WARSHIPS IN HARBOUR:
A COST-EFFECTIVE RISK MANAGEMENT SOLUTION

BY

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ABSTRACT

The presence of large quantities of ordnance, munitions and explosives on warships and their proximity to centres of population when in harbour has for some time been a challenging issue for the Ministry of Defence. The risk associated with Warships in Harbour may be characterized as 'high consequence, low frequency' and has the potential to affect members of the public. As such, it is comparable to other major hazards that warrant a robust, risk-based regulatory framework. Management of the hazard is complex, having to consider many platforms, many locations, a great number of Duty Holders and a corresponding multitude of interfaces.

Through the Warships In Harbour Study Group, an enduring safety management system has been established to manage the conventional explosives risks associated with Warships in Harbour. These have been published in the form of Naval Authority Regulations and supporting guidelines to assist Duty Holders in managing the Warships in Harbour risk.

The article outlines the principles and approaches, which have allowed a proportionate and cost effective risk management solution to be developed for a complex risk management issue. It demonstrates how using different approaches, protocols, models, data and generic information can help make a very complex issue manageable, whilst still ensuring it is based against modern best practice and meets legal requirements for suitable and sufficient risk assessment. This article does not furnish the reader with the Warship in Harbour solution but uses it as an example to guide personnel faced with a complex safety issue.

Introduction

High consequence, low frequency risks exist in many places within society and the military and are characterized by similar factors which can make them very difficult and therefore expensive to understand, manage and regulate. These characteristics include:

- Little (if any) historical or empirical data
- Involve high consequence often characterized by multiple fatalities.
- Complex consequence mechanisms, which are difficult to accurately predict.
- Involve subjective and ethical issues.
- Have political implications or drivers.
- Involve significant costs both in terms of:
    - Asset loss.
    - Ongoing costs.
    - Clear up costs.

- Involve complex interactions on many levels:
  - Chemical.
  - Physical.
  - Organisational.
  - Regulatory.
  - Political.
  - International.
- Involve operations which cannot be avoided.

Anyone of these can result in risk management becoming expensive. A combination of all of them can quickly raise significant resource and operational issues and present a seemingly intractable problem.

The presence of a warship carrying explosives alongside in a populated harbour brings with it a degree of risk that cannot be dismissed, it includes aspects of all of the characteristics described above and as such presents a significant safety management challenge. This risk can be described as 'high consequence, low frequency' and has the potential to affect members of the public. As such, it is comparable to other major hazards that warrant a robust, risk-based regulatory framework. Management of the hazard is complex, having to consider many platforms, many locations, a great number of Duty Holders and a corresponding multitude of interfaces. As a result the WIH Study Group (WIHSG) was tasked with understanding the level of risk and developing an enduring safety management system to manage the conventional explosives risks associated with Warships In Harbour (WIH).

This article does not develop any new techniques to provide the silver bullet for all high consequence low frequency risk problems, nor does it offer anything radically new to experienced practitioners versed in safety and risk management. It will however illustrate how a very complex issue has become manageable through development of a cost effective solution which represents modern best practice and meets legal requirements for suitable and sufficient risk assessment.

The article consists of three parts. The first explains how a generic complex safety problem can be understood and characterized using WIH as an example. The second is an overview on the WIH specific solution and provides the reader with details of the approach adopted in tackling this particular problem. The final section is a summary of the key principles and techniques adopted in developing the WIH solution. It is this later section, which suitably adjusted by the benefit of hindsight and lessons learnt describes some of the principles, which help in the development of complex safety cases.

GAINING AN INSIGHT

Understanding the Issue

Key to understanding the issue is the time and analysis effort spent gaining an insight into the context and interactions of the problem at all levels. These levels can be categorized as:

- Physical.
- Organization.
- Procedural.
- Regulatory.

In the WIH example the problem was extremely complex. It involved many vessels in many harbours and many berths, with different ammunition states and different activities underway. It involved several regulators and duty holders, and over a dozen key stakeholders from within and external to the MoD. It crossed physical, organizational and regulator boundaries and even a simple ship to berth view results in millions of permutations. All of which indicated that a simple single safety case was probably going to be a challenge to achieve and even more taxing to maintain and regulate.

