mean different things to different groups outside the regulated regime. However, if all stakeholders strive to achieve and agree on 'acceptable standards', then maybe

there will be less pressure on the designer to make political/economical decisions without compromising his/her integrity.

When it comes to the operational and practical aspects of a design, decisions are very much driven by cost. What may be a good idea or decent upgrade to a design is frequently translated into 'how-much-does-it-cost?' Perhaps this is one area in which naval architects are often misunderstood - incorporating what is good can sometimes mean pushing it too far till the project is no longer viable. The same is true for the shipbuilder, who takes the opposite stance to the owner. Tucked in the middle is the end-user.

The difference in standards or expectations can be quite remarkable between owners, builders and seafarers. For example, it is still common to find new ships built in Japan today intended for crews from developing countries to be equipped with shared or common toilets/showers. This may be permitted for signatory countries to the International Labour Organization (ILO) 1992 Convention but it will not be deemed to meet European standards. Another popular justification for low standards of equipment or accommodation is the fact that the owner may sell the ship within the next 3 years - so why spend all that money on improving the design when it will only benefit the future buyer? Such philosophy towards ship designs will not translate well

with naval architects, especially in the eyes of the people onboard.

So, where can we go from here?

For **future naval architects**, the Royal Institution of Naval Architects is actively pushing for sponsorships from ship owners and industry to provide young designers with the opportunity to spend time at sea/ industry and increase their awareness of good and bad designs, and their implications to the people serving onboard the ships.

For **practicing naval architects**, walking the fine line remains an occupational hazard but it is left to the individual on how to decide and convince the owner and/or the builder which of the 'wish-list' is not only nice to have but also 'good to have'.

For all **designers, owners and operators**, it is essential to maintain contact and encourage dialogue with the people at sea, as well ashore, as there is no substitute for practical knowledge and feedback on how well a design has performed. On this note, the Nautical Institute's publication *Improving Ship Operational Design* contains practical tips that will not be found in any college course work and is a good place to start.

For the **seafarers**, we know naval architects may not exactly feature high on your top ten list of favourite personalities, but they do listen and they do try to fulfil their professional obligation for safer and better designs within the confines of the project - so long as you don't ask for satellite TV in every cabin!



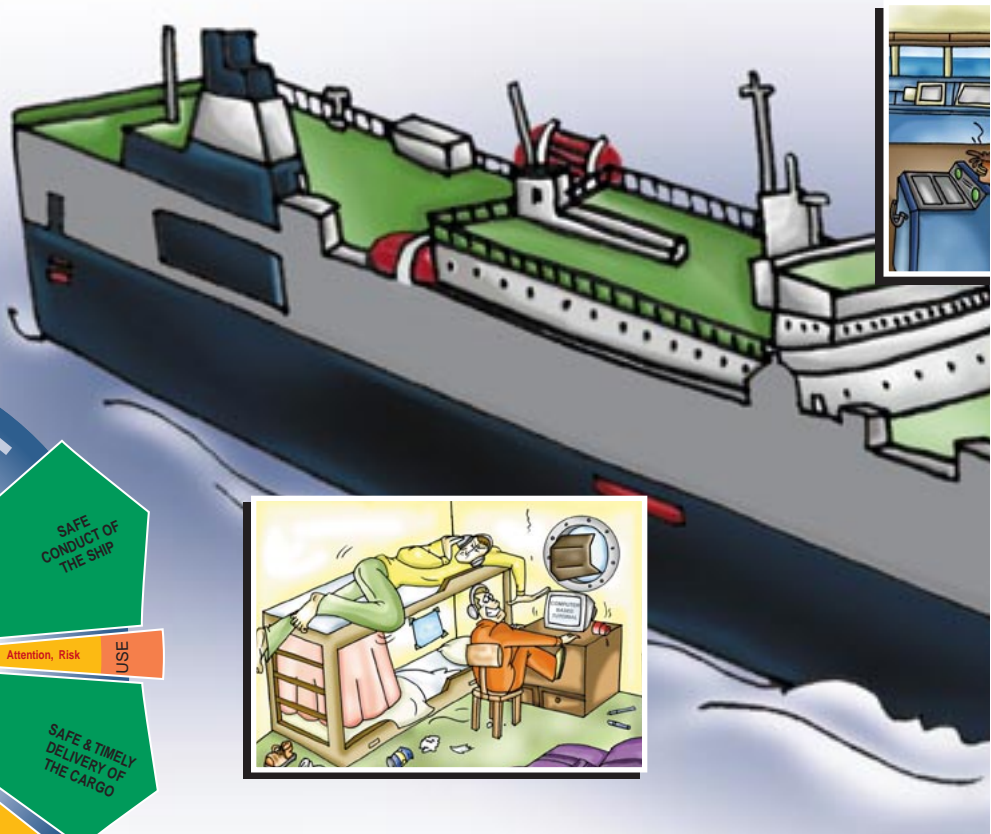
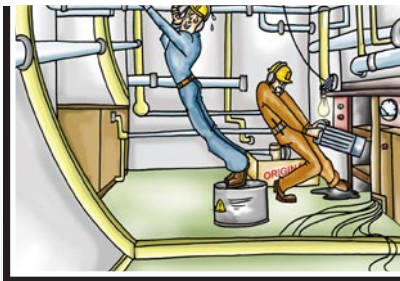
An A to Z of Ergonomics

