AN OVERALL COMBAT SYSTEM APPROACH

BY

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The Need for Combat Systems

Traditionally, MOD has procured sensors and weapons on a black box basis and this was for many years the only way in which it could be done—much of the research and development came from the MOD, most of the black boxes were self-contained and their technology tended to be unique. Where there was a need for any form of cross-connection or communication between black boxes, this was achieved through the medium of the Action Information Organization (AIO), also designed—in theory anyway—to present a composite picture to the Command. Only now are warships appearing on the scene with a working position for the Captain in the command system.

This situation still obtains. Both the Operations Room staff and the Procurement Executive (PE) are organized on tidy, watertight lines—ASW here, Above Water Warfare there, AIO somewhere else. There is much talk of command systems, but it is very much in the sense of post-system acquisition. Once all these black boxes have been cobbled together in a ship, a submarine or a helicopter, the result is called a combat system. I exclude fixed wing aircraft where, for a number of years, a command system approach has been forced on the Procurement Executive by tight design budgets. Shortcomings of the present system include:

- Data overload
- Command overload
- Operational mismatch of performances
- High manpower
- Higher operator training level
- Multiplicity of operator specialities
- Difficulty of performance enhancement
- High maintenance cost
- Inevitable obsolescence
- Low commonality of equipment practice

The Defence industry, in a perfectly proper attempt to meet the requirements of the customer, is also divided into black box companies, largely devoted to specific, traditional areas of technology, whether it be sonar, radar, ESM, AIO, or weaponry. The advent of the software house has introduced a non black box supplier, although they are handled the same way by the PE. Systems Houses have begun to abound in recent times, but it is not clear to me what their title is meant to imply beyond a rather up-market software house.

But technology has moved along, and at an ever quickening pace. Increasing commonality of distributed processing allows multi-function use and the marked shrinking of electronic volume for a given task permits ever greater capability in a given space. On the other hand, the vast amount of data now readily available brings its own problems, particularly in terms of man-machine interface and user friendliness. A tour of a modern ship or submarine, with its Heinz variety of console types and range of user skill requirements, makes the point very clearly.

The classic purpose of the AIO, to develop tracks and display end product information, is also called into question when the sensor is itself more intelligent and can increasingly perform all these functions.

All this points towards the need for a combat system approach to procurement, to achieve maximum integration, to match the man-machine interface with the capability of the end user, to reduce through-life costs, and to make use of technology commonality to provide built-in growth potential. Our systems do, after all, have to last at least twenty years.

A fairly fundamental re-appraisal is required. We believe, from industry's point of view, that it is possible progressively to implement this top-down approach to procurement, hopefully to everyone's benefit. Benefits to the Navy as customer should include:

- Low cost of ownership
- Functional flexibility
- Being Command Team driven
- Being user friendly, hence reduced operator skills needed
- Flexibility of operator deployment
- System redundancy
- Designed for through-life enhancement
- Common maintenance, hence simple logistics

The Development of Combat Systems

The new situation now demands the more coherent approach hinted at earlier. This is where:

(a) the full requirements are declared as far as possible;

(*b*) the whole system is concurrently analysed by a common team;

(*c*) major functions are designed concurrently;

(*d*) major functions are developed concurrently.

This might appear to be a tall order, but for a true combat system design it is necessary. Such a definition is essential when the requirements of a new platform are addressed and all the real-life constraints of limited parallel funding and resources have to be resolved.

The two principal challenges are:

(*a*) how to use evolving technology, and

(*b*) how to manage the evolution,

bearing in mind that evolutions and generations of processing technology are now occuring every two to three years. At present the communications electronics between processing groups has not advanced as quickly as it should but it is now beginning to change more rapidly (FIG. 1). The processor developments have been accompanied by an equally dramatic increase in data store densities.