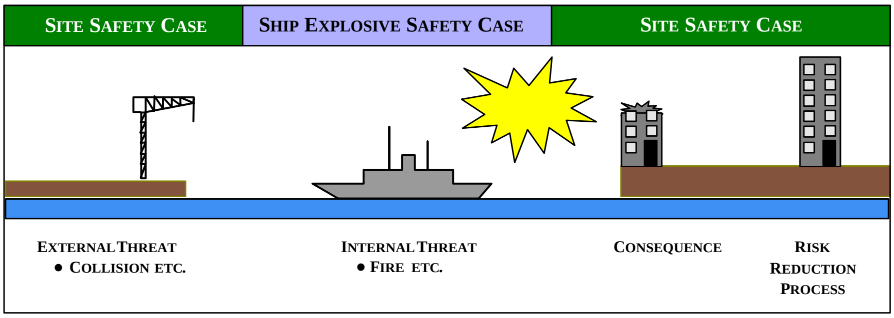

FIG.1 – WARSHIP IN HARBOUR SYSTEM OVERVIEW

Therefore, in order to gain an insight into the WIH issue a high level systems overview was taken. The physical system diagram is shown at (FIG.1). Whilst appearing trivial, when produced alongside similar diagrams looking at organizational, regulatory and management aspects a clear understanding of interfaces, weaknesses and gaps and areas of confusion readily becomes apparent. This led to several key deductions, the first of which was the need to clearly understand the context of the problem.

Understand the context

Understanding the context is essential to developing a solution. This means understanding not only what the existing regulatory, legal, best practise and de-facto standards are, but also why they exist. This can involve going back to first principles and then building a clear understanding of where the problem sits. It is vital when doing this to ask the "so what" questions. If a standard or regulation exists, it needs to be assessed on its merits. Must the standard be followed because:

- There is a legal requirement?
- Because it is best practice?
- Because we always have done it that way?
- Is this the most suitable regulation?

For complex safety issues such as WIH, it is likely that no single approach is suitable for all aspects of the problem. If that is the case then referral back to first principles is absolutely vital. Whilst a standard or set of regulations in a similar context can provide useful insight and allow a base line against which to demonstrate a suitable and sufficient approach has been adopted, trying to follow these verbatim may cause unnecessary difficulty and be detrimental to the overall safety management approach adopted. An understanding of what that standard is attempting to do, then developing an approach which achieves a similar objective by a more suitable means can often be a simpler, more effective and policy compliant approach.♣

♣ JSP 375 Volume 1 4th Edition:

In the WIH example, the identification, selection and adaptation of standards for use as regulatory instruments was fundamental to developing a suitable safety management system. Current approaches to managing explosives safety rest mainly on consequence management. This entails the application of rules, which assume that an event would happen at some point and therefore to ensure that adherence to 'rules' would provide sufficient separation between the explosives and people to prevent casualties. This approach, which was developed for the storage of explosives ashore is a sensible solution to that particular situation and withstands scrutiny in this context. It was not however designed to deal with WIH and it is hardly surprising that applying this 'solution' in the WIH context produces a safety management system, which would have been unfeasible. While the consequence-based approach represents one way of dealing with risk, it is not the only possible solution. WIH therefore investigated other approaches which could be adopted to deal with risk, looking at statutory, departmental and HSE guidelines and industry best practice for other high consequence activities, such as airports in built up areas and petroleum and chemical plants. This provided a clear understanding of the context of the WIH problem and provided insights, which made subsequent aspects of developing a suitable risk management system much easier.

Scoping the Issue

The second key observation was that of scoping in detail what the risk management system is going to actually do, and what it is not going to do. This manifests itself as a series of questions, which should be clearly articulated and therefore understood by all stakeholders. These questions include the very simple, what is the risk, to who and from what? For WIH this was stated as the risk of death to a 3rd party, caused by an explosive event on a warship in harbour whilst the explosives were in the quiescent state. By clearly articulating the issue stakeholder understanding could be achieved and the understanding of concerns or misunderstanding which could later cause problems with the safety management solution could be avoided.

In reality this scoping produces a simplified subset of the complete real world problem and could be criticized for this approach. However this was considered appropriate as the insight gained from understanding the issue had demonstrated:

- When warships were in harbour the munitions generally remained in the quiescent state.
- Conventional practice provides 3rd parties with more stringent risk targets than either 1st or 2nd parties, therefore representing a more difficult and therefore inclusive target.
- The ship's crew would be on the warship whether it was alongside or at sea and as such where independent of the WIH issue.
- Non-quiescent activity (e.g. ammunitioning) was already regulated and safety management processes were in place regulated to manage the risk.
- The quiescent state provided the clearest interfaces at all levels and so would allow for the simplest solution which could then be used as a baseline for further work.

