A Framework for Addressing In-Service Submarine Safety Cases

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Abstract

The UK's Ship Safety Board, through its Ministry of Defence (MOD) Ship Safety Management Policy (ref 1) requires that safety cases (SCs) are to be in place for all legacy platforms by the Spring of 2005.

In meeting this requirement, the in-service submarine Duty Holder, the Submarine Integrated Project Team Leader (SUBIPTL), wants to ensure that retrospective submarine safety cases are useful to all key stakeholders. As a consequence, an extensive consultation process was initiated to catalogue the views and opinions of system and equipment design authorities, maintainers, trainers, operators, contractors and disposal organisations. In addition, Regulators and Naval Authorities were invited to participate.

The consultation process took the form of face-to-face interviews, briefings and interactive workshops. It identified a number of safety management aims, technical issues, policy considerations and expectations.

The paper explores the approach that was adopted and the underlying rationale. It then discusses the whole boat safety goals and the scope and boundaries of the retrospective safety case. The paper concludes with a description of the framework against which SUBIPT could action the requirements of Joint Services Publication (JSP) 430 for in-service submarines that meet the expectation of key stakeholders.

Introduction

Background: Generic guidance has been produced to assist Duty Holders and contractors in the production of safety cases and in addressing the acquisition cycle (refs 1-3). This guidance is generally equally appropriate to both a ship's system and the whole platform. However, a more tailored framework was required to help the SUBIPT address the complex, whole submarine issues of: safety across the entire acquisition life cycle (CADMID cycle), working across equipment boundaries and multiple interactions with other organisations and facilities.

To be of benefit the structure had to mirror MOD working practices. Concomitantly, it had to be sufficiently innovative to promote whole submarine cross-organisational safety thinking that encapsulated platform protection, human factors, inherently safe equipment and systems. It also had to promote a management culture based on continuous safety improvement.

Project Approach: An iterative approach was adopted, which allowed key stakeholders to fully express their needs for the retrospective safety case and to provide comment on its content and scope. The major stakeholder groups were drawn from the:

- Defence Procurement Agency (DPA)
- Warship Support Agency (WSA)
- Operators
- Trainers
- Design Authorities
- Equipment IPTs (EIPTs)
- Platform IPTs
- Regulators

- Independent Safety Assessors (ISAs)
- Budget Holders
- Contractors.

Concepts, issues and the safety case framework were tested through a series of thematic workshops, the topics for which arose out of the stakeholder consultation process and covered:

- Safety Case Structure, Content, and Linkages
- Whole Boat Safety Case Aims
- Operator Interface
- Whole Boat Hazard Identification and Management
- Nuclear Authorisation; Safety Case Interactions
- Safety Case Supporting Evidence
- Regulators & ISAs Interface.

Safety Context: JSP430 and its equivalents for land systems (JSP454) and defence aviation systems (JSP533) are based on the concept of safety requirements or safety claims. They describe those aspects of the system or platform that must be met, or be in place, in order to ensure compliance with the Secretary of Defence's safety objective of ensuring that levels of risk, which may result in death, injury, ill health to crew or other parties, damage to ships, their equipment and the environment, are As Low As Reasonably Practicable (ALARP).

The goal of the whole boat safety case (WBSC) is to clearly and credibly argue that the most appropriate/best practicable/ALARP level of safety management is being achieved across the boat and that the safety requirements are:

- Traceable
- Consistent
- Maintainable
- Coherent
- Manageable
- Fit for Purpose.

The safety requirements and hazards, together with the corresponding safety arguments and justifications, are the outputs of the formal safety assessment. It is key that the whole boat safety requirements and justifications reflect the individual equipment and system hazards, safety requirements and justifications.

Within this context, the current SSN and SSBN classes of submarines were designed a number of decades ago and some of the historical evidence supporting their original safety requirements may now be difficult to find. It does not necessarily reside within the WSA and much of the corporate knowledge in this area has been diluted. This must be matched against the goal of meeting continually improving safety standards and relating these standards to those which were extant when the submarines were constructed and the equipment procured.

The proposed WBSC framework needs to accommodate all these issues, while recognising that the remaining service life of some of the SSNs is relatively short.

The Framework

Scope of the Framework: The proposed framework covers the entire life cycle of the submarine and brings together, at the whole boat level, the safety justifications for individual equipments and systems such as the nuclear steam raising plant (NSRP), ordnance, munitions and explosives (OME), strategic weapon system (SWS) and regulated key hazards. The depth and rigour of the safety arguments being based on their safety significance with respect to whole boat events.