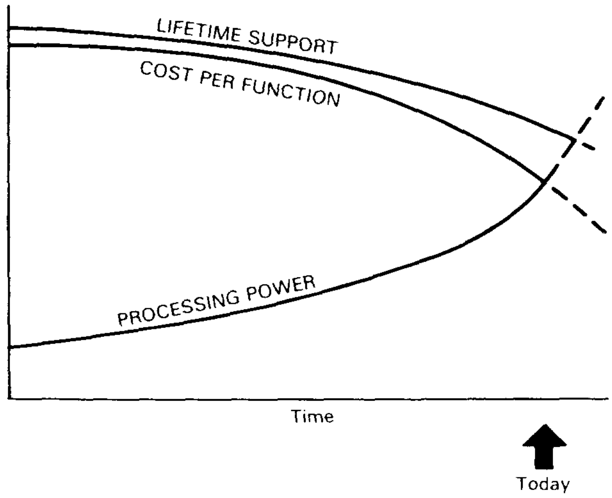

FIG. 1—TRENDS IN PROCESSING POWER, ITS COST AND SUPPORT LIFE

The reason why processing power has dramatically increased is because of price. With volume manufacture the unit cost plummets (FIG. 1) and new applications are brought into electronics, thus widening the market. In practically all instances the commercial outlets have 'driven' the chip designers. Thus the reason why high density graphics displays are available is not because of defence needs but because of the amusement arcade game industry. This price decrease can be used to cheapen equipments or to increase the functions processed.

With this performance advantage it is not surprising that there are some disadvantages as well. Since it is the commercial world that is driving the changes, the lifetime support provided is limited. Manufacturers are forced constantly to introduce new chips with better performances in order to maintain or increase their business share. Realistic economic support for equipment which takes advantage of this power is much reduced from the current MOD requirement of 25 years (FIG. 1).

Experience has shown, however, that replacement equipments can be supplied to MOD which typically have half the volume and less than half the price of these 'obsolescent' equipments. Indeed the performance enhancement which can be simultaneously achieved is often embarassing MOD into making such changes before true obsolescence occurs. Lifetime figures of 12 years or less would be a realistic target given today's rate of change.

The conclusion from these trends is that, providing it is properly managed, processing technology is no longer the fundamental limitation to the scope, size, or performance of a combat system. The limiting factors are now the definition of what is required, and the manner in which it can be competitively procured.

Specification and Procurement

The question now therefore is can MOD achieve a (real) combat system? The method can be very simply stated: define what is required, decide from whom it is to be acquired, and then monitor their ongoing achievement. The practical facts and politics of procurement life make this a far from easy task.

Can the Navy actually define what it needs? In the past it has never had to, to the extent of public competition. Various attempts are being made to define the requirements but the problem is that the skill to do so lies increasingly within industry. As the MOD technical support organization has been slowly run down, the complexity of the threat and of technology have been increasing. How can this skill be unlocked in a non-competitive environment from the same contractors who will ultimately compete for the contract to build? No one has successfully achieved this and indeed it must be questioned whether it should be done.

How can MOD select a combat system contractor and monitor his performance? The U.K. 'new look' procurement has introduced competition at every level of equipment. Previous procurement policies forced industry into separate watertight compartments such that no U.K. companies currently exist with all the appropriate skills and experiences to accomplish a real combat system design independently. The present competitive situation has to be given time to evolve to this new requirement. The same indeed must be said of the MOD Procurement Executive.

Can the MOD restrict its activities to monitoring and advice? There is a very real need for MOD to remain an informed customer in order to control ongoing investment and other competitors' programmes.

Can industry actually supply a real combat system? Industry has been gradually increasing the skills necessary to take over the work. A true combat system will only come about if companies are prepared to co-operate and identify their future prosperity with a successful design, and if their next contract does not place them in direct competition with those with whom they were collaborating.

Thus the challenge to industry of the Combat System. Can industry carry out the tasks and achieve the objectives?

As technology has advanced, the actual skills necessary to achieve a design have been declining due to the increasing sophistication of Computer Aided Design (CAD) techniques and the power of technology. This has freed the skilled designers to address the wider combat system algorithms and performance requirements. A real combat system design is now within the scope of understanding of these designers.

