ATOMOS IV

REVISION

WP8.5 RATIONALE FOR SOLAS REGULATION V/15 TEMPLATE

Document ID Code: A408.05.08.055.002

Date: 2003-10-12

Contract No. 1999-CM.10540

CLASSIFICATION AND APPROVAL

Classification: Public after Review

DEFINITIONS

<u>Public after Review:</u>

The document may be freely distributed after successful EC review. Publication is governed by the EC Contract and the DISC Consortium Agreement

<u>Confidential for the Duration of the Project:</u>

As for 'Confidential', but only for the duration of the Project. After final Project Approval by the EC, status for reports classified 'Confidential for the Duration of the Project' are automatically down-graded to 'Public'.

<u>Confidential:</u>

The document is for use of the Contract No. Contractors within the ATOMOS IV Consortium, and shall not be used or disclosed to third parties without the unanimous agreement within the ATOMOS IV PMC and subsequent EC approval since document classification is part of the EC Contract.

<u>Confidential for the Task:</u>

The document is for use of the 1999-CM.10540 Task Participants, and shall not be used or disclosed to third parties without the unanimous agreement within the Task Participants and subsequent EC approval since document classification is part of the EC Contract.

AUTHORS:

Name	Date	Signature
Brian Sherwood Jones, Lloyd's Register, UK		
Jonathan Earthy, Lloyd's Register, UK		

APPROVAL:

Approved for release by:

Jonathan Earthy, Lloyd's Register, UK

DOCUMENT HISTORY:

Issue:	Date:	Initials:	Revised Pages:	Short description of changes: File name:
001	2002-12-17	JVE/BSJ	New	A408.08.053.010_bsjv1a
001a	2002-12-20	JVE/BSJ	all	Editorial response to comments. As document reference. A408.08.061.010
001b	2003-02-17	JVE/BSJ	all	Response to meeting of 27/28 Jan 2003 Updated rationale A408.08.061.010
002	2003-05-06	JVE/BSJ	all	Conversion to ATOMOS template from LR ATOMOS TN format. Response to meeting 2003-04-22/24, A408.08.061.010revisedv1a
002a	2003-05-19	JVE/BSJ	all	Addition of sections on barriers and aspirations for incident prevention. Local comments added throughout. A408.08.053.002v2
002	2003-06-03	JVE/BSJ	all	Response to comments from Jorgen Rasmussen A.408.08.053.002v4
002	2003-06-09	JVE	all	Response to comments from NTUA and CMR. First version as document type 055 A.408.08.055.002
Etc.				

DISCLAIMER

Use of any knowledge, information or data contained in this document shall be at the user's sole risk. The members of the ATOMOS IV Consortium accept no liability or responsibility, in negligence or otherwise, for any loss, damage or expense whatever sustained by any person as a result of the use, in any manner or form, of any knowledge, information or data contained in this document, or due to any inaccuracy, omission or error therein contained.

The European Community shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof.

CONTENTS

1 INTRODUCTION

Lloyd's Register (LR) has a continuing programme of Rules development for computer systems in marine applications. This programme takes account of both the increasing degree of integration of marine computer systems and the increasing awareness of software-related safety issues. As part of long-term Rule development, LR is involved in the European Waterborne Transport research initiative through the ATOMOS® and DISC initiatives. These initiatives are realised through a series of projects to develop and test open, user-centred integrated control systems. In ATOMOS II and the related DISC and DISC II projects LR investigated alternative ways of assessing the safety of marine computer systems.

The ATOMOS family of projects is a part-funded project under the Waterborne Transport research programme. The strategy of ATOMOS is to enhance maritime safety and efficiency by combining evaluation of user needs with technology development. The ATOMOS IV project has five themes:

1. The development and validation of a process and tool to support equipment upgrade strategy for the European Fleet. This is the main deliverable for the project;
2. A trial retrofit of an advanced control system to an icebreaker. This will involve a detailed analysis of the requirements, development and/or adaptation of components, evaluation and refinement of the user-system interface using simulator trials, integration and installation of the complete system and sea trials to prove the concepts and operational capability of the system;
3. Full verification and validation of the retrofit project. The project will use a risk-based approach and perform all the evaluation activities required by the latest standards in safety-related IT systems development. These will be subjected to third party assessment. This assessment will be a validation of a new approach to the problem of certification of complex systems;
4. Project evaluation. The project will be extensively evaluated for safety and cost-benefits of retrofit. The findings will feed back into theme 1;
5. Project dissemination. In order to achieve maximum impact from the work the activities on, and findings of, the project will be actively disseminated to all relevant parties using techniques ranging from web sites to development of standards.

The ultimate objective of the research is the widespread acceptance and subsequent adoption of the results generated. This work was carried out in Task 8 of the ATOMOS IV project. This document addresses objective 5 in the above list.

2 ABOUT THIS DOCUMENT

2.1 Purpose

This document is a supporting document to a set of templates for making submission statements attesting conformance with SOLAS Regulation V/15 2002, referred to in this document as the Regulation. It is intended to give guidance to Administrations and owners making submissions in the interpretation of the Regulation and its application.

The set of templates comprises three templates for conformance to decisions of different scale. The templates are as follows:

- A pocket card (performance aid) for day to day changes (A408.05.08.055.003);
- A form for attesting conformance to minor changes e.g. fitting a new item of equipment (A408.05.08.055.004);
- A more extended form with guidance for preparing submission statements for major retrofits and new builds (A408.05.08.055.005).

The intended use of these templates means that the ATOMOS report format is not suitable for the templates. These will therefore be produced separately but bound in this one volume for delivery to the EC.

2.2 Scope

The rationale to support a set of templates for the submission of evidence of consideration of the Human Element in Ship Control Centre design and operation.

The interpretation of the Regulation as innovative is presented. The approach to demonstrating conformance is described. The roles and responsibilities in compiling a submission to an Administration are described, together with the information flow and management of data. The relationship between SOLAS Regulation V/15 2002 and other regulatory requirements is outlined. Guidance to assessors in reviewing submissions based on the templates is given. A bibliography of information sources used is provided.

Regulators that wish to examine submissions for compliance to good practice may require a different version of the guidance provided here, annotated with suitable guidance. Since there is currently no consensus on the form of such examination this version is based on the assumption that assessors will be sufficiently skilled in human element issues to not require such guidance beyond the technical discussion contained in this document and the templates.

2.3 Background of the readers

Readers are expected to have an understanding of the ATOMOS initiative and its goals and the rationale for the inclusion of the Regulation in the 2002 revision of SOLAS chapter V.

Assessors using this document are expected to have (or have access to) skill and knowledge in addressing human element issues sufficient to judge if the attestation in a completed template is valid.

2.4 Legal and contractual aspects

Attention is drawn to the disclaimer on page 3 of this document.

Any dispute concerning the provision of LR's services and/or the contract under which such services are provided is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Lloyd's Register of Shipping, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'LR Group'. The LR Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant LR Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

2.5 Evolution to date and response to comments and initial trials

The initial document combined the rationale with the template. It was decided to separate the various versions of the template, and to make this rationale document a separate ATOMOS report.

The initial version of the template was worded with Administrations as the target audience and the wording stressed the mandatory aspects of conformance to the Regulation. Following an ATOMOS meeting 27/28 January 2003, the template was changed to act as a record to support a submission statement. Following the trial of the template at DMI 22/23/24 April 2003, it was decided to give the template more procedural support to the user in terms of specific questions to answer and boxes to fill in, but without losing the need for thoughtful consideration of the decision. It was also decided that the distinctions between mandatory aspects and guidance aspects should be retained, in the form of guidance to assessors in this document.

The major finding from the trial at DMI was the closeness of the linkage to BRM and the need to focus on the specifics of the aims in the Regulation.

The version of the templates issued in conjunction with this version of the rationale reflect discussions with regulators, Masters, owners and ship managers. The major change in the templates has been to clarify who completes which section and to structure the decision making more completely. The role of the system engineer has been introduced to the templates.

2.6 Document maintenance

This document is a final deliverable from ATOMOS IV task 8. This document will not be revised after approval and release.

NOTE 1: As described above the templates will be issued separately in a simple format for review, trial and dissemination. It is expected that they will be incorporated into the existing document systems, e.g. of Administrations and companies, rather than being maintained in their own right.

3 DEFINITIONS

Note: The definitions for alarms, warnings and the different types of alarms have not been included here, as it is understood that the IMO Code on Alarms and Indicators (1995) is being revised.

Abnormal condition When internal technical system failures require operation of basic back-up systems or when they occur during an irregular operating condition, or when the officer of the watch becomes unfit to perform his duties and has not yet been replaced by another qualified officer.

Aim The Regulation has seven aims to be considered when making decisions.

ALARP As Low As Reasonably Practicable. The degree of risk in a particular activity or environment can be balanced against the time, trouble, cost and physical difficulty of taking measures to avoid the risk. The greater the risk, the more likely it is that it is reasonable to go to very substantial expense, trouble and invention to reduce it. (UK HSE HS (G) 65)

Change Some decisions (see below) result in a change to manning, training, operation, equipment installation or ship design. The Regulation applies to the decision, but as the decision is implemented it can be more appropriate (in a template) to talk about a change.

Context of Use The users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a system is used. (ISO 9241-11)

COTS: Commercial Off The Shelf

Decision The Regulation applies to decisions that affect safe and effective operation of the bridge/SCC.

Distress situations When the ship has lost its navigating or manoeuvring capability.

Emergency situation When failure of internal ship systems not affecting the ability of navigation or manoeuvring, or fire incidents occur which need to be controlled and managed from the bridge.

Ergonomic criteria (Informative) Elements of recommendation or advice derived from the application of the human sciences to the design of a worksystem.

EXAMPLE The main text of IMO MSC Circ.982, ISO 9241 Parts 12-17

Ergonomic principles (Normative) Requirements regarding the ergonomics of a worksystem.

EXAMPLE The principles of software ergonomics in ISO 9241 Part 10

Event Occurrence of a particular set of circumstances. (IEC Guide 73)

Factor An aspect of design or operation that affects safe and effective operation. The factors cover training and manning, operation, equipment design and bridge design. Changing one factor may create issues in any or all factors.

Harm Physical injury or damage to the health of people or damage to property or the environment. (IEC Guide 73)

Hazard Potential source of harm. (IEC Guide 73)

HCI Human Computer Interaction

Irregular condition When external conditions cause excessive operator workloads requiring professional assistance on the bridge.

IEC International Electrotechnical Commission (standards body for electromechanical and electronic issues)

ISO International Standardisation Organisation (standards body for issues and items not reserved to a specialist body)

Issue Candidate for a hazard.

Mode awareness The mariner's understanding of the functionality and design intent of the various operating modes provided by SCC systems and their interaction.

Mode error Inappropriate action taken by the mariner based on incorrect mode awareness.