This scoping work also led to several key heuristics:♣♣

"…where there is no relevant legislation, internal standards will aim to optimize the balance between risk and benefit to the ministry and employees……".

♣♣ A heuristic is a statement of the obvious which generally holds true.

An ideal model does not exist

The real world is complex, and all models of it are flawed – but some are useful and can provide an insight. By accepting this and understanding the clear limitations of the model, then a solution can be developed which provides a clear baseline and which will facilitate further future work to fill the gaps should it be required. Searching for the ideal model can quickly become a resource drain, which presents the implantation of the 99% solution in the search for the ideal.

'They' do not exist:

Only by understanding and taking account of the concerns and views of the many different stakeholders can a solution be developed. However, with a complex issue which does not fit into an existing paradigm there can be a tendency even with the best will in the world, to assume a suitable solution cannot be found. This can manifest itself into a 'they will not allow it' situation, where although a particular stakeholder understands and agrees in principle with the proposed way forward, another party (the 'they' referred to) is cited as a reason for non-acceptance. Tracking the 'they' down and understanding their view is key to unlocking a solution. Occasionally, the 'they' is a circular argument which runs through several stakeholders, each providing helpful observations, with the 'they' perpetually moving around the circle. Once the circle is broken into, the 'they' vanish and the issue can move forwards.

Having gained an understanding of the WIH problem from all these aspects, it was then possible to identify and assess the viability of the various approaches available and determine the most effective programme strategy, making best use of available methods, tools and data.

Learning from Experience: Previous Approaches

Making use of previous work can help to provide effective solutions to risk management issues. However, the temptation of trying to fit a partial solution to the problem should be avoided. A clearer approach which compares previous work to the understanding gained by analysing and scoping the problem is far more likely to provide a better solution, whilst conducting GAP analysis on this can help determine the strategy required to develop the solution allowing previous work to help rather than hinder progress.

In the context of WIH previous work to develop a 'Warships In Harbour Safety Case' had adopted a bottom up probabilistic approach, looking at the munitions in the platform and attempting to quantify the threats they were exposed to and the subsequent scale of consequence. Although this work was successful in building an understanding of the baseline threats it quickly became extremely complex as the modelling and evidence required to determine how munitions would interact in different combinations and the subsequent impact on ship structures was increasing beyond the level of resource considered proportional to the risk posed.

In an attempt to avoid this increasing expense and complexity a generic safety case argument was produced which aimed to demonstrate that the likelihood of an explosive event was so small that it could be ignored ('beyond design basis'). Again, this work had had some success but was unable to provide the level of confidence to meet the objective of demonstrating the risk to be considered negligible.

Other discrete work was undertaken under the auspices of other organizations and all this previous work has been used in developing the WIH Solution.

Having gained an understanding of the problem, and an understanding of the previous work undertaken in terms of respective strengths and weaknesses it was possible to make most effective use of previous work. These stepping stones, when utilized with the techniques described further on in this article allowed rapid progress to be made in developing the WIH solution.

THE WARSHIPS IN HARBOUR SOLUTION

Developing the Solution

With a clear understanding of what the WIHSG was attempting to do, the key issues, the context and the previous work that had been undertaken, it was possible to begin to look at developing a suitable safety management solution. This section of the article will provide an overview of how the WIH solution was developed. Key generic observations on developing the safety cases will be covered in the final part of the article.

The use of safety cases to demonstrate that risks were being suitably managed is prescribed MoD policy,[♣♣♣] therefore some form of WIH safety case framework would need to be developed. The complexity of the problem had become obvious through systems analysis and the development of a single safety case for the complete issue was quickly discounted as not viable. However the systems analysis made the identification of interfaces very clear. These interfaces existed at the physical, i.e. ship to berth level, duty holder i.e. platform to naval base, and regulatory, i.e. ships explosives versus shore stored explosives, boundary. Therefore, if the interfaces could be developed to allow independent safety cases and safety management systems to interact across a clearly defined and simple interface whilst maintaining their validity and allowing regulation then it would be a significant step toward the solution.