The explosion of processing technology is reducing the cost of functions at the same time as CAD is making it easier to realize them. Coupling this with a decline in the U.K. military budget means that companies must widen the scope of their businesses to survive commercially. Thus the right business environment exists.

Better performance can be achieved for the Navy. You have only to walk through a defence manufacturer's laboratories to realize that the equipments currently at sea are somewhat removed from what is possible. Where people are risking their lives they should have the best that is affordable.

Could a U.K. (only) combat system business compete internationally? The answer is yes, but only if the U.K. infrastructure can be radically changed, and only if the MOD changes its real attitude to defence exports.

Whether a U.K.-led international combat system consortium compete internationally remains to be seen. More on this shortly.

Can industry be successful in combat systems and maintain or increase its profits? Remember, industry exists to make a profit for its shareholders. If competition is too fierce, or if conditions of contract are too swingeing, or if other national or international companies compete with unfair government assistance, then the answer is no. Industry does want to compete with some chance of success.

Increased risk means that industry will try and amortise this risk across itself. This will lead to increased inter-company agreements or company mergers. Time and business opportunity are needed to resolve this.

In the summer of 1984 Plessey had to face most of these issues in putting together the PISCES 4 System concept. This system contained all the major functions of a 2000 ton submarine powerful combat system with the sole exclusion of the weapons themselves. It was a U.K.-led international consortium in which negotiations were held with sixteen international companies of whom eight were chosen as principals. Only one company (which was British) refused to negotiate, and all the others were very eager to participate. It involved a major feasibility study for a system with a high level of integration, fault tolerance, flexibility of operation and commonality of equipment at card level. Commercially it was a major step forward in co-operation, in which a successful integration/business formula attracted wide interest and the architectural features required have been carried forward into other proposals.

What lessons can be learned from this experience and why should companies want to be involved? The major reasons are that it involved a choice of combat system contractor before specifications were firm and thus removed one layer of extremely difficult competition especially on the international scene, and it was for a customer who wanted (or at least seemed to want) to let industry get on with the job with the least number of procurement constraints. It was industry's chance to show what could be done and industry wanted to take it.

Conclusion

Given that the U.K. needs real combat systems, the major challenges appear to be:

(*a*) Can the MOD define the requirement to a level at which meaningful competition could take place?

(*b*) Can the MOD PE organize itself to procure and control such complex integrated systems?

(*c*) Can industry offer the performance risk assurance for the whole system which the MOD currently undertakes, at an acceptable price?

From industry's point of view we believe we are ready. We wait to see if our customer is.

SPECIFICATION FOR SHIP PROJECTS

BY

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Yarrow Shipbuilders, who are in the final stages of design development and the initial building stages of the Type 23, are in a unique position to comment upon the present methods used for specifying what the ship and its equipments should be able to do. Basically the Navy requires vessels that work, having the latest in technology, built within tight cash parameters. We in industry believe we can give you this.

After a review of the methods used for specifying the Type 23, this article will suggest the way ahead for future projects. It concentrates on the method of specifying the requirements and the concept of delegating responsibility and risk to industry.

Type 23 represented a major change in MOD policy in that the shipbuilder was involved at a much earlier stage than on previous frigate designs (FIG. 1). It is important to be aware of the time-scale of this involvement (TABLE I) and relate it to the progress of the ship.

The article reviews the 'paper chase' involved in turning the Naval Staff Requirement into specifications which enable major items of equipment and also the first-of-class ship to be ordered.