NOTE: The major performance shaping factor in mode errors is inadequate display of operational status combined with inadequate training.

Normal condition When all shipboard systems and equipment related to primary bridge functions operate within design limits, and weather conditions or traffic do not cause excessive operator workloads.

Novel feature A function, aspect, use or some other attribute of a service or product that is different from a previous version, application or use of that service or product.

NOTE 1 A novel feature has one or more of the following attributes: Introduction of a new technology, introduction of a new concept of interfacing with the crew, different use of an equipment with or without its integration in interfaces, or the introduction of a new operational procedure.

NOTE 2 A novel feature is introduced if commonly-held beliefs and understandings, or conditioned practices and learned procedures are changed significantly by the introduction of a new technology or concept. A novel feature is introduced where negative transfer of training may be introduced.

OSH Operational Safety and Health

Risk Combination of the probability of an event and its consequence. (IEC Guide 73)

SCC. The system of work housed in the bridge, including non-navigation functions such as administration and cargo handling.

Situation awareness The mariner's perception of the navigational situation, the state of ship systems and the bridge team activity, the comprehension of their meaning and the projection of their status in the near future, as required for the timely reaction to the situation.

Source Item or activity having a potential for a consequence. (IEC Guide 73)

System engineer A role that manages the emergent properties of the work system and reviews the consistency and coherence of aspects of the work system that cut across scope of supply boundaries e.g. aligning equipment supply and training provision.

Workspace A volume allocated to one or more persons in the work system to complete the work task. (ISO 6385)

Worksystem The work system comprises a combination of people and working equipment, acting together in the work process, to perform the work task, at the work space, in the work environment, under the conditions imposed by the work task. (ISO 6385)

4 INTRODUCTION

The ATOMOS Consortium is uniquely placed as a source of expertise on SCC design and operation to support the interpretation and implementation of SOLAS Regulation V/15

(Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures).

Conformance to the Regulation should be declared in a submission statement. The ATOMOS expertise has been used to develop a set of templates to assist the owner in this task. The principles-based approach developed by the Consortium has been used in the development of the template.

This project note describes the structure of the template, with a statement of the rationale behind it, and a bibliography of the source material used.

Some notes on terminology is appropriate. The Regulation uses the word 'aim' to describe the seven objectives to be considered when making decisions that relate to bridge design, equipment and procedures. The word 'principle' occurs in the title of the Regulation and in MCA guidance. Accordingly the word principle is treated as a reserved term, and where ATOMOS would normally use the word 'principle' the word has been replaced with 'issue' to avoid confusion outside the Consortium. For ease of reference, the Regulation is copied below.

> *All decisions which are made for the purpose of applying the requirements of regulations 19, 22, 24, 25, 27 and 28 and which affect bridge design, the design and arrangement of navigational systems and equipment on the bridge and bridge procedures* shall be taken with the aim of:*
>
> *1.1 facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;*
>
> *1.2 promoting effective and safe bridge resource management;*
>
> *1.3 enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;*
>
> *1.4 indicating the operational status of automated functions and integrated components, systems and/or sub-systems;*
>
> *1.5 allowing for expeditious, continuous and effective information processing and decision- making by the bridge team and the pilot;*
>
> *1.6 preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot; and*
>
> *1.7 minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.*

* Refer to Guidelines on ergonomic criteria for bridge equipment and layout (MSC/ Circ.982)

* Performance standards for IBS (resolution MSC.64(67); annex 1); and for INS (resolution MSC.86(70); annex 3).

The Regulation came into force for all relevant decisions made on all ships from July 2002.

5 Interpretation of the Regulation

The recently introduced Regulation, SOLAS Regulation V/15 (Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures), is not easy to understand and there are many interpretations of it e.g. it has been described as moralistic. Even within ATOMOS, ergonomists, manufacturers and surveyors read the intention of the Regulation very differently. A number of possible ways of applying the Regulation are under discussion in various fora. The templates proposed as part of this work package are based on a detailed analysis of the activities that led up to the Regulation, discussions with those responsible for drafting it and careful review of the wording (e.g. see 408.06.08.061.009a). The templates draw on the most extensive dataset available to the Marine sector.

Annex 1 offers some comments on the aims in the Regulation.

The Regulation is considered to be innovative in nature. It cuts across the life cycle (e.g. Decision for new build, plan approval, build survey, ISM) and activities by a range of stakeholders. It addresses the work system rather than being focused on either equipment or manning and training. Any demonstration of conformance would require forms of analysis new to the marine sector. The investigations that led to the development of the templates identified that these innovations are intentional and should be addressed.

In addition, it has been determined that, while the Regulation applies to decisions applying the requirements of Regulations 19, 22, 24, 25, 27 and 28, it also applies to decisions that affect bridge design, bridge equipment and bridge procedures. For example, adding engine room alarms to the bridge would need to be considered in relation to the aims of the Regulation. However, additional alarms in the engine room would not form part of the scope of the Regulation.

5.1 Scope of the Regulation and required response

Because the Regulation is under the heading of SOLAS Chapter V, its scope is constrained to Navigation. ATOMOS has recognised that the scope of activities on a modern ship's bridge goes well beyond Navigation, and also that there is considerable commonality between different types of control centre. Accordingly the template is sufficiently general to address the full scope of ship control but recognises the boundaries of the Regulation.

The analysis that led to the template concluded that the decisions affected by the Regulation include decisions related to navigation carriage requirements, but also other decisions, including operational decisions, that affect, say, the effectiveness of bridge resource management.

Regulatory Approval of ship control as a socio-technical system is currently split among a number of agencies. The templates make no attempt to change approval responsibilities. Demonstrating conformance to the Regulation does, however, require a consistent approach to obtaining these approvals. For example, if safe operation of an item of equipment requires specific training, then it is necessary to show that this training has been identified, implemented and monitored for effectiveness. The responsibilities for equipment approval and for approval of policy for resources and personnel are unchanged.

The Regulation is seen as endeavouring to introduce a unifying effort to integrate human engineering and to give full consideration to Human System Integration, as sought in the NTSB Report on the grounding of the ROYAL MAJESTY. The response proposed here is at the level of the work system rather than solely at an equipment or training level. An implementation at the level of the work system is seen as necessary to prevent incidents such as ROYAL MAJESTY. The relationship between the Regulation and incidents is discussed in Annex 2.

Annex 2 also discusses the state of existing design standards and guidelines in relation to the Regulation, and proposes some possible ways ahead.

The template for major retrofits and new builds provides a structure for the new forms of analysis that are required to go from owner's requirements, through to a design, and finally an operating solution. Such analysis is required by the Regulation due to the introduction of new technology, new types of crews and increased demands for safety. There are currently many clauses in SOLAS that implicitly or explicitly address human element issues in bridge design.

For example, indicators and alarms, decision support systems, fire panels, bridge-bridge communications, etc. The template has been used as an opportunity to propose a common treatment for all requirements in a way that delivers a consistent, integrated design solution.

The Regulation applies to all ships all the time. It applies to decisions that affect bridge design, the design and arrangement of navigational systems and equipment on the bridge and bridge procedures. The logical starting point for information gathering is therefore decisions made during ongoing operations. The scope of application of the Regulation and the template ranges from a review of existing procedures through to the design of a new bridge. The technology addressed ranges from minimum equipment, through COTS, to novel or specific designs. In the case of spec build, the information submitted will need to be sufficiently general to cover the range of uses and crews envisaged as the basis for the design.

The risk incurred by a decision is not necessarily correlated with the scope of the decision. A small decision made by the Master and bridge team may be as risky as a decision to build a novel SCC. The potential consequence for all sizes of decision is loss of ship and crew.

5.2 Success criteria and minimum standards

A question that is as yet unanswered is that of the success criteria. What level of excellence in layout, equipment design, procedures development, manning, training and competence is required? It would be possible to set standards so high that very few ships met them. It would also be possible to set them at a level where most ships under reasonable management and free of obvious design flaws meet the Regulation. It could also be considered that the standard will be gradually incremented over time, though it has also been argued that this would be very difficult, and that the Regulation has to be seen as a one-off opportunity to address the Human Element in (SCC) watchkeeping.

Some guidance to owners and to Administrations will be required on this topic. It is considered that the ATOMOS Advisory Board is particularly well-placed to provide advice on this topic.

The implication of the templates in their current form is that changes need to show an improvement in safe and effective operation, and that current operations forms the baseline. For new builds and major retrofits, the assumption is that the submission statement must be able to support an ALARP statement i.e. that potential hazards have been identified and minimised. Submissions would need to be seen in the context of the company Safety Management System and its obligation for Continuous Improvement.

The ergonomic criteria for the factors set out in the template are all well-established items of good practice. Most are already mandated in Rules or Regulations or are called up in standards, and the intention in the template has been to set criteria that are already in place but which may not be assessed in the correct context. However, the discussions within ATOMOS have indicated that the tone to be used in the template should be encouraging rather than demanding. Given that the Regulation does not demand evidence of detailed compliance, this is considered to be the appropriate way to encourage owners to meet the factors that will determine the achievement of the aims. An encouraging tone with the use of ‘should’ is also compatible with a risk-based approach.

5.3 Assessment issues

The aims set out in the Regulation are difficult or perhaps impossible to assess directly.

Whilst good bridge layout criteria (e.g. windows) can be set out quantitatively (for Northern European crews at least) in a way that is easily assessed, other aspects of system and equipment design e.g. HCI design are difficult to specify in a manner that is easy to assess. This is discussed in Annex 2. The 'operability case' approach proposed in the templates enables criteria to be seen in context and so appraised in a balanced manner, supported by objective evidence as appropriate or as possible.

The bridge and SCC will continue to be the focus for new technology, changes in manning, and changes in operating practices. Multi-function displays, as proposed by ATOMOS, are a very good example of this. Specific guidance will need to continue to evolve, but is always likely to lag behind innovative solutions, and the response to the Regulation needs to allow for this. Again, the operability case approach provides the necessary flexibility.

The templates anticipate the continuing evolution of guidance by focusing on the submission requirements rather than attempting to be a stand-alone document. However, there will be a continuing need for a coherent set of guidance that is kept up to date.

5.4 Aim of Regulation and required characteristics

The Regulation considers ship control as a socio-technical system. To address the work system the template draws on a range of material, including equipment-focused ergonomics, and material from a range of sources on Bridge Resource Management, teamwork, training, procedures design, and management. The provision of information on the bridge and use of information by the bridge team and pilot are covered equally in the Regulation, which is concerned with resource management rather than just equipment design or training.

There are a number of factors that need to be considered when making a decision so that the aims can be achieved. These factors are based on established Human Factors and safety findings.