ATTENTION - the faculty or power of mental concentration. **Divided** ~ applying one's mind to two or more tasks at the same time; **Selective** ~ monitoring several channels or sources of information at the same time so as to perform a single task; **Focussed** ~ concentrating on one channel or source of information; **Sustained** ~ concentrating over a prolonged period of time so as to detect infrequent signals.

BODY MEASURES - the ranges in size, shape and strength of the human body as a function of gender, race, and regional origin (Anthropometrics). The mechanics of human movement (Biomechanics).

CONTEXT OF USE - the users, tasks, equipment (hardware, software and materials) and the physical and social environments in which a system is used.

DISPLAY - a device or feature designed to provide status, position, or condition information to the operator through visual or auditory feedback.



If you don't get the ergonomics right, overall ship performance may be compromised!

WORKPLACE DESIGN - the physical design and arrangement of the workplace and accommodation - the whole ship - taking into consideration environmental conditions such as weather, temperature, humidity, air quality, lighting, noise, vibration, cleanliness, ship motion (pitching & rolling), and its effect on the safety and performance of personnel.

USER-CENTRED DESIGN - designing for users with users, in order to achieve systems that are effective, efficient, safe and satisfying to use.

VIM & VIGOUR - maintenance of strength and stamina through appropriate diet, rest periods, exercise, periodical medical review etc.



ERGONOMICS - the study and design of working environments (e.g., ship bridges, machinery control rooms, galleys) and their components, work practices, and work procedures for the benefit of the worker's efficiency, effectiveness, health, comfort, and safety.

FUNCTION ALLOCATION - the process by which tasks or functions are allocated between humans and machines/systems, and/or amongst different operators/maintainers.

GOOD PRACTICE - learning from other organisations that have developed successful projects or approaches to problems.

HUMAN PERFORMANCE - human sensory capabilities (e.g., sharpness of eye, hearing ability, sensitivity to touch), and the impact of environmental factors (e.g., lighting, noise) on human sensory systems, as well as mental capabilities for storing and processing information and for making decisions.

INTEGRATED SYSTEM - a collection of applications on computer based systems and equipment designed to provide correct, sufficient, timely and unambiguous information to, and support control by, one or more users.

JOB DESIGN - the specification and achievement of successful job performance, typically focussing on tasks, responsibilities, accountabilities, knowledge and skill requirements.

KNOWLEDGE - a theoretical and/or practical understanding of a subject.

LAYOUT - the integration of people with equipment, systems, and interfaces, such as controls, displays, alarms, video-display units, computer workstations, labels, ladders, stairs, and overall workspace arrangement.

MAINTAINABILITY - designing operational maintenance tasks to be rapid, safe and effective in order to allow equipment and systems to achieve a specified level of performance. This includes consideration of access, removal routes, tools, expertise, disposal, and through life support.

NORMAL - conforming to a standard; regular, usual, typical.

OCCUPATIONAL HEALTH AND SAFETY (OHS) - the effect of work, the working environment and living conditions on the health, safety and well-being of the person.

PERFORMANCE SHAPING FACTORS - the environmental, ergonomic and job design factors that are correlated with effective and safe task performance by a human working within a system. (See Alert! Issue No 2).

QUALITY OF LIFE - the combination of good occupational health and safety, good workplace design, good management and the impact on a person's physical and psychological fitness to work at sea.