The framework assumes that the individual formal equipment and system safety assessments are adequate and appropriate and that only whole boat events should need to be addressed. These are covered in part by the assessments required to obtain individual certificates of safety for the ten key hazards, which are self regulated by the Naval Authorities. However the safety aspects associated with integrating the individual safety cases, accommodating the submarine working environment, overlaying of key hazard certification and meeting specific 'normal' and 'abnormal' operational requirements needs additional attention.

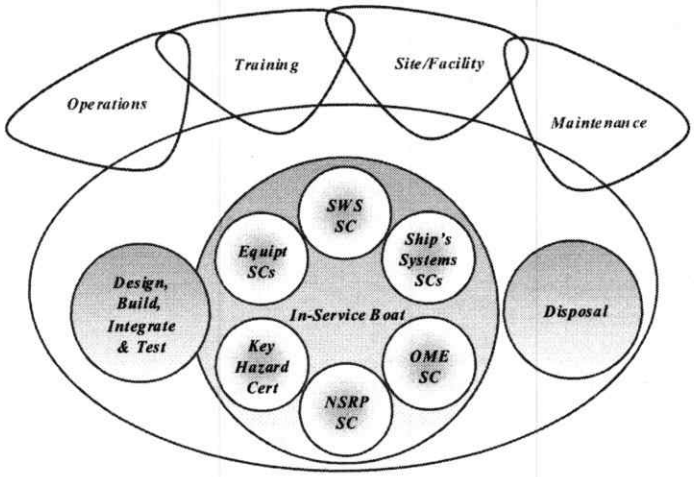

Figure 1 - Dovetailing of the WBSC within the Acquisition Cycle

Figure 1 provides a pictorial representation of the scope and content of the in-service WBSC, depicted as the central ellipse, and the way it dovetails with the safety cases covering the other aspects of the life cycle.

The framework depends on the principal of mutual assurance between Duty Holders and rigorous checking of the integrity of system and organisational interfaces. It involves cascading whole boat safety requirements down to a sufficient level of detail to provide confidence that the level of risk is acceptable. This relies on a complete understanding of the safety functions of the whole boat, its systems, equipments, personnel and support structures and will necessitate the need for the involvement of Suitably Qualified and Experienced Persons (SQEP).

The proposed framework, which is under consideration by the MOD, represents one possible approach to the production of a WBSC.

Safety Review and Policy: An exploratory investigation across relevant organisations within the MOD identified both strengths and weaknesses in submarine safety management. Strengths were the robust approach to design and engineering and familiarity of functioning within a procedural working environment. Weaknesses were in the areas of target setting, safety reporting, cross-organisational communication and maturity of safety management systems (SMS). It also highlighted the need for an approach that helps to qualify the significance of hazards for the whole boat and leads to the development of the high level safety requirements.

Figure 2 illustrates a process which could be used to identify gaps which may exist and could point to safety hazards. In addition it helps draws conclusions from the information presented as part of the individual equipment and system safety assessments and in the key hazard certification process.

The whole boat impact of the issues and hazards identified during the safety review are qualified by assessing how significant they are in terms of the submarine safety principles and criteria.

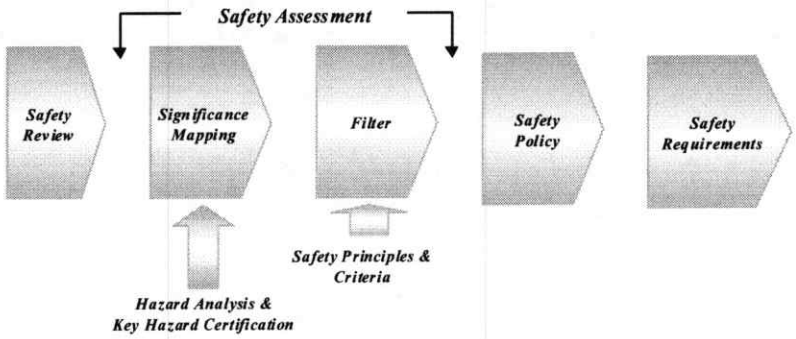

Figure 2 - Significance Mapping of Whole Boat Hazards

Typical whole boat safety principles and criteria are shown in Figure 3. The principles encapsulate the submarine safety philosophy and the criteria provide the standards and targets against which safety is measured.

Safety Principles

- Meeting Secretary of State's safety objectives
- Meeting all user needs
- Based on good management practice and best practices
- Covers engineering, management and communications

Safety Criteria

- Loss of the boat targets
- Loss of life targets
- Conventional explosion targets
- Radioactive release limits
- Radiological exposure
- Health & Safety Executive compliance
- Environmental compliance

Figure 3 - Potential Submarine Fleet Safety Principles & Criteria

The aim is to short-list those issues and hazards which are most significant and use them as the basis for the high level whole boat safety requirements.