It would be accurate but misleading to call these factors Performance Shaping Factors, because the template takes a broader approach than classical Human Reliability Analysis. The UK HSE has 'individual', 'job' and 'organisation' as 'human factors' in health and safety. The word 'factor' is used in the template as a term that seems appropriate and has not been already reserved. The factors to be taken into account when making a decision are:

- manning operations and procedures,
- training;
- equipment and system design;
- bridge layout.

These factors need to be considered when:

a) Defining the scope of a decision;

b) Identifying the potential risks associated with a decision;

c) Identifying the means of mitigating the risks associated with a decision (where they include the ergonomic criteria in the Circular).

The Regulation requires that decisions be made with the aim of meeting the seven aims. These aims are mostly concerned with the performance of the work system, although there are aspects concerned with product characteristics. Table 1 below indicates this.

Aim number	Work system **Performance** characteristics	**Product** characteristics	Development **Process** characteristics
1.1	Facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;		

1.2	Promoting effective and safe bridge resource management;		
1.3	Enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner	Using standardized symbols and coding systems for controls and displays;	
1.4		Indicating the operational status of automated functions and integrated components, systems and/or sub-systems;	
1.5	Allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;		
1.6	Preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot;		
1.7	Minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.		

Table 1 Required Characteristics in SOLAS Regulation V/15

The achievement of work system performance characteristics can be assessed only at a late stage of implementation. However, it is possible to provide guidance on product characteristics and process characteristics to support the process of moving from a decision to make a change through to its implementation. These characteristics are the factors that will influence the achieved work system performance, and it is possible to set ergonomic criteria for these factors to de-risk the implementation of the change. As can be seen from Table 2 below, most factors affect the achievement of most aims.

Factors	Aim from SOLAS Regulation V/15						
	1.1 facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;	1.2 promoting effective and safe bridge resource management;	1.3 enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;	1.4 indicating the operational status of automated functions and integrated components, systems and/or sub-systems;	1.5 allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;	1.6 preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot; and	1.7 minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.
Training	Training will need to support good bridge watchkeeping and operations.	Need to be able to show that BRM (ERM) training is done.		Training needs to cover different states and modes of equipment.	Bridge team need training	The Master needs training in work organisation, fatigue etc.	
Manning and operations	Safe navigation. Operations under failure conditions (loss of equipment or crew) will need to be reviewed to check for safety.	The Master needs to be able to run effective procedures. Procedures need appropriate task assignment and priorities.		Procedures need to account for and reflect operational status e.g. cross-checking vs. fallback, normal, abnormal and emergency modes.	Quality of decision making etc needs managing, improvement	Tasking and management need to be able to avoid fatigue and unnecessary work and distractions. Alarm management to avoid distracting noises and messages.	Alarm management, to ensure that set points and thresholds are at values that give enough time. Developing procedures that help to avoid and recover from human errors.
Equipment selection and design	Equipment will need to facilitate the operators' tasks. Equipment will need to support operation in all conditions.	The equipment needs to be able to support BRM e.g. SIC, oversight and supervision, cross-checking	User interfaces will need to be consistent and well-designed. They may also need to be dependable to meet the continuous access requirement. Essential' information will need to be identified as such. Cross-system consistency will be required.	FMECA etc. will need to be undertaken to ascertain the operational status of equipment and to determine what indication should be provided.	Equipment needs to be able to support human information processing, decision making and team working.	Design and selection needs to avoid unnecessary work e.g. software menus. The design should not cause distraction (loss of dark adaptation, irrelevant messages).	Design needs to address human error prevention and recovery, including alarm philosophy for acceptance, inhibit, transfer etc.

Factors	Aim from SOLAS Regulation V/15						
SCC layout and design	Information provision to each operating position will need to be fully considered.	The layout needs to allow supervision and teamwork	SCC design needs to proceed in an integrated manner. Proving that this aim has been met will require user-centred design through the life cycle.	Some system integration may be required to ensure that operational status is defined, assessed and indicated.	Layout needs to provide good access to information and to allow team working.	Equipment location needs to avoid causing distraction. If it is not part of SCC operations it should not be on the bridge. If it is relevant, then it needs to be appropriately located.	Alarm messages need to support the bridge team and pilot in location and visibility.

Table 2 Relationship between the aims in SOLAS Regulation V/15 and factors used in the templates for submission statements.

5.5 SOLAS Regulation V/15 requirements and process characteristics

As can be seen from Table 1, the Regulation does not require any characteristics in the way that decisions are implemented, but instead prescribes the aims for decision making. There has been discussion within ATOMOS on the role of the user-centred approach used on ATOMOS, as this is seen as a vital means of de-risking changes in the SCC. This section outlines the user-centred approach, and discusses the extent to which such an approach could be considered in relation to the Regulation.

The approach used within ATOMOS has been to consider SCC design at four levels:

- At the highest level there is a description of the mission of the vessel and a context-of-use.
- At the second level there is a function and task analysis.
- The third level deals with task allocation, based on typical scenarios derived from the first two levels.
- The fourth level then deals with implementation issues.

This is consistent with other applications of user-centred design, such as that in ISO 11064-1 (Ergonomic design of control centres – Part 1: Principles for the design of control centres), which has the following phases and steps:

Phase A: Clarification

- *Step 1: Clarification of goals and background requirements*

Phase B: Analysis and definition

- *Step 2: Define system performance (functional analysis and description)*
- *Step 3: Allocate functions to humans and/or machines*
- *Step 4: Define task requirements*
- *Step 5: Design job and work organisation*
- *Step 6: Verify and validate the obtained results*

Phase C: Conceptual design

- *Step 7: Design conceptual framework of the control centre*
- *Step 8: Review and approve the conceptual design*

Phase D: Detailed design

- *Step 9A: Control suite arrangement*
- *Step 9B: Control room layout*
- *Step 9C: Workstation layout and dimensions*
- *Step 9D: Design of displays and controls*
- *Step 9E: Operational and management systems design*
- *Step 10: Verify and validate detailed design proposal*

Phase E: Operational feedback

- *Step 11: Collect operational experience*

This approach is a good statement of best practice for user-centred design. It takes a 'clean sheet of paper' approach, whereas the Regulation is concerned with changes to an ongoing situation, and procurement based largely on COTS. There are ways in which elements of the approach are incorporated into current marine requirements and these links have been made in the templates. These links are discussed with reference to the template for major retrofits and new builds. However, it must be stressed that the Regulation does not require any process characteristics, and best practice can only be used as a resource to inform the implementation of decisions. In particular, the approach recognises the benefits of standard arrangements. Special consideration need only be given to decisions with novel features. Also, it is not envisaged that each new build would require detailed analysis. Proving that an item of equipment meets ergonomic criteria will be done in the timescale of equipment development. All that will be required during a ship build will be to check that the individual items of equipment on the bridge do not introduce inconsistencies that could bring about human error.

Phase A is compatible with SMS policy, and there ought to be a link between SMS policy and the owner's requirements. The items in the 'scope statement' of the template use SMS policy to seek information that is compatible with activity based on Phase A.

Phase B seeks a level of formality in setting out requirements that is not normal in current marine operations. The scope statement includes relevant items, and the Human Hazard Assessment can be considered to identify changes in requirements and constraints in an ongoing situation. Steps 3, 4, and 5 have equivalent activities in the SMS (especially as regards completion of a Minimum Safe Manning Document) and are equivalent to good practice of BRM (e.g. clear assignment of duties). The aim of requesting this type of information in the scope statement is to bring together equipment and ship procurement with considerations of manning and training at an early stage when there is scope for ensuring that the change is made in a way that meets the aim of the Regulation. Sections 4 and 5 of the template conduct a review of organisational implementation broadly equivalent to Step 6.

Sections 6 and 7 of the template check that the ergonomic criteria applicable to Phases C and D have been implemented, but do not prescribe particular design activities.

The activities in Phase E are equivalent to activities that may be conducted under the Continuous Improvement of the SMS.

Insofar as the template requires a particular approach, it is one based on SMS. There are considerable similarities with the ILO approach, discussed below in Section 6.7.

5.6 The Regulation requirements and the use of specialist expertise

The principles of Human Centred Design in EN ISO 13407 include multi-disciplinary design teams and the active involvement of users. There has been some discussion within ATOMOS on the need for specialist Human Factors input. It is clear that the Regulation does not require such input, but there is a question as to what competence is required to undertake the activities associated with implementing a decision to conform to the Regulation.

Some guidance to owners and Administrations on the topic of training and experience would appear to be appropriate.

As noted in the MCA Guidance to the Regulation, Masters have specific responsibilities. The competence necessary to carry out these responsibilities could be readily provided by extending BRM training a) to ensure that it includes automation awareness and b) to include material specifically on the Regulation. The need for this training should be stressed to owners, yards and Administrations.

Administrations should be encouraged to point out the innovative nature of the Regulation, and stress that provable competence in owners and equipment manufacturers could be obtained by them attending appropriate BRM training and the Regulation training. In general, the need for specific expertise in any of a number of areas is a function of the novelty and risk of the decision. The following guidance is offered to Administrations on the topic.

It is recognised that the Regulation is innovative in nature, and may require particular methods and resources if high-risk decisions are to meet the aims. Table 3 below sets out some of the options for how to meet the aims with high-risk decisions at the scale of major retrofits and newbuilds, and identifies their main strengths and weaknesses.

Number	Approach	Strengths, opportunities	Weaknesses, risks
1	Technical input (from yard and equipment suppliers) only, no input from Masters or HF		Unlikely that the risks will be identified properly or that the criteria for mitigation will be correctly implemented.
2	Technical input with HF specialists providing input, but no user input	Aspects of design that are specified in standards or are not context-specific likely to be met. Well-established risks likely to be addressed.	Operational risks unlikely to be correctly identified or assessed. Context-specific design decisions and trade-offs may not be correctly
3	Technical input but no real owner input (e.g. because of organisational difficulties or because it is a spec build)		Context of use not fully understood, so risks hard to identify. Someone else would need to produce a context of use statement to form a basis for subsequent activity.
4	Input by BRM-trained Master, with technical support (no specialist HF input)	Operational aspects well-addressed. Opportunity for good integration with the SMS.	Ergonomic criteria may not be correctly set if not addressed in readily-available literature. Risk of too much subjectivity.

Table 3 – Options (not all acceptable) for approach and resources in responding to the Regulation

5.7 Barriers to effective implementation of the Regulation and some opportunities

This section discusses findings from trials and reviews of draft templates with various stakeholders, including regulators, ISM auditors, ship owners, managers and Masters and equipment suppliers.

In summary, the trials and discussions identified that the pocket card and short form template – suitably implemented could be put into effect, and would be broadly welcomed, but that there would be a number of barriers to the effective application of the template for new build and major refit. There are possible ways round these barriers which are also discussed here, together with some opportunities for improved human-centred design of SCC's.