TRAINING & COMPETENCE - the development of skills or knowledge through instruction or practice; and the levels of proficiency achieved for the proper performance of functions onboard ship in accordance with internationally agreed criteria, incorporating prescribed standards or levels of knowledge, understanding and demonstrated skill.

RISK - the probable rate of occurrence of a hazard causing harm and the degree of severity of the harm.

SYSTEM - a combination of interacting elements (human and/or machine) organized to achieve one or more stated purposes.



The Human Element in Pilotage



Captain Steve Pelecanos
Vice President
International Maritime Pilot's Association



Of all the working environments in the maritime industry, a ship's bridge during pilotage operations is perhaps the one most likely to breed human behavioural and performance induced errors. A key role of the pilot therefore, is to use such management techniques and skills that ensure appropriate controls and defenses are in place to reduce the risk of human error.

The modern-day bridge is a complex mix of physical, psychological and pathological variables that can impact on human performance.

For example, it is common in today's shipping environment for the pilot to arrive on a ship and be greeted by a multi-national bridge team where language and culture can impair proper communications. It is also common to find a bridge team of varying competencies where a proper understanding and appreciation of the pilotage operation cannot always be assumed.

Non-standardisation of bridge equipment, symbology and bridge layout can also add to confusion, especially as the operating

environment intensifies, as in the case of reduced visibility, increased traffic density and narrow operating margins.

Commercial pressures on the pilot and master as always are a source of stress. These may be in the form of requests to use fewer tugs or to berth/unberth within certain time-frames. It is not unusual to find a fatigued master and crew, especially when a ship is making a number of port calls within a short space of time (as in the case of container ships and car carriers). The pilot cannot depend on proper back-up from the bridge team in such circumstances. Fatigue induced stress can also be caused by adverse weather, high workloads and poorly planned duty cycles that do not incorporate sufficient rest periods.

One would think that the plethora of new technologies that find their way onto ships' bridges would go some way toward

easing the workload of the bridge team. However, it is ironic that the more advanced the control system, the more crucial we find is the contribution of the human operator. It is common to find bridge teams that are not properly trained in the use of these new technologies and it is ultimately the pilot that has to properly understand the limitations of such equipment in confined waters.

Within this complex, highly operational and time critical environment there is a potentially volatile mix of the key ingredients that lead to the classic human error type accidents. In order to improve safety and efficiency, it is important for the shipping industry to understand and acknowledge this critical aspect and implement strategies to address the issues arising from this recognition. The airline industry's experience in this area can assist us enormously.

(See page 8, Reports and Studies - **SPLASHER**)

Prevention through People: An Overview

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Since 1994, the U.S. Coast Guard, in cooperation with the maritime industry, has been working to refocus accident prevention efforts toward the human element. Prevention Through People (PTP) is the US Coast Guard's cornerstone strategy for guiding efforts in pursuit of safety, security, and environmental protection. PTP systematically addresses the root cause of most accidents and incidents - the human element. PTP also recognizes that a major portion of mishaps comes from organizational errors, and that a safe and profitable operation requires a balanced interaction between management, the work environment, the behaviour of people, and the technology available.

Therefore, PTP promotes positive cultural changes within organizations.

An organization with a solid safety culture can identify and manage current risks, greatly reducing the risk of incidents that may lead to severe losses, costly or arduous reforms, or loss of public image. Over the past decade, the PTP approach enabled the development of many non-regulatory programs, with the following guiding principles:

- Honour the mariner
- Take a Quality approach
- Seek non-regulatory solutions
- Share commitment
- Manage risks

PTP has also enabled the development of our Risk-Based Decision-Making (RBDM) resources. These resources help decision

makers make more informed management choices by providing methods to calculate the possibility of unwanted outcomes. PTP also made possible the development of the Crew Endurance Management (CEM) program. More than just fatigue management, CEM provides a systematic method for an organization to optimize crew productivity and take charge of its safety culture.

PTP is a systematic, people-focused approach to reducing security threats, casualties, and pollution. Working together, PTP is helping us make the seas cleaner, safer, and more secure.



www.uscg.mil/hq/cg5/cg5211/cems.asp

Anthropometry - Designing to fit the user

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Denise B McCafferty
(Safety Assessment & Human Factors Manager, American Bureau of Shipping)

Anthropometrics is the branch of ergonomics which deals with body measurements, particularly those of size, strength and physical capacity. Good ergonomic design makes provision for the range of variability to be expected in the user population.

