*"This paper was presented at the "Warship 2007 – The Affordable Warship" Conference, Organised by the Royal Institution of Naval Architects".*

# MAKING WARSHIP SURVIVABILITY AFFORDABLE

BY

DR J S THORNTON,
*DSTL, UK*

DR M D COURTS,
*VT SHIPBUILDING, UK*

DR M ROBB,
*BAE SYSTEMS, UK*

ABSTRACT

Recent experience with RN warship procurement has shown that there is great variability in the amount of survivability that is achieved. The reasons behind this are complex. This paper will examine some of the history and explore the problems. These range from how the MoD writes its requirements for survivability through to what the cost of a particular feature is and the extent to which it should be ascribed to survivability or to other requirements. The paper presents procurement models aimed at overcoming the existing problems.

**Nomenclature**

| | |
|---|---|
| AAW | Anti Air Warfare |
| Dstl | Defence Science and Technology Laboratory |
| DERA | Defence Evaluation and Research Agency |
| CNGF | Common Next Generation Frigate |
| COTS | Commercial Off The Shelf |
| CVF | Carrier Vessel Future |
| LPH | Landing Platform Helicopter (HMS Ocean) |
| LR | Lloyds' Register |
| MoD | Ministry of Defence |
| NFR | NATO Frigate Replacement |
| RN | Royal Navy |

## Introduction

If we look across the current RN surface fleet it is clear that the UK is very good at survivability. In every area – susceptibility, vulnerability and recoverability, both above water and under water – there are examples of excellent survivability features. These have not come about by accident. They are deliberate design decisions.

Naturally each ship class has its strengths and weaknesses. This partly reflects the requirements dictated by the different roles; there was a certain rationale about it all. But in recent ship procurements that has disappeared. It's not that survivability has got uniformly or steadily worse. It hasn't. The Type 45 AAW Destroyer is up with the best of the older classes. What is apparent is that there is now a lack of consistency. The Type 45 is bracketed by the LPH and the CVF. HMS Ocean was mainly constructed to commercial class rules, (Lloyds' Register Rules and Regulations for the Classification of Ships[1]) with specific survivability features applied to a very few select systems. Whilst the CVF will have more than this, it will certainly have less in the way of deliberate survivability than the T45.[2].

Why is this? The authors suggest that there are a number of factors:

- Lack of a central policy on survivability;
- Perceptions that survivability features are expensive; and
- The way the MoD contracts for survivability.

The first of these is being addressed by the MoD's Survivability Working Group for maritime platforms and will not be discussed here. The second two are being addressed by the National Warship Survivability Committee (NWSC). The NWSC is a MoD/Industry group set up to explore the issue of getting survivability into new ships in a cost-effective way. These are the issues this paper seeks to explore.


FIG.1 – HMS DAUNTLESS BEING LAUNCHED AT BAE SYSTEMS SURFACE FLEET SOLUTIONS LTD.

## Is Survivability Expensive

Discussion about the cost of survivability tends to gravitate towards particular topics – signatures and vulnerability and, to lesser extent, recoverability. Defensive weapons and electronic warfare are rarely mentioned. This is unfortunate – a proper assessment of survivability should take a balanced view across all aspects. This includes through-life costs and manning implications. It is quite possible that if this were done, remote sensing of spaces and remotely-controlled or automatic fire-fighting installations might be more common. In this paper we'll stick to the commonly discussed topics but many of the principles apply to all aspects of survivability and, indeed, to the whole ship.

### *Perceptions*

Whilst the old maxim "you don't get something for nothing" generally applies, the cost is not always as great as is sometimes assumed. One of the authors was asked some time ago about the CVF shock requirements. They were seen as rather demanding and the questioner wondered whether they could be relaxed. Underlying this was the assumption that it would save money.