The ATOMOS consortium has taken the whole SCC as its area of interest, and so finds the navigation constraint of the Regulation artificial. For the Regulation to fully achieve its safety aspirations, there needs to be expansion of application to the whole SCC. The wider the application of such a Regulation (e.g. to cover the Engine Control Room), the greater the momentum, and the more easily a skill base will be developed. It is understood that there has been some discussion of the value in expanding the application of the aims in the Regulation from navigation to the whole ship. The experience of the ATOMOS consortium indicates that this would be of benefit to safety and to the uptake of human-centred design.

Meeting the aims in the Regulation was seen as likely to be difficult when dealing with some equipment suppliers, naval architects and owners because of their technical focus and lack of understanding of BRM. Encouraging, and even mandating, that relevant technical staff went on extended BRM training (i.e. BRM training that included automation awareness and an understanding of the Regulation) was seen as one way to break down this barrier.

It was agreed that the best approach was to build on the expertise of BRM trained Masters and bridge staff. Over time, particularly with experience of using the pocket card and short form template, this would help to build a base of informed customers.

The cross-cutting nature of the Regulation requires the introduction of a new role to bring together the various elements in the SCC work system. The templates refer to this role as a 'system engineer' role. To some extent this is because other terms have already been used and do not cover the requirements of the role. For example, the role does not operate at an exclusively technical level, and so the current usage of 'system integration' is inappropriate. The role goes beyond that frequently associated with Human Factors specialists and also that associated with Bridge Resource Management, and so these titles cannot be used. There may well be a shortage of suitable staff to fulfill such a role, and also of organisations that would support the effective application of such a role. These shortages represent significant barriers to the implementation of the Regulation. In the absence of such a role, the highly compartmentalised interpretations of the Regulation currently found in different parts of the sector will prevail, event though they are mutually contradictory. It is hoped that suitably qualified parties can offer to provide this role as a service to owners and yards, packaged as a Human Factors study (though it must be stressed that the service would not be a Human Factors research one, but one which embraced all the sub-areas of Human Factors Integration together with a good understanding of technical and contractual issues). The increasing recognition of the need to scrutinise onboard computing (e.g. the LR Dependable Systems Review, also based on ATOMOS research) will help the introduction of such a service.

The marine sector as a whole is still coming to terms with the introduction of complex computer systems. Until there is a greater familiarity with the implications of system architecture options and other aspects of implementation the mariner will be confronted with a design that does not encourage mode awareness and where there will be mismatches between design, training and procedures. The various regulatory bodies have an obligation to take a lead in overcoming this barrier.

A barrier the considered application of the Regulation for new build is the lack of time. The pace at which new ships are built gives little chance for the data gathering and analysis required to mitigate human element risks. There are some opportunities here, but it will be necessary to overcome organisational boundaries to realise them. High value bespoke ships could be improved over a run of ships. While there may be some opportunity for work related to Regulation on the first of class, there may well be significant opportunities on sister ships. In the case of spec built standard ships, there may be the money and time to gradually improve human element aspects.

The current state of guidance and standardisation of bridge layout, system and equipment design could be considered a barrier to the effective application of the Regulation. This topic is discussed in Annex 2.

There appear to be gaps in regulatory cover that will impede the enforcement and uptake of the Regulation. The early stages of new build are not directly covered by Class, whose first serious involvement will be at plan approval. The initial decisions for new build may be made by an organisation that has an SMS. The decision would be made in the context of ISM and could be audited. However, new build decisions are frequently made by organisations that do not operate ships and do not have an equivalent to ISM. This means that the risk-driven approach advocated in the ATOMOS templates may not be underpinned by a Safety Management System at the critical early stages.

The day to day decisions and minor changes can be considered to be made within the context of a Safety Management System, and are of the type that could be addressed in an ISM audit. The pocket card and short form template are seen as the least problematic to introduce, and the emphasis should be on them in the first instance.

Clear statements from Flag Administrations on the importance of this Regulation in incident prevention and on the means by which conformance will be assessed are required.

Without such statements, it is likely that risk-based elements in the templates, such as the Human Hazard Assessment will not be undertaken. Organisations that might undertake such work on behalf of an owner will be in price competition with organisations prepared to do plan review without this additional cost, and so it is unlikely to be offered unless Administrations look for it. Although the marine sector does not normally work in a risk-based manner, there is ready access to the expertise to do so e.g. from the offshore sector. The barrier is price not skill. A lead from the ATOMOS Advisory Body is required in this area.

ATOMOS has been an important application of human-centred design to the marine sector, and the body of experience gained through the project will be important in helping to introduce the more widespread application of human-centred design in the sector. Work by the community that has been leading the development of methods for human-centred design (mostly for office IT, control centres and web applications) offers a number of opportunities to the marine sector. The first of these is the development of rapid low-cost processes, methods and tools. The second is EC-funded resources to make these readily available, such as www.UsabilityNet.org.

6 Relationship between the Regulation and other activities

The approach proposed is intended to minimise (and preferably avoid) additional work and documentation, and to build the submission around existing documentation and practices. This section identifies the main sources of information that already exist and describes how they relate to the templates.

6.1 ISM

It would be expected that most of the material to be provided will be generated under a company's Safety Management System (SMS), and that the process of completing the templates would be incorporated into the SMS.

There are factors in the template that would not normally be covered in current ISM documentation, and some expansion will be required:

- The explicit linkage between ISM and equipment design is new.
- The risk-based approach used in the template is similar to expected developments in ISM, and any additional effort in producing the template will continue to be minimised.

6.2 BRM

Bridge Resource Management (BRM) is explicitly mentioned in the Regulation. It is concerned with effective teamwork. The factors concerned with layout and equipment design to support teamwork are not normally addressed in BRM (although some BRM training does include automation awareness). Including such factors in all BRM training is considered worthwhile, with an extension to current BRM training to address the Regulation explicitly.

6.3 Safe Manning

The Principles of Safe Manning should be considered in decisions affected by the Regulation. The analysis required for producing a Minimum Safe Manning Document under Regulation 14 has many similarities with the analysis required for the Regulation. However, the Regulation is concerned with practical day to day watch conditions for the bridge/SCC, while Regulation 14 is concerned with absolute minimum manning figures, and so there may be limited transfer between the analyses required for the different Regulations.

6.4 BDEA/IACS bridge guidance, MSC 982, ISO 8468 and guidance in ATOMOS 1.7

There are a number of sound sources of guidance on bridge layout and equipment design that can be used to support the relevant sections of the template for major retrofits and new builds. The template complements these and draws on them rather than competes with them. The discussions held in drawing up the templates concluded that the reference to Circular MSC 982 does not mandate the circular, but merely recognises its relevance. The approach adopted here does not consider the Circular MSC 982 on its own to be an adequate response to the Regulation (discussed in Annex 2).

Because the bridge will continue to be the home of new technology, there will be a continuing need to update guidance on ergonomic criteria.

6.5 Class, and construction Rules

There are factors in the template currently addressed by Class, and again this is drawn on rather than duplicated or contradicted. The area of greatest potential overlap with Class (particularly in the future) is with system design and dependability. It is not expected that there will be unnecessary duplication or contradiction.

6.6 Human Reliability Analysis

The approach here does not include the specific use of Human Reliability Analysis (HRA). There may be aspects of innovative equipment design where HRA would be advantageous or even essential, but this would be an activity determined as part of risk mitigation rather than required by the template.

6.7 Safety management in general

The approach taken in the templates is compatible with the approach in 'Guidelines on occupational safety and health management systems', ILO-OSH 2001. The most relevant section is quoted below:

> *3.10.2. Management of change*
>
> *3.10.2.1. The impact on OSH of internal changes (such as those in staffing or due to new processes, working procedures, organizational structures or acquisitions) and of external changes (for example, as a result of amendments of national laws and regulations, organizational mergers, and developments in OSH knowledge and technology) should be evaluated and appropriate preventive steps taken prior to the introduction of changes.*
>
> *3.10.2.2. A workplace hazard identification and risk assessment should be carried out before any modification or introduction of new work methods, materials, processes or machinery. Such assessment should be done in consultation with and involving workers and their representatives, and the safety and health committee, where appropriate.*

3.10.2.3. The implementation of a "decision to change" should ensure that all affected members of the organization are properly informed and trained.

6.8 Equivalent activities in other sectors

The approach to demonstrating conformance to the Regulation draws heavily on JAR 25 from the aviation sector.

The type of training in Human Factors proposed as an extension to current BRM training has equivalents in aviation, where even private pilots are given some HF training.

7 INFORMATION FLOW AND MANAGEMENT IN RESPONDING TO THE REGULATION

7.1 Flow from the owner to assessment organisations

The innovative nature of the Regulation has also affected the proposed form of response. The responsibility for responding to the Regulation lies with the owner. Until formal assessment by Flag is required, it has been proposed that the response by the owner comprises an attestation of conformance to the aims. The templates are designed to assist the owner in presenting information to an Administration or other assessor in a standard form, and also to act as tools for collecting the information. In time they could be used as a framework for assessors to apply assessment criteria. Depending on the approach taken by Administrations, it would be possible for:

- the owner to send in a complete submission statement at the time of starting operations, or for
- the owner to supply information at each stage or for
- the timing of submitting information to be a function of risk and novelty.

Although the most complex of the options, the last option is preferred.

The template structure gathers evidence of conformance to ergonomic criteria for manning, training and the design of procedures, equipment, documentation and SCC layout. Human Centred Design processes will be necessary to gather the evidence, but they are not made explicit.

The information flow to Type Approval organisations and Class is considered to be unchanged by the Regulation.

7.2 Flow to the owner from operator, yard, equipment manufacturers

The conformance submission statement is effectively an operability case. The template sets out the aims required for the operability case taking a risk-based approach. The template - and the completed submission statement - are probably best implemented as a hyper document with a company SMS. The intent is for the template to reflect the structure of existing documentation (e.g. IMO publications, company SMS documentation), minimising the effort required to generate the report.

The material generated specifically for attestation in the submission statement needs to be minimised, with maximum usage for other purposes e.g. equipment procurement. The extent of supporting evidence would be a function of novelty and risk (the risk is operational, covering both economic and safety risks).

For a major retrofit or new build, information will be required from a range of sources. The main information flows are envisaged to be as follows:

- Equipment suppliers will provide information on how the equipment meets ergonomic criteria to the yard or integrator. Assumptions about training and qualification will be supplied to the ship operator (or yard in the case of spec build). The information from various sources will be collated and checked by the yard or integrator and assembled into a conformance statement for referencing in the template.
- The yard will provide information on the ergonomic criteria for the SCC layout.
- The operator will provide information on the training, manning and operational aspects.
- Superintendents (and/or other Masters) with extended BRM training will contribute to the Human Hazard Assessment, the reviews of whether the ergonomic criteria have been met (e.g. at Plan Approval and commissioning) and will track residual risks in the SMS.