Variation in user population can affect design for safety. For example, in the Nautical Institute's book *Improving Ship Operational Design* (see page 3) the point is made that Korean and Japanese ship designs assume that the height of seafarers will be about 5'6" (1.68m) rather than 6' (1.83m), and that extra length in bunks and settees may be required for European crews. Furthermore, the International Life-Saving Appliance Code specifies a seat accommodation of 433 mm, but field anthropometric measurements of Gulf of Mexico offshore workers have revealed an appropriately clothed hip width of 533 mm - a potential overestimate of maximum lifeboat occupancy for this population by about 20%. A similar difference in average weight (75 kilos v 95 kilos) had the potential to affect buoyancy and stability.

The application of anthropometry to design establishes limits (or boundary conditions) for sizing equipment for human use. In essence, it defines size limits in design based on the dimensions of the anticipated population of operating and maintenance personnel. By imposing size limits in design (e.g., designing so the shortest expected operator or maintainer can reach all controls), it follows that personnel who are less demanding in their requirements will also be accommodated (e.g., have greater reach than the limiting personnel).

Given the range of variability of human bodily dimensions, anthropometric data are typically expressed as percentile

statistics. A percentile statistic defines the anthropometric point at which a percentage of a population falls above or below that value. For any body dimension, the 5th percentile value indicates that 5% of the population will be equal to or smaller than that value, and 95% will be larger. On the other hand, the 95th percentile value indicates that 95% of the population will be equal to or smaller than that value, and 5% will be larger. Therefore, use of a design range from the 5th to the 95th percentile (for either male or female populations, but not both) values will theoretically provide coverage for 90% of that (male or female) population using those limiting dimensions, and only those smaller than the 5%, and larger than the 95% will be excluded by design.

However, the notion of the *average person* is misleading in that an individual will vary among different anthropometric dimensions. For example, individuals who are of average (50%) stature can be comparatively smaller or larger on other dimensions, such as arm length.

In general, there are four principles of applied anthropometrics in design:

1. Design for the Smallest - applies primarily to application of physical force and vertical and lateral reach distances, such as the forces required to pull, push, or turn a handle. Usually, the maximum force that can be readily applied by the 5th percentile person for that movement is used as the criterion. Similarly, the reach of the 5th percentile person is often used as the criterion.

2. Design for the Largest - applies primarily to clearances, such as escape hatches, maintenance accesses, lifeboats, walkways, and overhead clearances. Clearances generally are such that at least 95% of the expected population is

accommodated. In some cases, persons whose body size exceeds the designed clearances are precluded from selection for the system.

3. Design for the Average - applies to workstations that are not adjustable (e.g. fixed height tables, desks, or other work surfaces). In these situations, designing for the average person better accommodates the entire population.

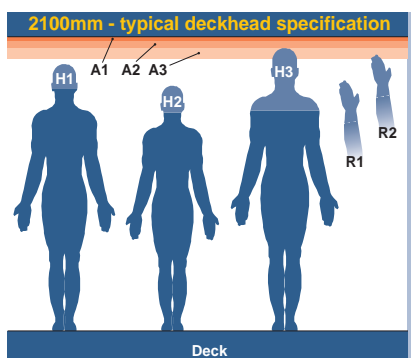
4. Design for the Range - applied to determining the amount of adjustability that should be built into such things as variable height work surfaces and workstation seating (e.g. horizontal and vertical adjustability). In general, the dimension criteria used for designing adjustability readily accommodates the middle 90% of the population.

The Figure summarises some of the issues involved in headroom and related topics.

The seafarer population is changing - not only in terms of nationality but also in that there are an increasing number of women seafarers. This is a design issue as well as an employment one. Using limiting dimensions for males and females (5th percentile female and 95th percentile male) will accommodate approximately 94% of the entire design population (since over 99% of males are larger than the 5th percentile female, and over 99% of females are smaller than the 95th percentile male, so few small males, or large females, are excluded).

In summary, anthropometric data and guidance exist to enable designers to identify limiting dimensions to use, based on an understanding of the context of use, i.e. the users, the tasks and the environment.