The WIH system is shown in the physical model at (FIG.2) and the functional model shown below at (FIG.3).

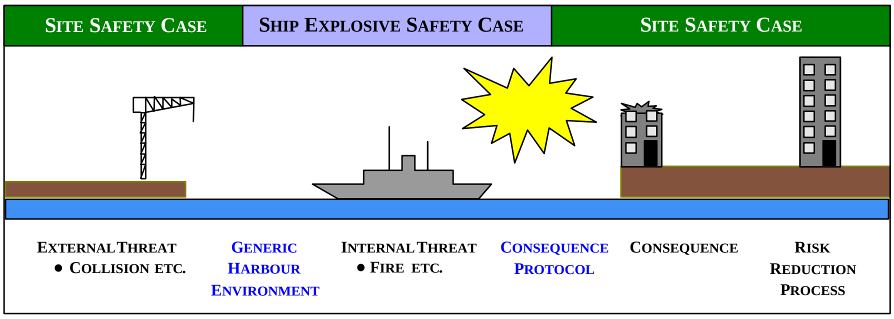

FIG.2 – SYSTEM OVERVIEW HIGHLIGHTING PHYSICAL INTERFACES

♣♣♣ JSP430 Part 1 Issue 3 Paragraph 4.7

"For all ships and equipment, safety cases are to be developed by material duty holders……..Safety cases are to be used to show that all risks, to people, material and the environment, have been reduced to a level that is broadly acceptable, or tolerable and as low as reasonably practicable."

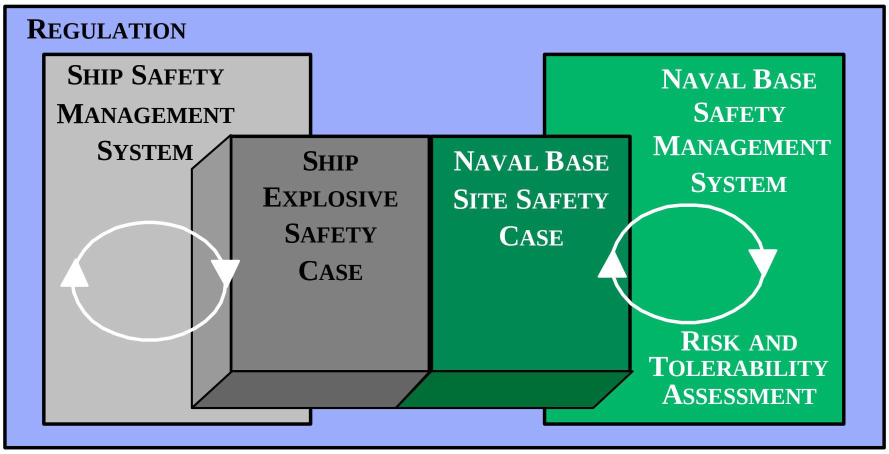

FIG.3 – WARSHIPS IN HARBOUR FUNCTIONAL MODEL

In line with the management of other key hazards, WIH risk management would be achieved in part through safety cases. The functional model therefore provided the basis for developing a safety case framework comprising of the following key areas:

(*a*) *Ship Explosive Safety Cases for Warships In Harbour (SESC(WIH))*

This safety case deals with the ship aspects and associated duty holders stakeholders and deals with the risk of an explosive event.

(*b*) *The Naval Base Site Safety Case for Warships In Harbour (NBSSC(WIH))*

This safety case deals with the harbour aspects and associated duty holders and stakeholders and is an assessment of the tolerability of the risk presented in (*a*) upon dockyard operations and 3rd parties.

(*c*) *Interfaces*

These provide a robust method of transferring data between duty holders, allowing the safety cases and safety management systems of both duty holders to interact and provide a method of ensuring validity in the many to many scenarios whilst preventing either side to require an detailed knowledge of the others safety case or regulatory activity

(*d*) *Regulatory Regime*

The regulatory framework and guidelines within which the safety cases function.

Development of the Safety Cases.

The clear delineation of safety cases was a significant step toward solving the problem, but there was still the possibility that overly complex or resource intensive approaches could be taken in developing the respective safety cases. In order to prevent this, several aims for the development of the regulations and guidelines were established:

(*a*) *Proportionality*

The processes and rigour with which WIH risks are assessed and managed should be proportionate to the level of risk. Effort should be focused on understanding and reducing key risk drivers.