One way of gathering the evidence would be to run the necessary activities as an SCC HF or system engineering study which would perform the following tasks in an iterative manner:

- Conduct the initial Human Hazard Assessment;
- Organise the information flow and validate that the information is correct;
- Check that the various factors met ergonomic criteria;
- Check that the elements in the bridge were consistent with each other and would come together as a working operation;
- Maintain an up to date set of material under configuration control to support the submission statement;
- Run an effective strategy for seafarer input to the design.

8 USE OF THE TEMPLATES

The basic procedure is the same for each application:

- Define scope of the decision, context, log the baseline of functions and usage, and identified concerns (possible hazards).
- Human Hazard Assessment – what issues might arise?
- Apply relevant Ergonomic Criteria to the resulting change(s)
- Check that the selected change works
- Track residual issues and risks in the Safety Management System

8.1 Steps for small changes

This level of change and decision making is applied to day-to-day changes in procedures, duties or crew training. It is performed by the Master with assistance of watch officers or the bridge team using a performance aid in the form of a two-sided "pocket" or "briefing" card. A meeting of the bridge team would be held. A note of the meeting would be recorded in the log, and any issues would be entered into the company SMS. A typical event to trigger such a meeting would be the introduction to service of a change, with support in form of notices, training, and procedures (via SMS). The headings on the pocket card would be based on those used for the (extended) BRM training given to the Master.

8.2 Steps for major equipment or operational changes

The steps in completing the short form template are performed by the superintendent with the assistance of the operating company, masters and bridge teams affected by the change(s).

The short form template is applied to changes in equipment, company training, changes to operational procedures and changes to crew where the new crew have a different background from the existing crew. The sequence of events is as follows:

- Establish change to context of use.
- Define equipment functional requirements.
- Conduct Human Hazard Assessment.
- Define workstation, training, equipment requirements.
- Procurement.
- V&V.
- Introduction to service.

8.3 Steps for new build or major retrofit

The compilation of the submission statement for major changes is performed by the owner with the assistance of the yard and the operating company, deck crew standing by, potential bridge team, manufacturers, and responsible organisation. This use will accumulate documentation (much of it generated for other purposes) in a study report. The information related to the early steps is best recorded early in the design; while other aspects will be documented towards the end of the change, depending on the specifics of the project.

The steps applied to newbuilding or retrofit where novel features are introduced are shown in Figure 1 below.

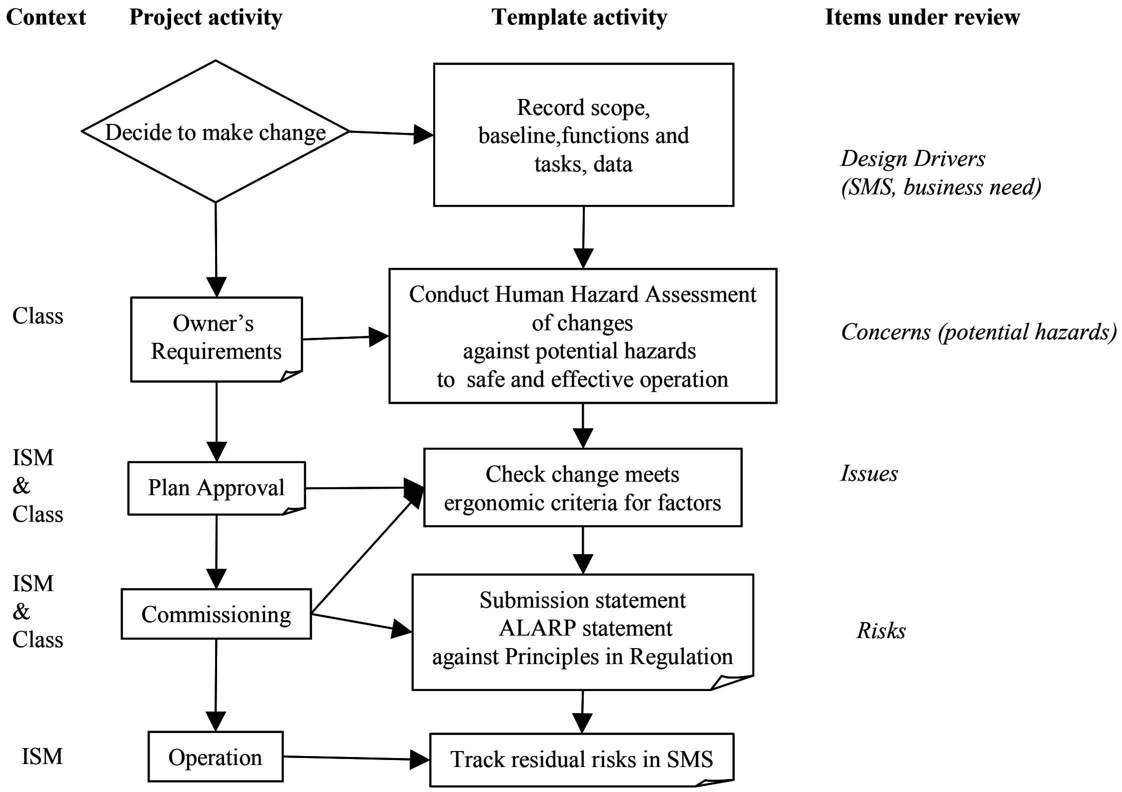

Figure 1 Flow chart of activity for use of template in conjunction with major retrofit or new build

9 GUIDANCE TO ASSESSORS

This section offers some brief notes by way of guidance to Administrations to assist in the assessment of submission statements.

The first point to decide is what level of visibility is to be required for high-risk changes i.e. whether information is required only on request, at implementation or at critical earlier stages.

The next point to consider is whether some specific point of contact to the Administration should be required. This has the benefits of providing clear lines of communication, assignment of responsibility and the potential for giving the project a 'champion', but may also risk generating a bottleneck. The wording of the Regulation as it stands does not require such an appointment.

The subject of lead and lag indicators in safety management has been raised in a number of applications in both Europe and the US. Should an Administration propose to take a pro-active approach to this Regulation (and has the resources to do so), then the lead indicators are associated with competence and process. Early scrutiny of these aspects would enable an Administration to assess the risk to obtaining a satisfactory submission statement and use resources accordingly.

The final point of general consideration is the setting of success criteria discussed above at Section 5.2. The aims set very high standards, and the requirements of ISM and the principles of safe manning combine to mean that high standards could be imposed without imposing higher criteria than are currently in place.

9.1 Day to day changes

The response to the Regulation can be assessed as an element of an ISM audit. Aspects available for assessment include:

- BRM (extended) training records;
- Log entries of meetings to review changes;
- The quality of achieved Bridge Resource Management;
- Aspects relating to the Regulation being addressed as part of Continuous Improvement under ISM.

9.2 Minor changes

The response to the Regulation can be assessed as an element of an ISM audit, but there may be aspects relating to equipment design and bridge layout that would not normally be within the scope of an audit. Aspects available for assessment include:

- Evidence of application of safety policy in the intent of changes;
- Evidence of appropriate review activities;
- Evidence that risk assessment is taking place in a realistic and structured way, and that high risk or novel changes are given appropriate attention and resource;
- BRM (extended) training records;
- The quality of achieved Bridge Resource Management;
- Aspects relating to the Regulation being addressed as part of Continuous Improvement under ISM;
- Evidence that equipment meets ergonomic criteria;
- Evidence that equipment training assumptions align with company practice and align with the principles of safe manning.

9.3 Major retrofits and new builds

The evidence for major retrofits and new builds should be available in the submission statement. The points to note include the following:

- This submission statement shall be completed for all decisions relevant to the aims in the Regulation, i.e. those that affect principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures.
- The goals and motivations of the decision and their compliance with Company policy for safety and environmental protection shall be stated. Ways in which the decision is being used to support leadership in safety and environmental protection should be indicated.
- The SCC shall be described, including compliance with carriage requirements. The plans and procedures for key shipboard operations shall be described.
- The risk potential (both increased and decreased) arising from changes made by the decision shall be identified under the following headings as applicable. Assessment of the SCC shall ascertain whether novel features in manning, procedures, equipment or operation are present. Where the decision introduces changes that are novel features then specific careful exploration is required.

- Data sources shall be reviewed to identify relevant data that identifies issues, risks or hazards that may be mitigated by the decision, or which may be exacerbated. Sources of data include incident reports and feedback from current operations e.g. reports from Masters of safety management deficiencies or SMS reviews.
- The programmes for drills and exercises that are affected by the decisions shall be updated and made available on board.
- Provision shall be made for meeting the training needs of new crew members to become familiar with their duties and how they are affected by the decision. Provision shall be made for instructions that are essential prior to sailing.
- Provision shall be made for continuous training for learning based on errors resulting from daily use of the SCC system. Training provision should include a means of simulation on board that covers different, real situations.
- The review of training provision shall include the types of training listed below, and ensure the correct certification as appropriate.
- The submission statement shall attest that the ergonomic criteria have been met, and that all statutory requirements have been identified and met.
- An attestation shall be provided that the safety and environmental risks from the decision are As Low As Reasonably Practical and in accordance with Company policy. It shall record the results of investigations to justify the decision and to indicate the reasons for the design option chosen.

10 ANNEX 1 - SOLAS REGULATION V/15 AND THE HUMAN ELEMENT

The Aims of SOLAS Regulation V/15 themselves can be seen as a quick operability risk assessment for navigation systems. The notes in plain text are interpretive and do not form part of the Regulation.

1.1 facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions; [NOTE: this aim requires consideration of manning, employment practice, training, certification, trading pattern as well as the design of equipment, workstations and the SCC].

1.2 promoting effective and safe bridge resource management; [NOTE: effective BRM can be achieved only by consideration of manning, employment practice, training, certification, trading pattern as well as the design of equipment, workstations and the SCC].

1.3 enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays; [NOTE: convenient and continuous access may require consideration of the dependability of the information source. The standardization of symbols and coding systems is independent of display medium e.g. dial, computer display, chart, manual and is not confined to items within navigation].

1.4 indicating the operational status of automated functions and integrated components, systems and/or sub-systems; [NOTE: operational status is the status as it affects operations, which is not necessarily conveyed by a technical diagnostic equipment status indication].

1.5 allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot; [NOTE: the criteria for effective individual and team decision making have been set out by those concerned with naturalistic decision making and Recognition Primed Decisions, and the criteria for Decision Centred Design have been developed].

1.6 preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot; and [NOTE: All sources of fatigue and distraction are to be considered. Excessive or unnecessary work can be physical activity or mental activity].

1.7 minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action. [NOTE: the addition of alarms incurs the risk of bringing about 'driving to alarms' and reduced situation awareness contrary to aim 1.1].