A free download of the ABS Guidance Notes for the Application of Ergonomics to Marine Systems can be obtained from www.eagle.org



This figure shows a typical headroom clearance and some related design factors. **A1, A2, A3** are allowances that may need to be made. **A1** - 25 mm for normal footwear; **A2** - 50 mm for the dynamic characteristics of walking and starting; **A3** - 75 mm for a hard hat. *Adding a safety clearance factor is a matter of assumption and judgment.* **H1, H2, H3** are the variations in height (stature) for three different populations (5th percentile to 95th percentile). **H1** - N European males, compatible with the deck height (design for the maximum); **H2** - male Philipinos; **H3** represents a range from a small female to a large male for a population up to 2015.

This is (just) compatible with the deck height but with no hard hat or safety factor allowances.

R1 (South Indian), **R2** (UK) are 5th percentile vertical functional reach heights for the two different populations.

For Europeans, controls over walkways are not quite possible, while for a wider population they are definitely out of reach.

Collision

between a Ro-Ro ferry and a moored vessel

This is a report of an incident, for which the immediate cause was human error but where there were a number of latent causes associated with the environment, equipment failure, and system layout and bridge resource management.

As a high-sided RO-RO passenger ferry was in the final turn to starboard on passage to her berth, in 35 to 40 knot winds, and passing close to a moored vessel, an inappropriate helm order was given by the master, which was not noticed by the other members of the bridge team. Shortly before the collision one of the two bow thrusters had tripped out and could not be brought back into operation immediately, the lack of which reduced control authority.

At the time of the accident the master had the con and was stood at the central control console from where he had a good view forward horizontally and down to the bow, but did not have a clear view of the vessels moored to starboard. The engine and thruster controls were within easy reach, but the layout of the console did not

allow one person to operate helm, engine and thruster controls from a single position, nor could he see the panoramic Rudder Angle Indicator (RAI) without taking a step back. He was steering the vessel with verbal helm orders which were repeated back to him by the helmsman. Control was therefore split (verbal and direct) and the master became overloaded and gave an inappropriate verbal order. He lost situational awareness, and was unaware of the rudder position in the time between giving the order and the collision.

The chief officer was standing forward of the starboard bridge-wing manoeuvring console, from where he had a good view forward and aft down the vessel's starboard side, but where sight of the engine and thruster controls was awkward, and sight of the RAI could only be achieved by changing position. He was about 14 metres from the master, such that he was not in his direct line of sight. He could shout advice to the master and could, if he listened carefully, hear the

helm orders given by the master and repeated by the helmsman.

The report concludes that the way that the bridge team was deployed, and the ergonomics of the instrumentation on the ferry, meant that monitoring of the master's actions (by the chief officer and the helmsman) and those of the helmsman (by the chief officer and the master) was difficult and not effective, because the master did not have easy sight of an RAI from his conning position, and the chief officer could neither hear the orders easily nor easily see an RAI.

The full report can be downloaded from: <https://assets.digital.cabinet-office.gov.uk/media/547c70e1e5274a42900000e1/pride-of-portsmouth.pdf>

The lessons to be learned from this accident should be of interest to all designers and operators of large ferries

Reports & Studies



STARTING POINT TO LEARN ABOUT SAFETY AND HUMAN ERROR RISKS

The Joint Aviation Authorities Human Factors Steering Group has produced a very useful bulletin - **SPLASHER** - which lists human element related reference material, some of which can be easily translated to the maritime environment.

Other useful documents are:

Flight Crew Training: Cockpit Resource Management (CRM) and Line-Oriented Flight Training (LOFT)

<http://publicapps.caa.co.uk/docs/33/CAP720.PDF>

Flight-crew human factors handbook
<http://publicapps.caa.co.uk/docs/33/CAP%20737%20final.pdf>

IMO GUIDELINES FOR ENGINE-ROOM LAYOUT, DESIGN AND ARRANGEMENT

(MSC/Circ.834, January 1998)

The purpose of these guidelines is to provide ship designers, ship owners, ship operators, shipping companies, shipmasters and engine-room staff with information to enhance engine room safety and efficiency through design, layout and arrangement. These guidelines are intended to improve engine room safety and efficiency and overall vessel safety, through good decision-making with regard to engine room layout, design and arrangement. They focus on the human-machine environment of the engine-room, with particular emphasis on familiarity, occupational health, ergonomics, minimising risk through layout and design, and survivability.

MSC/Circ.834 can be downloaded from:

www.imo.org/blast/DataOnly.asp/dataid%3D8819/834.pdf