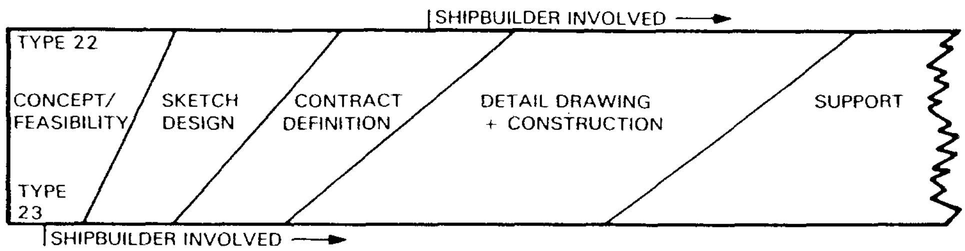

FIG. 1—SHIPBUILDER INVOLVEMENT IN THE TYPE 22 AND TYPE 23

TABLE I—*Type 23 Major Milestones*

Place orders for major development items (gearboxes, machinery controls, diesel generators, main propulsion system)	Jan.—Feb. 1983
Start ordering other long lead items	March 1983
Start production drawings	Feb.—May 1983
Admiralty Board approval	Nov. 1983
Approval of complete mock-up	June 1984
Issue Build Contract Definition	March 1984
Invite tender	Nov. 1983
Order	Oct. 1984
Launch	Mid 1987

Statement of Technical Requirement

The Naval Staff Requirement (of 78 pages) was translated into 101 separate Statements of Technical Requirement (STR) related to:

(*a*) Ship and accommodation—22 STRs
(*b*) Ship systems—15 STRs
(*c*) Machinery and systems—26 STRs
(*d*) Electrical—17 STRs
(*e*) Weapon—21 STRs

As far as the shipbuilder is concerned the Statement of Technical Requirement was the fundamental starting position and is now the contractual baseline between the MOD and Yarrow Shipbuilders. Yarrow has the responsibility for developing the design to meet the Statement of Technical Requirement.

TABLE II—*Typical contents of Statements of Technical Requirement*

	Gas Turbine pages	*Propulsion Motor* pages	*Gearbox* pages
General	3	3	4
Definitions	2	3	1
Technical	5	30	31
Mandatory references	1	2	1
Abbreviations	4	4	4
	15	42	41

The content of each STR obviously differs, but the make-up of three typical ones is shown in TABLE II. Each has a general introduction, followed by a definition section. The amount of technical content varies greatly: the gas turbine, which is fairly familiar, has five pages; for the propulsion motor—this is the first time an electric propulsion has been used for a frigate—it is much longer, and so is that for the gearbox. 'Mandatory references' will be discussed further.

The Statement of Technical Requirement was used by the Yarrow design teams to develop Technical Engineering Specifications which could be sent to potential suppliers of major equipment. These equipments were ordered ahead of the contract for the first ship, and required competitive or single source tendering. MOD was involved in all aspects of this tendering phase, which by its nature caused considerable time delays in the ordering of equipment.

Certain aspects of the Statement of Technical Requirement need to be pointed out:

(*a*) The one (or so) pages of mandatory references gives a list of Naval Engineering Standards (NES) and other standards, to which the designer must refer. But the introduction to the STR causes confusion by including the conflicting instruction:

> 1.3.2 Mandatory references are to be applied in full unless otherwise stated or, subject to the agreement of the design sponsor, found to be impractical during the design development.
> However, these requirements . . . are to be incorporated into the system design only after careful scrutiny has confirmed they are essential and provide the most cost effective solution.

(*b*) For the purpose of the contract, these mandatory documents are frozen at the time of the contract and can only be changed by formal contract action.

(*c*) A Design Development Documentation System has to be set up for each Statement of Technical Requirement, to record the design development 'from cradle to grave'. The decisions made as the design progresses have to be recorded so that the reasons for each decision can be traced.

Naval Engineering Standards

In some cases the Statements of Technical Requirement refer to many Naval Engineering Standards almost in the hope that they will cover all eventualities. That is dangerous; it completely stifles industry coming up with any new ideas. Some Naval Engineering Standards are extremely good; they have really captured the experience of operating plant and systems, and the designer welcomes them. Other standard demand certain requirements to be met, but they do not say why. One of Yarrow Shipbuilders's main tasks has been to extract the relevant clauses from Naval Engineering Standards and incorporate them in the Technical Engineering Specifications.