For a more thorough interpretation this list should be extended with the aims related to job design ISO 6385 *Ergonomic principles in the design of work systems*, human behaviour safety in ASTM-F-1166-88, principles of dialogue design from ISO 9241:10 and principles of user centred design from ISO 13407. Particular issues, translated into design criteria for job, arrangements and layout are presented in ISO 11064 *Control centre design*, ISO 9241 *Ergonomic requirements for office work with visual display terminal (VDTs),* ISO 8468, 1990, *Ship's bridge layout and associated equipment - Requirements and guide-lines.*

11 ANNEX 2: SOLAS REGULATION V/15, SUPPORTING GUIDANCE AND INCIDENT PREVENTION

The NTSB Report on the grounding of the ROYAL MAJESTY stated:

> *"Thus, while human engineering is a known concept in the marine industry, there have not been any unifying efforts to integrate this concept into the marine engineering and manufacturing sector. Additionally, human engineering in the broader context of Human System Integration has been given little or no consideration. Consequently, the potential for error causing behavior related to these [automated] systems has not been adequately addressed by the marine industry".*

It has been taken as axiomatic in the development of the ATOMOS response is that the Regulation aspires to provide a unifying effort to integrate human engineering, and to give full consideration to Human System Integration.

It is not necessary to justify the need for the Regulation in terms of incident prevention. The Regulation exists and must be followed.

There has been some discussion on the frequency of incidents related to the scope of the Regulation, and therefore on the "importance" of this Regulation in the overall regulatory regime.

Also, it is necessary to understand something of incident causation and the scope of the Regulation so that the way the Regulation is implemented will prevent them.

11.1 Frequency of incidents in relation to the scope of the Regulation

The Regulation addresses the human element, which is frequently considered to be 80% of risk exposure. The 80% figure has been quoted by the MCA. The navigation element of this 80% is probably large.

The Regulation addresses principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures. Logically, this scope covers most aspects of collisions and contacts, which account for 22% of merchant vessels investigated by the UK MAIB.

As a check on the frequency discussion, the latest batch of 12 incident reports from the MAIB were reviewed in relation to the Regulation. Two incidents were directly related to the operation of modern bridge equipment in the context of the bridge work system, two were related to BRM in simple operations, and one incident was prevented from being much worse by good BRM under adverse conditions. This small sample is presented in the table at the end of this Annex. Producing a comprehensive analysis of incident frequency is not part of this ATOMOS work package, but anecdotally it is the experience of the author that similar time slices from such incident reporting systems would produce similar frequencies.

Regardless of current frequency, bridges are becoming home to more and more equipment of greater complexity to be used in more demanding circumstances by a changing seafarer population. The risk potential has to be considered to be rising rather than falling (if measures such as the Regulation were not taken).

11.2 Nature of incidents related to the Regulation.

There are some incidents (such as the collision of the HIGHLAND PIONEER with the offshore rig DOUGLAS) where the causal factors appear to be all related to manning, procedures and training, rather than equipment design or bridge layout. Since the Regulation addresses changes to procedures, there is the hope that it will reduce the frequency of such incidents. However, such incidents are also of interest to equipment design from two points of view; a) would better equipment design have made the incident less likely (in the case of this incident, better speed indication and simpler radar zone alarms would be candidates for consideration)? and b) should equipment design take such scenarios as design cases?

There are some incidents where the principal factors involved appear to be manning, procedures and training, but where equipment design has a contribution. NORDSEE/POOLE SCENE (reported by MAIB) was an incident of this type, where a 'sunspot' in the radar coverage removed the last element of contingency from the situation. ATSB report 163 gives another such example:

> *"At about this time the skipper in Lipari's wheelhouse heard the ship's whistle. He made his way to the fly bridge where he identified the ship dead ahead. He turned the fishing vessel's helm hard to port but it responded slowly as the auto pilot was still engaged in the wheelhouse."*

A similar balance of contributions may be said to have occurred in the grounding of YORKTOWN CLIPPER (MARS offreport 7023), although the equipment could be said to make it easier to do things the wrong way than to do them the right way. Another such incident was the grounding of CONCERT EXPRESS (MARS offreport 7022):

> *"The conclusions reached on this incident highlighted the lack of communication between the pilot and the master and the fact that a large vessel was proceeding in confined waters with visibility of 100m with no blind pilotage organisation in effect. With the speed vector superimposed over the heading marker, there is also the possibility that the pilot mistook the heading marker for the EBL, radar manufacturers may like to consider this when designing new sets and try to make the HM and EBL as visually distinctive as possible. Although the report does not mention it, a radar range of 0.75 miles when proceeding at 10 knots is totally inappropriate."*

For all of the above examples, incident prevention will only work if the impact of a preventative change is considered at the work system level.

However, there are incidents where it is fairly clear that shortfalls in all of the various factors come together to bring about an incident. The human element is very flexible, and introduces resilience into the work system – but only up to a point. An example of such incidents is the ANL EXCELLENCE, reported in ATSB report 181. The report concluded that the following were considered to be factors in the incident:

1. *The pilot did not follow his normal procedure of checking the position of the course alteration using his portable electronic chart system.*
2. *The temporary buoy marking the original position of the original east cardinal beacon E5 (the turning mark) was obscured by rain.*
3. *The green light on the temporary buoy was not as conspicuous as a white light, which would normally be associated with a cardinal navigation mark.*
4. *Although not suffering from chronic fatigue, the pilot's performance was probably affected by the trough in his circadian rhythm associated with the hours between 0400 and 0600.*
5. *The pilot's electronic chart system was placed at a significant distance from where he was standing, with its display in power saving mode at a critical moment.*
6. *The bridge team did not detect the erroneous helm order as a result of:*
    - *Both the master and mate were probably fatigued as a result of their hours of work during the passage through the Great Barrier Reef, which was exacerbated by the 'time of day' effect.*
    - *Neither the master nor the mate were sufficiently aware of the ship's situation, at the time, to challenge the pilot's premature order for the course alteration.*

- *Insufficient attention was paid to the ship's radar display.*
- *The navigation chart in use by the ship did not show the temporary replacement of E5 cardinal beacon with a temporary starboard lateral buoy marking the southeast extremity of Middle Bank.*
- *The interpersonal tension between the master and mate effectively nullified the active participation of one qualified navigator in the bridge team.*

As can be seen, all the factors in the templates were involved to some degree. Some of the most widely discussed incidents are of this type, including ROYAL MAJESTY, SLEIPNER, BALTIC CARRIER/TERN, AQUITAINE, DIAMANT/NORTHERN MERCHANT, ASH/DUTCH AQUAMARINE etc.

11.3 Use of existing guidance and standards in relation to the Regulation and for incident prevention.

11.3.1 Guidance and standards for the factors

Since all four factors in the template affect the aims of the Regulation, it is reasonable to expect guidance and standards on ergonomic criteria for all of them being cited. However, this study has identified that some people involved with bridge layout and equipment design have not yet appreciated the need for complementary guidance on manning, operations and training, or the need for all four factors to be aligned. The cross-cutting human-centred approach to the work system proposed in the templates is considered essential to prevent incidents which arise from the conjunction of shortfalls in design, training, BRM and regulation. Any response that is restricted to a particular sub-area in Human Factors (see Annex 3) will not prevent incidents of this type.

Any proposed solution in a particular sub-area that makes untested assumptions about the other sub-areas (rather than ensuring consistency by a system engineering role) will do little to reduce the likelihood of incidents. For example, consider the application of MSC Circ. 982 as a preventative measure for the grounding of ROYAL MAJESTY and as a sole means of achieving the aims of the Regulation.

To the extent that the Regulation was stimulated by the grounding of ROYAL MAJESTY, it is instructive to see how few of the causes of the grounding are addressed by the guidance in the Circular or the BDEA/IACS document.

The aspect of the incident that relates most obviously to the Circular is the alarm on the GPS. Vigilant supervision may have determined that the loss of GPS sensor input and reversion to DR warranted an alarm (5.4.1.4 in Circ. 982). The audible for the alarm in the GPS device would not have met the requirements of 5.4.3.4 in the circular. Changing the audible would have required revision of the decision to use the particular COTS equipment, which would have required vigorous supervision to implement. The visual indication of the alarm may or may not have been considered to have met 5.4.2 in the Circular (it can be noted that the crew knew the meanings of the various indications on the GPS set). The Circular would not have demanded integration of the alarm and changes to the interface to enable such integration. The Circular would not have supported any concerns raised by vigorous supervision of the manual that came with the NACOS bridge which recognised the problems of supervisory control.

It is not at all clear how the Circular could have been used to ensure that a design of fathometer was adopted (together with appropriate procedures) such that it would not have produced nuisance alarms in harbour and would definitely have been switched on when sailing. The NTSB report called for an independent authority to maintain system integrity. Even should such a body have existed, the Circular does not consider system dependability in its guidance, and at best would have allowed for 'driving to alarms' rather than "*enabling the bridge team* *and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays, or indicating the operational status of automated functions and integrated components, systems and/or sub-systems."*

Defining competence in relation to the ship, the bridge systems and equipment and the type of operation is not integrated across factors in any of the factor-specific Regulations or Circ. 982. Similarly, ensuring that the training need is identified and that suitable initial and continuation training is provided would be beyond the scope of the Circular. This would cover IBS training and BRM training.

The development and use of procedures that reflected the system and equipment design would also be beyond its scope e.g. procedures for cross-checking different sensors, plotting and logging.

The failures in BRM and the over-reliance on equipment would not be addressed by a Circular focused on equipment design and bridge layout. Neither would such a Circular identify the procedural and training issues that arise from the equipment and system design in a way that they can be addressed.

In relation to the aims of the Regulation, the section on error detection and correction in Circ. 982 falls short of the needs of aim 7 as regards equipment and system design.

11.3.2 Equipment design and bridge layout guidance

This section discusses the state of guidance on the factors that relate to equipment design and bridge layout.

It is recognised that navigational systems and equipment type approved in accordance with current IMO and IEC performance standards do not necessarily meet the requirements of the Regulation. There is work in WG 13 on a Common Display Surface, work in IEC on common functionality for INS and work within IACS on updating the IMO Code on Alarms and Indicators. When these developments are complete, it *may* become the case that compliance with equipment and system standards will meet the requirements of the Regulation. However, from investigations to date, that is not an explicit co-ordinated aim of these developments. Furthermore, there will need to be a continuing process of updating such guidance as both technology and operations evolve.

The work by IACS for the BDEA standard has identified that there are overlapping and conflicting requirements in the area of bridge layout and visibility e.g. between MSC Circ. 982, ISO 8248 and SOLAS Regulation V/22. Reconciliation of these conflicts would have the effect of encouraging compliance as well as simplifying it. However, it is suspected that the underlying anthropometry for all of the above criteria is North European, and criteria that reflect the whole of the mariner population are still required. Means values for a population can vary over time. Studies have indicated that there has been an increase of about 3 cm in the stature of Europeans during the past decade. Anthropometric data should therefore be validated at least every 10 years. It has been found that the difference in stature between American and Japanese males is largely attributable to difference in leg length, and that the differences in sitting height, a factor of the trunk, is insignificant

In the area of user interface design there are a great many sources of guidance, to the point where the non-specialist is likely to be overwhelmed.