Shock requirements relate to the hull and to equipment within the hull. For a hull the size of the CVF a shock requirement is almost superfluous. It would meet the most demanding requirement likely to be placed on it just by being properly designed to have good fatigue resistance. You would have to work hard, or design it very poorly, to *fail* to meet the shock requirement. So this really is a survivability feature that comes free. Nevertheless there is a perception that it must be costing something. For smaller ships, LR Naval Rules[3] give information on how to improve the shock resistance of the hull. If these result in any additional costs they are most likely to impact on first of class costs where some additional design effort might be required to introduce alternative design solutions and where design assurance might be required. In general, with modern production methods, they should not have a significant impact on production costs.[4]

Shock protection for the equipment does not come free. However it is wrong to think that lower shock protection will cost less than better protection. Moreover studies have shown that, in general, properly designed shock mounts can protect COTS equipment up to the level where the hull would be starting to fail. So the cost of mounting is at least partially offset by the saving in costs achieved by buying COTS rather than militarised equipment.

The cost of mounting is not directly related to the choice of mounts; it is in the design effort associated with mount selection, provision and assessment of shock clearances, provision of flexibles and the QA costs associated with the installation inspections of these features. So the potential cost savings associated with reducing the requirements are of second order compared to the cost associated with the decision to use shock mounts. These costs fall predominantly into the first of class cost category.[4]

For the relatively small numbers of equipment that cannot be shock mounted (e.g. main propulsion motors) the costs are related to, although not directly proportional to, the shock design level. In these cases there may well be benefits in investigating the cost/capability trade off associated with changes in shock performance. For these items of equipment the shock requirements will have the greatest impact on the first of class costs, as a result of additional design work, the production costs may also however increase since they may require higher specification components and additional material.[4]

Consequently since it is the *imposition* of a shock requirement and not the *actual* shock level that is driving the costs for both mounted and unmounted equipment, reducing the level will not produce savings unless the design requirements are reduced sufficiently to allow the equipment to be used unmodified and without shock mounts. In other words, *good* shock protection is cheap once it is accepted that *some* shock protection is required.

A similar story applies to blast-resistant bulkhead doors. Individually these were expensive items compared to the conventional door design used up to this point, consequently they were originally specified only for the blast bulkheads. In the event, due to trading within the programme they were fitted to all the transverse bulkheads. There were several reasons behind this; not least that it gave improved survivability for no significant additional cost to the programme.

The recent RN warships have sought to control their radar signature with superstructure shaping and reduced microgeometry. Because these were addressed early on, the design costs were less than had been expected and the production costs minimised. Reduced microgeometry generally means hiding equipment behind bulwarks and beneath decks. This means that is it better protected from the elements and easier to maintain. As a result it has been suggested by one study that the small additional cost will more than pay for itself over the lifetime of the ship.

*Risk*

A feature of the MoD's procurement strategy in recent years has been to pass risk to industry. Three or four decades ago when the MoD designed ships for itself this was not the case; but as design capability has progressively transferred to industry the integrators / prime contractors are responsible for achieving the performance requirements. In many respects this is reasonable, for example to achieve a given range or top speed. It does not work so well for survivability, where the requirements may not be well understood and the means for achieving them not necessarily obvious. This is compounded when a prime contractor passes risk down the supplier chain. At all stages, risk in the supply chain leads to contingency costing. The gross result is increased cost to the MoD or, more likely within fixed budgets, either the loss of some other capability to pay for survivability or the rejection of the survivability measure on affordability grounds.

The effects of risk go wider than this. The current CADMID model is based on a Top Down Requirements driven approach[6]. This will inevitably encourage development, with its associated cost and timescale risks, in the production of solutions. It is a fact of life that solutions must be defined in physical terms before costs can be properly estimated. If the Main Gate decision is taken before the solution has been well defined physically, this will inevitably means that a high risk will remain to be accommodated by the project budget.

In the case of complex systems such as ships it is not possible to completely isolate costs against individual capabilities, particularly for properties that involve many features such as the so called transversals: the "ilities", including survivability. This makes any attempt to trade off costs and capabilities before their interaction can be appreciated, through analysis of physically well defined solutions, potentially misleading.