Conversely, excessive effort should not be expended in areas of low risk.

(*b*) *Flexibility*

The WIH solution should be able to accommodate different levels of detail and assist decision making at various organizational levels within MoD.

(*c*) *Credibility*

The outputs from the risk management processes should provide adequate justification for operations, activities and decisions. The results should be credible from the perspective of all key stakeholders, including other regulatory bodies.

(*d*) *Endurance*

The solution would provide an enduring risk management framework, future-proofed in terms of accommodating foreseeable changes to operations, new ships and development of Naval Bases.

By following these principles WIH adopted two safety case approaches that were very different, yet compatible and appropriate for the respective domains.

Naval Base

The functional breakdown identified a Naval Base safety case structure, which did not need to be complex. The hazard was clearly understood and the parameters for this hazard would be passed across from the ship by the interface. The regulatory boundaries could be established and a suitable management process developed that was suitable in a site safety context. Therefore, the Naval Base safety case structure could be derived from conventional and well documented approaches for hazardous installations, e.g. COMAH/MACR sites. A safety management system was developed around credible, well established structures and was compatible with existing site safety management arrangements. By adopting the principles explained above, a structure suitable for all naval bases could be developed which provided sufficient flexibility for the naval base duty holder to ensure the safety case met their requirements, but reduced workload and eased regulation significantly. This approach produced a simple robust cost effective safety management structure.

Ship

The warship safety case domain was much more difficult to deal with. Whilst the interfaces had provided a clear and simple format for communicating the risk of ship explosion (i.e. frequency and consequence of events) to the naval base, the process of developing this information within the ship safety case was more difficult to define. The complexity of the problem precluded probabilistic ‘bottom-up’ approaches to be adopted, whilst the severity of the consequence meant that a simplistic approach would be unlikely to achieve regulator acceptance.

WIH therefore investigated the approaches adopted in similar industrial safety management areas. The methodology selected was based around a ‘Bow Tie’ format, which provides a comprehensive risk management framework where the level of effort expended can be varied proportionate to the risk. By readily giving visibility of the key risk drivers, resources could be concentrated in these areas, enabling cost-effective management of the safety cases. Whilst full details of the approach its implementation and the specific advantageous and disadvantages are not detailed in this article they can be obtained from the WIH documentation. In brief, other cost-effective features of the WIH risk management methodology include:

(*a*) Progressive filtering to eliminate insignificant accident event sequences.

(*b*) Maintaining a holistic view and perspective on all aspects of risk, thereby avoiding detailed analysis in areas where it will bring little benefit (applying the 'So What?' principle).

(*c*) Use of sensitivity analysis and comparative approaches to understand significance of individual risks and hazards and avoid unnecessarily explicit assessment.

(*d*) Use of conservative assumptions to handle uncertainty which need only be refined if the results are particularly sensitive to them, e.g. where they relate to key risk drivers.

(*e*) Providing a basis for informed decision making, with clear indication of the contribution of control measures (in place or proposed) to the overall risk.

(*f*) The methodology enabled the ALARP principle to be applied at differing levels of abstraction (the operational and strategic levels).

(*g*) Provided a baseline from which 'What ifs' could be assessed and the true value of safety mechanisms can be established.

Interfaces

This approach requires clear and effective management at the interfaces for it to be successful. The importance of these interfaces was recognised early in the project and these have been defined by two separate protocols, the Generic Harbour Environment (GHE) and the Consequence Protocol (CP), which are depicted in (FIG.4).