The work under way for the Common Display Surface, common INS functionality and updated alarm code is bound to improve the situation considerably, but a greater transfer and tailoring of guidance and criteria from the mainstream HCI design community would be necessary to provide the material to support good design on a regular basis.

The ergonomic criteria that are readily available to the marine sector e.g. MSC Circ. 982 on their own are not particularly helpful in achieving assurance of safe and effective operation. However, this is the normal situation.

Some of the ergonomic criteria are at the level of the physical interface and relate to an individual action by the operator. For example "Red flash coding should be reserved for Alarms" is a concrete, specific, testable criterion. However, an alarm is defined as "An alarm announces by audible means, or audible and visual means, a condition of an abnormal situation requiring attention." Defining exactly what "requiring attention" means is much harder. Consequently, guidance at the task level, such as the following becomes very far from concrete: "A method of acknowledging all alarms (silence audible alarms and set visual alarms to steady state),including the indication of the source of the alarm, should be provided at the navigating and manoeuvring workstation, to avoid distraction by alarms which require attention but have no direct influence on the safe navigation of the ship and which do not require immediate action to restore or maintain the safe navigation of the ship." Guidance such as this is good common sense to the seafarer, but very difficult for the designer to work to. The best way (and perhaps the only way) to meet ergonomic criteria such as this is to follow the right human-centred design process. It has been found in HCI research that the vast majority of usability problems occur at the task level and not at the action level. Consistent labelling is vital, but is the tractable tip of the usability iceberg. Guidance such as "Displays should be as uncluttered as possible." makes sense only in the context of use when considering the specific user task. It cannot be applied to a physical design out of context.

11.3.3 Brief Review of MAIB time sample of incidents.

The batch of incident reports on the MAIB website was taken as a small sample to contribute to the discussion on the frequency with which aspects related to SOLAS Regulation V/15 occur.

There were 12 reports in the time-based sample. The findings from a review of the reports follow:

Incident	**Reg. V/15 aspects?**	**Comments**
Ocean Star report of the failure of a warp block on board the UK registered fv Ocean Star resulting in one fatality on 26 November 2003 (Adobe Acrobat 424kb)	No	
Pride of the Dart report of the grounding of the class vi passenger vessel Pride of the Dart on mew stone rocks near the entrance to River Dart on 28 June 2002 (Adobe Acrobat 288kb)	Yes	Lack of good BMR in small operation
Diamant and Northern Merchant report of the collision between Diamant and Northern Merchant 3 miles SE of Dover on 6 January 2003 (Adobe Acrobat 1,078kb)	Yes	Definitely Reg. V/15 territory
Queen Elizabeth 2 report on the flooding of aft engine room of passenger cruise ship Queen Elizabeth 2 on 21/22 May 2002 (Adobe Acrobat 386kb)	No	

Maria H report of Maria H striking the Keadby railway bridge 29 May 2002 (Adobe Acrobat 407kb)	Yes	Lack of good BMR in small operation
Ash and Dutch Aquamarine report of the collision between mv Ash and mv Dutch Aquamarine with the loss of one life on 9 October 2001 (Adobe Acrobat 538kb)	Yes	Definitely Reg. V/15 territory
Pride of Bath report of a barbecue fire in the galley of Pride of Bath on the River Avon, Bath 20 July 2002 (Adobe Acrobat 444kb)	No	
Stena Explorer report of the fire on board HSS Stena Explorer entering Holyhead on 20 September 2001 (Adobe Acrobat 385kb)	No	Good BMR prevented a serious incident e.g. operation with CCTV failed.
Tullaghmurry Lass report of the sinking of Tullaghmurry Lass with the loss of three lives on 14 February 2002 (Adobe Acrobat 279kb)	No	
Osprey report of a fatal accident to a man overboard from fv Osprey on 20 April 2002 (Adobe Acrobat 647kb)	No	
Radiant report of the capsize and foundering of Radiant PD298 with the loss of one life (Adobe Acrobat 896kb)	No	
Kodima report on the cargo shift, abandonment, and grounding of mv Kodima on 1 February 2002	No	(? incorrect use of GPS data)

11.3.4 Conclusion

Out of a sample of 12 incidents chosen as an arbitrary convenient time-based sample, 2 were directly related to use of bridge equipment, and 2 were related to aspects of BMR such as passage planning in very simple ships. The report of Diamant/Northern Merchant mentions the Finnish report of three groundings where bridge ergonomics played a role.

Tentatively (it would take more time to confirm definitely) MSC 982 or the BDEA document would have done nothing for the 4 incidents involved.

Logic should permit completion of a transaction sequence with the minimum number of actions.

12 ANNEX 3: HUMAN FACTORS AND THE SCC

In this document the term 'Human Factors' refers to a multidisciplinary field of science and its application. Human-centred design applies human factors knowledge in the light of experience. In applying human factors to the design and operation of the SCC it is important to take human capabilities, skills, limitations and needs into account when exploring the interaction between people, technology and the work environment. The SCC should be seen as a work system which has the goal of operating the ship safely and efficiently. This work system consists of the users, equipment, software, space, environment, roles, duties, operations and command structure and the interactions between them. The equipment, even the ISC, is only one aspect of the work system of the SCC and should not be considered in isolation. Good design starts with the user and takes into account how the user is expected to interact with the equipment and how the equipment fits into the system as a whole. Human factors knowledge may be divided into the following set of sub-areas:

- Manpower
- Personnel
- Training
- Human Engineering
- Safety
- Health & Safety

Input should be taken from each of these sub areas at each stage in the lifecycle. Advice on how this should be done is given in the DERA Guide for Industry, Building Human Factors into Systems Design (1998, UK MOD Acquisition Management System).

The sections below describe the components of each of the items listed above. For any SCC the sub-areas and the considerations should be reviewed against the particular context of use and the requirements for the SCC (for example, manning level, operational philosophy, etc,). The specific considerations which are generated should be addressed at the earliest possible point in the lifecycle.

12.1 Human Resources

Manpower

The number of personnel required and potentially available to operate, maintain, sustain and provide training for the SCC. The following factors influence the choice and number of qualified people required to operate an SCC:

- Phasing. Planning the availability of people at introduction and throughout the life of the SCC. This should consider operation, training, maintenance and support personnel and also the management of change
- Work structure. The SCC supports new ways of working in which the control of the ship is mediated by equipment and software. This may require a change in philosophy in respect to crewing since the conventional structure of a crew may no longer be applicable.
- Availability. The proportion of labour resources and their demography required for all of the specified tasks involved, including operation, maintenance and support.
- Workload. The amount of work expected to operate, maintain and support the SCC. Factors affecting this are the balance between manning and task sustainability.

Modern merchant ships possess a working structure that is mainly based on the type of activity they carry out. Planning, work structure, availability and work load will determine how many crew members are to man an SCC.

For example, the number of crew members on a passenger vessel differs significantly from a chemical carrier when considering their total number. However the number of technicians does not vary so greatly. That is: A passenger ship carrying out cruises in the Mediterranean sea may carry, for example, 2,000 passengers and 300 crew. The technical staff of the crew will probably be approximately 30 people and the rest will be catering staff, office staff, passenger service staff, etc.; A medium tonnage chemical carrier will carry a total of 12 to 15 people. The reason for the difference is in the activity carried out. Technically speaking, crew numbers increase on passenger ships because of work and functions to do with attending to the passengers, not because of the complex ship system. For example, the chemical carrier would not have a communications officer whereas the passenger vessel would have two or three. The passenger vessel will have three people dedicated to maintenance whereas the chemical carrier would only have one person.

Personnel

The cognitive and physical capabilities required to be able to train for, operate, maintain and sustain the SCC and provide optimum quality and quantity of the crews to man a modern ship fitted with an SCC.

- Physical. Current and future profiles including fitness levels, physical size, gender and not-typical specific requirements. These are defined in STCW.
- Cognitive. Current and future profiles including trainability and mental aptitude. These are defined in STCW.

NOTE: As part of ISM requirements, shipowners should address crew preparedness and training for all expected on board situations.

- Recruitment/retention. Engaging new personnel or maintaining current personnel. Modular design and standardisation of applications is an advantage since it facilitates a quick familiarisation with the particularities and characteristics of the equipment and favours the exchange of officers among ships.

NOTE - Crew retention is a serious problem for the shipowner, because loss of crew requires constant training of new crew. Some shipowners have provided a solution consisting in wage increases and improvements of living conditions on board ship. Time spent at sea is rewarded by longer holidays.

- Cultural/Social factors. Influential factors based on maritime and/or national culture. Expectations with regard to career prospects, ambience and aesthetics.
- Previous experience/training. Attributes that are inherent with the predicted resource pool, which will provide closer match or disparity with requirement; such as educational requirement and achievement, current trade, career pattern, knowledge of parallel systems.

NOTE - Shipowners are asking for increased consistency of operations and equipment on their ships. This assists crew members when they have to change ships.

- Human-human interaction. Structure of envisaged tasking roles between people, whether based on team or individual work, likely role of the personality in interaction.

Training

The instruction or the education, and on-the-job or part-task or full-mission training required to provide personnel with their essential job skills, knowledge, values and attitudes. These are defined in STCW.

NOTE - Resolution 9 of the final Act of the 1995 Training Conference, states that international ruling is necessary to legislate on the physical condition of seafarers. Governments are invited to construct such legislation that reflects recommendations that arise from opinions and rulings of the International Labour Organisation and the World Health Organisation.

- Legacy transfer. Main or sub systems that require switch between different styles of operation. This could be due to multiple style sub-systems, or retrofit of differently styled sub-systems. “De-skilling” can occur when some basic functions are automated.

NOTE: On the other hand, familiarisation with a human-centred SCC can be faster than for conventional bridges since the controls and elements are designed to facilitate work and diminish fatigue, and may result in increased safety levels.

- Type. Mix of training technologies (for example, synthetic environment, computer-based simulation, use of individual versus group sessions, instructors with actual experience versus simulated experience etc. and the effects of each on performance). Definition of standards and fidelity of performance.

NOTE: Orders and working procedures may change in character because instructions can be based on a more thorough analysis of a situation.

- Availability. Timing and proportion of initial training and continuation for new and existing personnel. Therefore requiring facilities for correct type and size. Minimisation of training “bottleneck”.

NOTE: Resolution 4 of the 1995 Training Conference, states that the Governments should adopt all necessary measures to guarantee that before 1st February 1999, there will be a sufficient number of people available with training and certificates in GMDSS radio operators.