The proposed one-page safety policy for the submarine fleet would set the basis against which safety is judged within the MOD. It lists the safety principles and criteria and the high-level safety requirements for the submarine fleet. The ability to meet these safety requirements will be justified and argued in the two 'class safety cases' (Swiftsure+Trafalgar Class and Vanguard Class) with the arguments and deviations for each individual boat addressed accordingly. The intention is to begin with these classes and then consider remaining non-operational submarines, for example moored submarines open to the public, on a case by case basis.

Safety Requirements: As a result of the exploratory investigation, a number of potential whole boat safety requirements have been proposed for in-service submarines. In combination with the safety

assessments of the various operational scenarios, these cover the full gambit of peace and war time activities. The high-level safety requirements are the links between the whole boat, operations, training, maintenance and disposal safety cases and demonstrate, both internally and externally, a commitment to continually improving the boat safety culture. Potential whole boat safety requirements could be:

- The Boat fully meets its specification
- The Boat is managed safely across the acquisition cycle
- All personnel involved with the Boat are adequately trained
- All personnel involved with the Boat have the correct level of expertise and experience

Looking in a little more detail at the statement that the boat meets its specification, it is immediately apparent that more than one organisation and Duty Holder is involved in satisfying this requirement. The example provided in Figure 4 demonstrates how this high level whole boat safety requirement is cascaded down through meeting the design intent to listing the requirements of a capable boat. Similar work breakdown structures (WBS) would need to be developed for the other components of this requirement.

Figure 4 - Examples of the lower level safety requirements supporting the boat meets its specification

Similarly the requirement to manage safety across the entire acquisition cycle of the boat (Figure 5) provides the links to the system integration safety requirements and demonstrates how certificates of safety for individual safety functions are re-inforced at the whole boat safety level. The safety requirements or functions addressed by the ten key boat hazards now become immediately obvious to all whole boat stakeholders and systems and equipment that contribute to these safety functions become transparent.

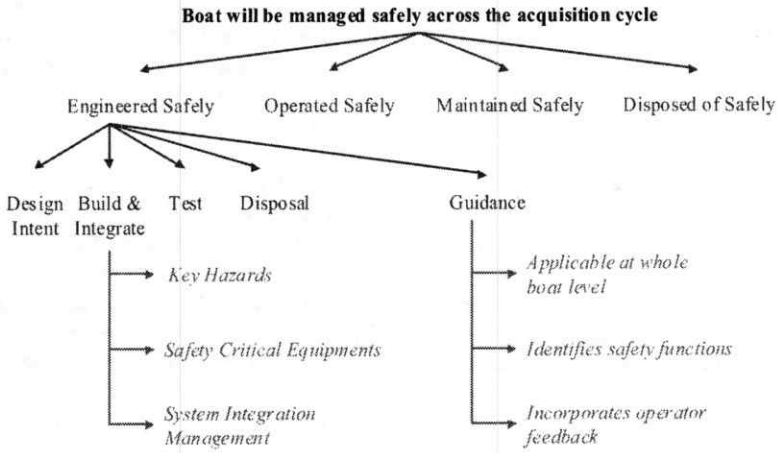

Figure 5 - Meeting the high level safety requirement of managing safety across the acquisition cycle

The suggested framework helps to draw out which Duty Holder has direct managerial control over a particular aspect of this safety requirement and those which can only influence safety management. In turn, it identifies those who will need to ensure that particular safety requirements have been met and the others that will want to assure themselves that whole boat safety aspects are adequately managed elsewhere within another organisation. It also demonstrates in a logical fashion how the original user definition requirements and staff requirements were transformed into an engineering and operational solution.

Ultimately, the framework provides a management tool that helps the Duty Holder (SUBIPTL) develop a logical and robust approach to the production of a WBSC in which all safety issues are addressed and critical whole boat requirements are properly justified and achieved.

Performance Indicators: The WBS approach to cascading safety requirements not only directs the focus for the safety claims and arguments but also helps to develop the performance indicators. These together with the management review process demonstrate that safety risks are maintained ALARP and that there is a co-ordinated measurement of the safety track record across the entire submarine acquisition cycle.

Potential whole boat 'engineering' performance indicators may be of the following type:

- Availability of the boat
- Reliability of safety critical systems
- Recognition of the significance of specific equipments to safety
- Maintenance of current levels of safety
- The number of safety-related Alterations & Additions (A&As).