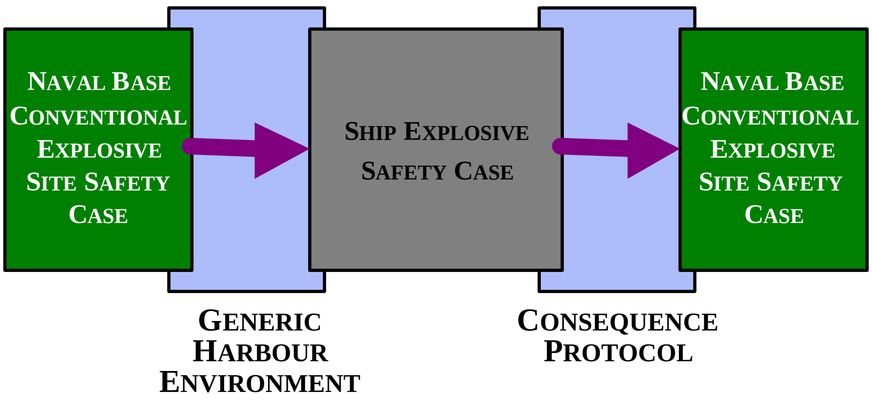

FIG.4 – SAFETY CASE INTERFACES: GENERIC HARBOUR ENVIRONMENT AND CONSEQUENCE PROTOCOL

By addressing the safety cases separately, Naval Bases can produce their WIH safety cases as a set of the wider site safety issues and the platform duty holders can produce their safety case as a subset of the wider Ship Explosives Safety Case

(SESC). In effect the WIH Solution consists of defined parts from both of these safety cases, allowing the duty holders to deal with their aspects in isolation of each other, significantly and necessarily simplifying the problem.

The final outputs from the WIH programme have been published in the form of Naval Authority Regulations and supporting guidelines to assist Duty Holders in managing the WIH risk.

GENERAL PRINCIPLES

In addressing the WIH issue, several principles were adopted to ensure the methodology represented a credible yet cost-effective solution. These principles and features of the approach taken in developing the WIH Solution are described below in terms of the benefits they've brought.

Initial Project Principles

The initial project principles were developed to assist in the development of structures and frameworks:

(*a*) *Simplicity*

The solution should as simple as possible whilst still providing a robust safety case. Thereby reducing the resources required to produce and subsequently manage the solution.

(*b*) *Generic*

The solution should contain a generic baseline, which provides duty holders with a workable structure in which they need only addresses the specifics of their situation, and deal with difference from the baseline rather than start from a blank sheet. Generally the generic solution should represent 80% of the work effort ensuring duty holders do not have to repeat or redo work which had been previously conducted.

(*c*) *Repeatable*

The structure of the safety cases should contain repeatability that can be easily identified and utilized to reduce unnecessary work effort.

(*d*) *Coherent*

The solution should be structured in such a manner as to allow duty holders to deal with their unique problems but in a framework, which ensured a coherent approach across all duty holders. This would help ensure ease of regulation, advice and assisting in making the work repeatable and allow skill transfer between duty holders.

(*e*) *Modular*

The approach should be modular in nature with clearly defined interfaces in place. This means that if a part of the solution proves to be unsuitable then this aspect can undergo further refinement without requiring a rework of other aspects of the solution. This is particularly important in the area where WIH has developed models, which may require refining in future or changing if more effective approaches are developed.

Key Factors for Achieving a Cost-Effective Solution

Use of a Pilot Study

The complexity of the ships explosive safety case for WIH and the novelty of approach represented a significant risk to achieving a workable WIH Solution. A pilot study was deemed essential to manage this project risk and ensure that the guidance being developed worked in practice and met the aims and principles of the project. The validation process not only provided confidence in the methodology as a Solution, but allowed identification and redevelopment of problem areas that were not envisaged when developing the initial guidance. As a result, further fine tuning of the approach could be done such that it reduced complexity and improved efficiency in developing other platform safety cases.

Proportionality

Recognizing that the contribution that individual hazards/faults make to the overall risk varies considerably (by orders of magnitude), it is necessary to retain perspective and manage the assessment to ensure the level of effort applied is proportionate to the risk presented. While all hazards need to be assessed, it is ineffective to apply a 'blanket approach' in assessing them explicitly to the same level of rigour. Instead, sensitivity analysis may be applied at various stages to avoid excessive analysis of insignificant risk and conversely as a check and balance that hazards 'filtered out' at an early stage are confirmed to make a relatively negligible contribution.

Generic Data Sets

In addition to providing a framework and guidelines for safety case development, it was recognized that many aspects of ship safety management are generic. The Pilot Study indicated that approximately 80% of the risk assessment is generic, with the specific aspects of a vessel making a relatively minor contribution to the content of a SESC(WIH). Hence, the WIH Methodology Suite also provides protocols, tools, models, data and generic information that serve to ensure compatibility and consistency, with associated benefits in efficiency and cost-effectiveness. Through adopting the principles described above, the generic nature of the data could be exploited to allow the production of safety cases for other vessels by a process of identifying the difference rather than by a complete 'rebuild'. This should significantly reduce future resource.