The implication of these two facts is that a high level of product definition is required before the main investment decision is made, i.e. a development phase leading to a complete product physical specification should precede the Main Gate decision. This was the intention of the Assessment phase in the CADMID process but the emphasis on performance specification through the use of an SRD and the desire to transfer risk to the contractor inevitably results in cost premiums being applied. The desire to transfer performance risk is ill conceived as in practice the consequences of not meeting it cannot be transferred. If a satisfactory product is not completed the Customer – MoD – still has a problem in that he cannot fulfil his obligations and will incur costs in finding alternative means of doing so. The liability to the supplier is the value of the product, and cannot practically include the consequential costs to the customer. The customer thus retains the real risk. This can be minimised by defining the solution to be supplied in physical and not functional terms but in sufficient definition to ensure that the functional performance can be modelled to a degree of fidelity acceptable to the customer prior to contract placement.

An additional driver for CADMID was the desire to drive down costs through the use of competition. This created a dilemma because either the suppliers would risk nugatory work competing for a contract or the customer would have to pay more than once to bring alternative solutions to a stage at which risk is acceptable. With the rationalisation within the National supplier base this is no longer possible and so customer supplier partnerships are necessary[6]. A more open relationship is required so that design development decisions can be made jointly.

The final, and probably most significant, factor to be considered in controlling costs is the incorporation of development items within a programme. Timescale is a major cost driver and this is notoriously the biggest uncertainty in any development activity. A cut off point must be imposed beyond which development cannot be accepted. This should coincide with the product physical definition, i.e. contract award following Main Gate. This requires that the physical definition of any development item, i.e. weight, space, interfaces etc. is bounded and that any performance risk is retained by the customer.

Ships will still require detail production data definition (Stage 2 Design and Drawing) to be completed after contract award but product definition at (Stage 1 Design) is sufficient for performance to be adequately defined and any residual risks to be manageable. Such a position is certainly commercially acceptable to suppliers as this is normal export practice.

## Good Practice

We've covered some of the problems with recent procurement strategy, but there are also some examples of good practice that we can build on to come up with better solutions. The cases discussed here are taken from the Type 45 procurement.

The Type 45 was the first major procurement with actual vulnerability targets. These were performance targets described in threat function tables, *e.g.* the PAAMS system must have X% chance of still being operational after a strike by weapon Y. Set by the MoD who drew on advice from modelling studies, with some experimental testing and technology demonstrators to provide some verification, the actual numbers were developed from work on the Type 23 frigate and the Common Next Generation Frigate (CNGF) Programmes. Essentially the targets were based on modelling and were thought to be reasonably achievable for a vessel of this type.[5]

The contract actually stated that the SURVIVE vulnerability assessment software tool would be used to determine compliance with the vulnerability requirement. The Type 45 Prime Contract Organisation (PCO) worked with DERA Rosyth (which became QinetiQ Rosyth) using the SURVIVE model developed for Type 45, and the expertise behind it, to influence the design as it was developed. Thus

QinetiQ's involvement in the programme became more than just an audit function.[5]

The close working relationship between QinetiQ and the Type 45 PCO allowed the effect of design changes on vulnerability to be assessed very quickly. It also gave weapons, propulsion and hull services integration teams access to vulnerability experts. The use of SURVIVE thus became an opportunity for the design teams to learn about weapon effects and how to design their systems to compensate rather than simply following the standards. All of this resulted in significantly reduced vulnerability for the Type 45.[5]

There is clearly a lot that is good about this approach. There is no analysis of the costs involved. Presumably these were reasonable as the process is principally about getting the design right from the outset. On closer inspection though, there are some odd features to the process. The MoD knew what could be achieved (and how to achieve it), largely through using the SURVIVE model. It then set these as contractual requirements expressed in a form which could only be assessed in SURVIVE. Thus a requirement which was not really a risk to the MoD (because it already knew how to achieve it) became a risk to the industrial integrator (because he didn't, but had to meet it anyway, and had to pay a subcontractor to help him). Risk means cost, so it appears that the MoD paid unnecessarily.