Managing the Interfaces: It is generally recognised that the current management structures adopted across WSA, DPA and Fleet quite deliberately lead to the 'stove piping' of responsibilities. For instance, SUBIPT is responsible for providing a safe boat that meets its user requirement while Fleet delivers the trained personnel to operate it.

However safety does not have clearly defined boundaries and analysis of recent transport accidents shows that it is at the interfaces between organisations that the safety systems are most prone to breakdown. Failure is more likely to occur due to poor communications, inappropriate articulation of the problem and operator misunderstanding than it is to engineering problems.

As discussed earlier in the paper, many of the whole boat safety requirements cut across organisations. A method to draw out these cross-organisational associations is shown in Figure 6. Strong interactions at the whole boat level are indicated by a (✓) and assumptions by an (A).

However, as the safety requirements are cascaded the number of interactions will be increased until the matrix becomes fully populated.

Safety Requirements	Key Hazards	Fleet	SUBIPT Contractor	EIPTs	Facilities	ISA
Operational	✓	✓		A	A	
Training	A	✓	A	A	✓	
Design	✓		✓			✓
Maintenance	A		✓			
Disposal			✓			
Personnel		✓	✓	✓	✓	
Safety Management	A	✓	✓	✓	✓	✓

A = Assumption
✓ = Interaction

Figure 6 - How Whole Boat Safety Requirements Cut Across Organisations

In order to articulate the cross functional components of whole boat safety and the strength of these interactions the framework assumes that a number of two-way protocols or business agreements are drawn-up. These will support the production and maintenance of the WBSC, help characterise the boundaries and will re-inforce the links between the SMS covering the various systems, facilities and organisations involved with the boat.

The protocols would include general sections covering the statement of intent, scope of the protocol and a description of the implementation approach. Specific sections would address:

- Interface boundaries
- Strength and characteristics of interactions
- Data exchange requirements
- Stakeholders
- Responsibilities
- Management
- Communications.

Whole Boat Safety Executive: In order to champion the whole boat safety requirements and to direct the production of the WBSC the formation of a Whole Boat Safety Executive (WBSE) has been proposed. The WBSE would be under the chairmanship of SUBIPT and would have representation from all key stakeholders involved with the acquisition cycle of the submarine fleet. The remit of the WBSE would be to:

- Agree and communicate the whole boat safety requirements, safety principles and criteria
- Promulgate the submarine safety policy
- Catalyse production of safety cross-organisational protocols
- Develop and agree the plan for producing and maintaining the WBSCs
- Action production of the WBSCs
- Monitor performance indicators
- Ensure the currency and usefulness of the WBSCs.

The WBSE should be more than a safety committee that reviews safety progress. It should have executive power, which would allow it to make policy decisions and enable free access to all relevant safety documentation from all stakeholder groups.

Summary

A framework is under consideration that will help SUBIPTL, as the Duty Holder, to champion the production of the WBSC for in-service submarines. It comprises a number of elements that complement and incorporate the existing work that has been conducted by individual EIPTs, Regulators, ISAs and Contractors. The major elements include:

- Formation of the WBSE
- A one page safety policy for the submarine fleet
- Whole boat safety requirements which are cascaded through to individual systems and equipments and to the management of system integration
- Protocols between organisations covering cross-functional safety
- Whole boat performance safety indicators.

The framework offers a simple and logical approach to the development of the WBSC. It endeavours to make the entire process transparent so that all stakeholders are able to constructively contribute at key stages in its development. This will ensure that the family of WBSCs which are produced communicate clear and credible safety arguments and benefit all the stakeholders.

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Biography

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Abbreviations

A&A	-	Alterations & Additions
ALARP	-	As Low As Reasonably Practicable
CADMID	-	Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal
DPA	-	Defence Procurement Agency
EIPTs	-	Equipment Integrated Project Teams
IPTs	-	Integrated Project Teams
ISAs	-	Independent Safety Assessors
JSP	-	Joint Service Publication
MOD	-	Ministry of Defence
NSRP	-	Nuclear Steam Raising Plant
OME	-	Ordnance, Munitions and Explosives
SC	-	Safety Case
SMS	-	Safety Management Systems
SQEP	-	Suitably Qualified and Experience Person
SSBN	-	Ship Submersible Ballistic Nuclear
SSN	-	Ship Submersible Nuclear
SUBIPT	-	Submarine IPT
SUBIPTL	-	Submarine IPT Leader
SWS	-	Strategic Weapon System
WBS	-	Work Breakdown Structure
WBSC	-	Whole Boat Safety Case
WBSE	-	Whole Boat Safety Executive
WSA	-	Warship Support Agency