With respect to training that is necessary for SCC ships personnel should be chosen in accordance with their knowledge and skills. Crew members should attend training and refresher courses covering the following subjects before they join an SCC ship.

- Education in the handling and function of the new equipment.
- Training to provide agility in the procedures in order to avoid misinterpretation of the information.
- Refresher training in order to forget antiquated concepts and defective use of conventional systems.

12.2 Human Factors

Human Factors Engineering

The comprehensive integration of human characteristics into the definition, design development, and evaluation of the SCC to optimise Human Machine performance under specified conditions.

Computer technology may be used to support flexibility in operating concept for ships of different type, role, operating environment and tonnage. Standardisation of equipment may be possible for ships of the same type. If modularity in design is used to achieve, for example improved economy, there should be provision for customisation.

Computer support should leave a margin of action by the officer in cases where there is uncertainty. Alternative solutions and their predicted consequences should be presented. The officer should always have the option of giving the final order.

- User System Interface: The point at which the user carries out the required tasks. The user may include the operator, maintainer or supplier. Performance factors of the interface will be physical and cognitive i.e. physical matching of the interface to the user, comprehensibility of the interface, etc. A central operations workstation in the SCC may be configured with fewer screens for data presentation (by use of all the current guidance related to equipment). This is the equivalent of diminishing the number of operational controls and the need for very quick data identification and reduces the number of opportunities for human error.
- Task Allocation: Matching of tasks with individuals and groups with associated performance effect on stress, fatigue, workload and motivation. Task and information analysis of SCC operations should be used to design each application and the required data exchange with other applications. SCC applications software may be provided to support all ship operations. Examples are: Ship Administration, Cargo Management, Hull Stress Monitoring, Robust Fault detection, Navigation, Propulsion, Communications, Manoeuvres, Maintenance.
- Environment: All external effects based primarily on neighbour work stations and users. Where appropriate this should include accommodation and habitability as a separate issue. The size and type of ship may restrict the space available for the SCC. Since the SCC is manned continuously the effect of layout, decoration and design on crew well-being should be considered. The operability of the SCC in both routine and emergency operations should be considered. Operability factors include: having all instruments to hand, working space sufficient to allow for easy movement, ergonomically designed equipment, adequate/ appropriate surroundings. Design for increased interaction by communication or sharing of information may give operational advantages in both routine and emergencies operations. The system may be designed to accumulate experience of routine operations.

The crew member must be prepared to react to the SCC needs. He must specially get to know the work procedures so that his decision making processes are supported by the computer applications and equipment provided by the SCC.

The complexity of the decisions to be made is further increased in emergency situation where it is required to analyse, evaluate and decide on what action to take in just a few seconds. The IMO is conscious of these difficulties and has drawn up certain rulings, such as, for example, IAMSAR.

Health Hazards

The identification, assessment and amelioration of short- or long-term hazards to health occurring as a result of normal operation of the SCC.

- Noise/vibration. Continuous/impulse sound or vibration that causes damage to hearing or vibration injuries in the short- or long-term. The values and references that cover the conditions that spaces on board ship should meet are to be found in the IMO Code for “Noise levels on board ship”.
- Toxicity. Poisonous materials or fumes generated by equipment, capable of causing injury or death in the short- or long-term. Also allergies
- Electrical. Equipment which may provide easy exposure to electrical shock.
- Mechanical. Exposed equipment with moving parts that are capable of causing injury.

- Musculoskeletal. Task that adversely affect either the muscles or skeleton separately or in combination, e.g. lifting of heavy weights, repetitive movements, incorrect disposition of displays and/or commands, etc.
- Heat/cold. Sources that provide potential hazards from equipment generation.
- Optical. Equipment that is most likely to provide ocular injury.
- Electromagnetic radiation. Other electromagnetic sources e.g. magnetic fields, microwaves, etc.

NOTE: Several of these considerations are studied under several MARPOL chapters, where information needed to correctly handle dangerous goods is given.

System Safety

The risks occurring when the SCC is functioning in a normal or abnormal manner.

The design and operation of the centre will influence, and be decisive at the moment proper decisions need to be taken.

The human factors safety domain should be regarded as the area where, within each phase of the SCC human centred design process, the human element should be systematically considered as one of the possible source of hazard during the use of the system.

The key issue is to identify and understand the factors that affect human performance in relation to the technical systems being operated and the environment in which work is taking place.

NOTE: This task should start from the early stage of the SCC definition and should refine its results as the design progresses, giving the necessary retrofits at different levels: from changes in concept definition to requirement modifications/extensions.

Human error analysis should also integrate with the traditional engineering approach during the phases of the overall safety lifecycle.

The activities under this domain should, at least, consider the following key aspects:

- Error sources. The use of the SCC in general, or of one of its subsystems, which is likely to lead to error. For example, long, complex procedures for simple operations.
- Use behaviour. Misuse and abuse of subsystems which have safety implications for the user. For example, inadequate materials, skill and attitude of the system's operator, ergonomic design, and the interpretation of information received, are all aspects that have a direct influence on checking human error.
- Surroundings. External environmental conditions which have safety implications for the SCC user or third parties involved in ship's operations. e.g. piracy, extreme weather, dangerous cargo (chemical, biological, explosion and fire)

Survivability

Personnel Survivability refers to using system design features that improve safety and operational success while in hostile natural or man-made environments. This includes the progression from the integrity of crew and passenger compartments, through safety, survival, escape and rescue systems, equipment and procedures.

13 ANNEX 4: ANNOTATED BIBLIOGRAPHY

This section identifies the main sources of material used to develop the templates and the rationale behind them. Some of the documents identified here were used directly, while others helped to shape the approach, or highlighted specific aspects that required consideration.

The approach to the template development drew on a number of sources.

The IMO Interim Guidelines for the Application of Human Element Analysing Process (HEAP) to the IMO Rule-making Process was considered for application at a ship level rather than a Regulatory level. The template has many similarities to HEAP. The use of a flowchart that reviewed a wide range of areas that might be affected has many similarities to the template. Highlighting the points concerning single person error, latent errors and man/machine interface design is very similar to the template. The final review of the acceptability of risks and consequences is much the same as the ALARP summary in the template.

The civil aviation Regulation JAR 25 (Human Factors Aspects of Flight Deck Design) was instrumental in determining the approach to the template. The problem being addressed was very similar – novel flight deck technology introducing new Human Factors issues. The focus on novel features is derived from this Regulation. The criteria on which the Authority must be satisfied are very similar to the Regulation, namely the following aspect of the Flight Deck Interface design:

- Ease of operation (including automation).
- The effects of crew errors in managing the aircraft systems, including the potential for error, the possible severity of the consequences, and the provision for recognition and recovery from error.
- Task sharing and distribution of workload between crew members during normal and abnormal operation.
- The adequacy of feedback including clear and unambiguous:
    - Presentation of information
    - Representation of system condition by display of system status
    - Indication of failure cases, including aircraft status
    - Indication when crew input is not accepted or followed by the system
    - Indication of prolonged or severe compensatory action by a system when such action could adversely affect aircraft safety.

The need to communicate training and procedural assumptions recognised in JAR 25 was also recognised as important in the marine context.

The criteria for the design philosophy were also reviewed for applicability to the SCC.

JAR 25 made recommendations about methodology and the use of specialist expertise which are recognised by the ATOMOS consortium as important elements in de-risking SCC design but the approach taken in the template differs from that in JAR 25 as a consequence of the different organisational and commercial context of marine operations.

Compatibility with ISM requirements and practical operation was sought. The ISF Guidelines on the application of the IMO International Safety Management Code and the ICS SMS document templates and example ISM documentation proved useful resources in attempting to maximise the ease with which the Regulation could be accommodated within a company SMS. The ICS Bridge Procedures Guide also proved valuable in this regard.

The ILO 'Guidelines on occupational safety and health management systems', ILO-OSH 2001 was taken as a risk-based framework into which the template will (at some stage) need to fit. The text quoted in Section 6.7 illustrates the compatibility of the approach in the template to the ILO guidelines.

Ergonomic criteria as regards training, manning and operation were drawn from a number of sources.

Ergonomic criteria for training given in Section 4 are based on the need for consistent assumptions and implementation, and do not draw from any particular literature.

Ergonomic criteria for procedures design are less well-established than criteria for other topics. The criteria in Section 5.2 were drawn from the needs of BRM and from experience in writing procedures.

The IMO Resolution A.890(21) 'Principles of Safe Manning' was used extensively. The process for producing a Minimum Safe Manning Document was examined, and it is intended that the template draws on this process if possible rather than causes any duplication of effort. It is also intentional that the template sets out a similar process to that for producing a Minimum Safe Manning Document. The aim is that by bringing the principles of safe manning into the template for equipment and ship changes, the cross-cutting intent of the Regulation can be achieved. There were a number of specifics also taken from the Resolution, including the principles and functions, and the STCW related items.

The section in STCW on 'Principles to be Observed in Keeping a Navigational Watch' was used in a number of places in the template.

A wide range of documents on BRM and CRM were reviewed and provided background material. The Transport Canada Marine Safety TP13117E Training Program in Bridge Resource Management contained a number of items of fairly direct use. Charts adapted from 'Bridge Team Management Course' Maritime Institute of Technology & Graduate Studies and American President Lines, LTD., 1992 were used.

The Intertanko Bridge Management Manual contained material directly useful to the template and valuable background on other aspects of bridge documentation.

IMO A.849(20) 1997 'Code for the investigation of marine casualties and incidents' provided useful background and some specific material, particularly the section on Human Factors, A.884(21).

Ergonomic criteria as regards equipment design and bridge layout were drawn from a number of sources.

MSC Circular 982 and the ATOMOS II Report – Conceptual Standard for SCC Design (including HMI) A217.00.11.053.001A were used as major inputs to Sections 6 and 7 of the template.

MSC Circular 891 'Guidelines for the On-board use and application of computers' was reviewed for applicability and some lessons drawn from it.

The EEMUA Alarm Systems Guide to Design, Management and Procurement (EEMUA Publication No. 191:1999) was drawn on for ergonomic criteria for alarms, although the criteria in the template fall well short of a full implementation of the EEMUA Guide.

EN ISO 11064 (Ergonomic design of control centres) was taken as the model of best practice for user-centred design of control centres in general. It was used as a reference model to see how good practice might be tailored to the marine environment without going beyond the scope of the Regulation.

Most guidance on user interface design is intended for a single user. Useful guidance on the needs of user interface design to support team working was drawn from NASA Technical Memorandum 109171'A Crew-Centered Flight Deck Design Philosophy for High-Speed Civil Transport (HSCT) Aircraft', by Palmer *et al*, 1995. The guidance from this document integrated well with guidance derived from BMR material. Material in the template that owes most to this document appears in Sections 6.2 and 6.3.