There are striking similarities when we consider the process for contracting for the radar signature on the Type 45, but also a subtle difference. As with vulnerability, the contractual requirement was a firm figure, but acceptance is by an actual measurement (on a radar range) rather than modelling. The RCS model SPECTRE was heavily used during the design process; QinetiQ working with the PCO as well as providing advice to the IPT. The process worked well and there was good cooperation all round.[5] SPECTRE, like SURVIVE is owned by QinetiQ but is essentially a MoD tool; having its origins in the MoD and still being largely (if not entirely) MoD funded. The requirement for the Type 45 was based on previous work undertaken for NFR 90 and the CNGF (precursors to the T45 project): the MoD knew that the requirement it set was achievable. So again a contractual risk was placed on the integrator which wasn't really a risk to the MoD but which could only be achieved with the aid of what is, essentially, a MoD tool – SPECTRE.

Formally, acceptance of the Type 45 RCS is measurement on a range, but how realistic is this? If the measured value exceeds the requirement by, say, 2dB what happens? One can envisage endless opportunities to argue over the detail of how the ranging was carried out, whether the modelling was accurate etc. What will almost certainly *not* happen is that the shipbuilder rebuilds the ship until he achieves the desired result. So the reality is that the MoD will get what it gets based on predictions from its own model. The MoD owns the risk all along, but pays by trying to hand it off to industry.

For the infra-red (IR) signature requirement there is a significant difference, although many aspects of the process sound familiar. Again the MoD set firm, numerical requirements and again QinetiQ/MoD modelling was used to assess how to achieve them. Now the difference: having determined the technologies needed to achieve the goal, the PCO was contracted to fit those technologies, not to achieve a numerical goal[5]. This removed the risk from the contractor – he had a requirement he understood and for contractual acceptance he had simply to show that he'd fitted the specified equipment and materials. There is no corresponding increase in risk to the MoD.

**Better Practice**

The common themes that emerge from the previous section are:

- for survivability the MoD has the latest threat assessments and corresponding operational analysis to understand better than the industry what is possible and how to achieve it;
- survivability requirements represent a risk to industry and the MoD pays for that risk; and
- in reality, the risk of not achieving the survivability requirement remains with the MoD.

The MoD is coming round to accepting that it must be prepared to accept risk. The leader of the Maritime Industrial Strategy has written "We cannot contract for complex warships *via* output specifications: if we are to aim high, MoD must bear, and be able to manage, large elements of performance risk." This applies to survivability probably more than any other aspect of warship procurement.

We do not build prototype ships. There is no opportunity to "try it out and redesign until it works". The first of class has got to be right and if it's not, the likelihood is that the RN or RFA will have to live with the deficiencies for the life of the ship. So, given that the MoD must take the risk that it achieves its survivability requirements, how can it best manage that? Let's look at the examples from the Type 45 development in the previous section.

*Vulnerability*

The Type 45 PCO was given numerical targets for vulnerability and advised that the SURVIVE model would be used to assess the platforms achievement against those targets. As stated previously, QinetiQ assisted with the design rather than merely assessing the result. It would have been better deliberately structured that way. QinetiQ - who, after all, had helped to set the requirement in the first place - could have been tasked to assist The Type 45 PCO in designing to achieve the vulnerability targets. Once achieved, that design could have been the requirement.

QinetiQ was tasked by the PCO, which made sense since it carried the risk for achieving the vulnerability targets. But if the MoD carries the risk instead this would not make sense. It would be better for the MoD to task QinetiQ. Of course, in this case it is because QinetiQ owns SURVIVE. For other aspects of survivability it could be other parts of the MoD who provide the advice and assurance, e.g. DE&S Sea Systems Group or Dstl.