Independent Peer Reviews (IPR)

The use of IPR at key stages in the project was beneficial in ensuring that confidence could be maintained in the final solution whilst problems could be identified and addressed early in the work.

Bounding Case Analysis

The lack of precise and explicit data could have presented a significant problem to the WIH in developing safety cases. However, through the use of conservative bounding assumptions, the pilot study revealed that it was often not necessary to know exactly what a specific value was, in that uncertainty could be accommodated. For example, the quantity of explosives carried on a particular vessel is difficult to know exactly at any moment in time, however it is possible to say with a very high degree of certainty that it is not more than x kg. Therefore, if using this assumption presents a result, which is acceptable, no further work needs to be conducted and the actual answer will be better than that. This use of bounding assumptions can make very complex problems very simple while still producing credible results. For example, in WIH the assumption for berthing was that the largest possible vessel that could be at the berth would be there 100% of the time, and levels of risk calculated. Although this was physically impossible (e.g. there are only two CVS vessels) the answer demonstrated that the risk was tolerable, therefore the real world was going to be significantly better than this. Further more detailed analysis was not required.

Centre of expertise

Whilst it is universally acknowledged that each duty holder needs to get real value from, and understand the risks they're responsible for, to expect each duty holder to have a skill base of sufficient depth and experience to deal with all aspects of complex issues such as WIH is an unreasonable expectation. Therefore the WIH solution recognizes this fact in apportioning safety management responsibilities which ensure an adequate level of duty holder understanding, supported by specialists in a MoD centre of expertise. The WIH safety organization is based around a hub and spoke model, with the WIH cell in the Sea Technology Group providing a core of expertise to assist all duty holders. This has several advantages:

- Ensures duty holders have assistance in developing safety cases in areas where it is not cost-effective for them to maintain a specialist capability.
- Allows regulation and advice to be given from a perspective of knowledge.
- Ensures that safety cases are more likely to be relevant and acceptable on first presentation reducing resource usage and improving safety.

Tolerability

Whilst this article does not seek to repeat arguments presented elsewhere, it is essential that a very clear understanding of tolerability is achieved before it is possible to conduct meaningful arguments about risks being tolerable or ALARP. This is particularly important for high consequence low frequency risks where multiple fatalities and members of the public may be involved. There can be a great tendency for subjective views of individuals to corrupt the risk assessment process. This is neither helpful in terms of the safety management problem being addressed, or more importantly for safety management across the MoD. The Government in general and the HSE in particular have produced very clear guidance on tolerability principles and these have been understood before developing the solution to ensure it is able to produce results assessable against the proposed criteria.

Methodology

The WIH solution uses a mixture of deterministic, probabilistic, qualitative and quantitative approaches in determining the overall risk management solution. There is no reason why any particular approach should be used exclusively, especially when some areas of a problem may be more suited to a solution than others. The applicability of approaches should be driven by proportionality rather than a fixed dogmatic approach. When combining approaches then it is necessary to ensure that the output from each approach is fully understood and compatible with the overall safety management system and objectives. For example, in considering frequency of occurrence of an event it is important to pay particular attention to the units of data. Recognizing the complexity of the WIH problem, the advice of statisticians has been beneficial in ensuring that data and uncertainty were sufficiently well catered for and establishing safety targets appropriate for the means by which risk is measured.

Conclusions

The WIH Solution is credible, robust and simplifies a complex problem so far as possible. The approach is benchmarked against best modern practice and meets the legal requirement for suitable and sufficient risk assessment. Finally, the WIH solution provides protocols, tools, models, data and generic information to ensure compatibility and consistency, with associated benefits in efficiency. It provides an enduring and proportionate approach to risk management, ensuring that resources are applied effectively and appropriately.

Rather than focus on risk assessment techniques and safety case methodology, this articl offers experience-based practical guidance on the approach taken in dealing with the issue of WIH. By using the WIH solution as an example, this article demonstrates how a complex safety management problem can be dealt with in a robust, pragmatic and cost-effective manner. Readers requiring further detail on the Warships in Harbour solution, i.e. regulations and guidelines, should contact the Warships in Harbour cell within Sea Technology Group.