*Signatures*

The radar signatures example is similar. A clear, numerical goal was set. It is not clear whether or not the Type 45 PCO was directed to use SPECTRE, but in any event it did so, in much the same way that it used SURVIVE for vulnerability; that is, for design guidance towards meeting the requirements, not simply assessment of whether it had done so. Again, if the MoD is to take the risk in future for meeting the requirements, it makes more sense to task QinetiQ directly. The Prime Contractor Organisation or Particular Alliance Organisation, with advice and assistance from modelling and subject matter experts, would produce a design which met the requirement and that design then becomes the requirement.

The IR signature process came closest to the model set out in the two preceding paragraphs. The only change required is that the MoD should pay for the assessments and advice leading to the agreed design.

*Partnership*

The examples above have concentrated on QinetiQ as suppliers of expertise and modelling. This is, of course, for historical reasons. Under the proposed procurement model QinetiQ would be acting as agents for the MoD. The whole process is really about creating a partnership between the MoD and the Systems Integrator. Most aspects of ship design can safely be left to the shipbuilder, but for many aspect of survivability the expertise still lies in the MoD. It must make that expertise available in the form of consultancy. The shipbuilder must, in turn, work actively with the MoD to achieve a design that meets the MoD's survivability targets. The pay-off for industry is a requirement in the form of a build specification which carries little beyond the normal commercial risk.

We should make it clear that this process does not mean that survivability targets will be abandoned. Targets will be required as much as before. They are an integral part of capability management. What changes in this process is that the targets are not passed as requirements to industry. The MoD and industry must work together to achieve them, agreeing a build specification which the MoD has satisfied itself has a reasonable chance of delivering the capability.

## Conclusions

There is a perception that survivability is expensive. In some areas this is not borne out by experience. For example, the shock requirement on the CVF hull comes free with good fatigue resistance. Good shock mounting costs little more than poor shock mounting. Only no shock mounting saves money, and that may be a short term saving.

In other areas survivability is more expensive than it need be. This is due principally to the MoD decision to pass risk for meeting requirements to the contractor. This is ill-founded because, in reality, the real risk remains with the MoD; but it pays a premium for *apparently* transferring risk.

Both these problems can be overcome. In the first case MoD and industry need to develop a better understanding of the cost associated with survivability measures. In the latter case the MoD needs to change the contracting process for survivability. The MoD and industry need to work in partnership to achieve designs which can be used as the basis for contracting, while the MoD does its best to assure itself of meeting its capability requirements. The National Warship Survivability Committee is working towards detailed proposals on how to implement this.

*References*


1. Lloyds' Register, Rules and Regulations for the Classification of Ships, Lloyds' Register, July 2004.
2. Schank John F., et al, Options for Reducing Costs in the United Kingdom's Future Aircraft Carrier (CVF) Programme, RAND Corporation, 2005.
3. Lloyds' Register, Rules and Regulations for the Classification of Naval Ships, Lloyds' Register, July 2005.
4. A Preece, 'Potential cost savings related to the shock requirement for the CVF', Annex B of STG/BF031, 30th March 2006.
5. P Horstmann, Private communication from QinetiQ, May 2007.
6. Defence Industrial Strategy, Defence White Paper, CM6697, December 2005.


**Author's Biographies**


**John Thornton** holds the current position of Principal Scientist for Maritime Survivability at the Defence Science and Technology Laboratory, which is a part of the MoD. He is responsible for developing an integrated approach to maritime survivability and advising the MoD. He chairs the National Warship Survivability Committee.

**Malcolm Courts** holds the position of Research & Development Manager at VT Shipbuilding. He is responsible for R & D aimed at new concept development and product and design process improvement within the division.

**Malcolm Robb** holds the current position of Principal Engineer at Business Development Engineering, BAE Systems Surface Fleet Solutions Ltd. He is primarily concerned with the development of Future RN Platforms.