For the Type 23 a 'fit-for-purpose' regime has been operated and the Company has been encouraged to examine departures from Naval Engineering Standards where there will be cost benefits to the project. Nevertheless there has been a certain reluctance in MOD to change, and often a Standard has had to be challenged repeatedly before it was deleted. There is a method whereby deviations from the NES can be made, with agreement by the project staff, but they take advice from their specialists some of whom seem to favour the NES they have created or always followed implicitly, irrespective of any cost saving or other advantages. While MOD has a technical and financial commitment to meet, it is not as onerous as the one the shipbuilder is facing. He has accepted the risk and the responsibility of meeting the Statements of Technical Requirement within a firm price for the ship.

Tender for Ship

In March 1983 the Statement of Technical Requirement and the General Arrangement of the frigate were considered as 'frozen'. Needless to say, systems were still being designed and equipments being selected and therefore it was necessary to produce a document which would define the ship, with its equipment and systems, and would serve as the contractual baseline for the tender.

This document is called Build Contract Definition (BCD). It was a jointly agreed document upon which the shipbuilder would base his price. This replaced the Class specification. It comprises 30 volumes and about 2000 drawings.

The Build Contract Definition was called a 'snapshot in time', because it defined the status of the ship and its systems at a specific date. It also defined any reservations that the builder had on the state of the design work in arriving at a firm price. Unfortunately the Build Contract Definition took many months to produce; meanwhile design proceeded in parallel—not so much a snapshot as a time exposure.

The Build Contract Definition also identified the work to be completed and hence the risk involved in going forward with a firm price on an incomplete design.

Risk

The MOD risk for the Type 23 is limited to two discrete types:

(*a*) Those that relate to the performance and characteristics of the ship. In this category would come such items as hull form and speed, endurance and sea-keeping, noise reduction, and reduced radar echo area.

(*b*) Areas where the MOD has ongoing developments, e.g. with reverse osmosis plants or aircraft handling.

Elimination of risk is in the interest of both the Navy and the shipbuilder. It is certainly in the shipbuilder's interest to reduce the level of risk in the first of class, and for that purpose type testing of equipment new to service is done at a variety of establishments. One of the major differences between previous frigates and the Type 23 is the use of diesel electric drive for main propulsion. MOD agreed that a test facility was necessary to prove that the basic system would work before installation in the ship and, in order to fit within very tight cash limits, a test facility was constructed in a car park in East Kilbride. It worked, and provided very useful information. The facility not only carried out complete and correct plant operation but also demonstrated that fault and mal-operation conditions could be induced and the system could still cope[1,2].

The software of the machinery control console and much of its system are also being tested ashore, again with the intention of reducing the risk during the Sea Trials period.

Recommendations for the Future

Statement of Technical Requirement

We believe that the Statement of Technical Requirement concept is basically correct, but:

(*a*) It should be system based and not equipment based, e.g. the propulsion system should have one Statement of Technical Requirement and the equipment specifications should be derived from this.

(*b*) The Statements of Technical Requirement should be progressively released, with the more important ones being jointly reviewed and developed before proceeding to produce other documentation. There is then less delay in starting the basic design.

(*c*) The STR should list the essential Naval Engineering Specifications or other documents, and define the relevant clauses.

(*d*) More use should be made of sketches, key diagrams and drawings, to aid understanding of the STR and reduce the possibility of different interpretations. This is particularly important in defining the operation or control of the system, for which there should be a separate section of the STR.

(*e*) The STR should also define the method of testing to be employed to demonstrate that the Requirement has been met, stipulating where shore testing or other special methods are to be used.

(*f*) The STR should be a living document, updated and expanded as the project develops.

Other Shipbuilder Aspects

The Build Contract Definition is an unnecessary excursion down a paper-work chain; it used many engineer man-hours at a critical stage in the ship development and did not assist in major design tasks.

The Design Development Documentation System is over-complicated and unwieldy. We agree that records are required, identifying why major decisions were taken, etc., but believe that this could be done more simply.

Feedback from the Ship

Because Yarrow Shipbuilders Ltd. is taking the responsibility and hence the risk for nearly all machinery aspects of the Type 23, it is essential that feedback from the ship during the first twelve months of operation is made available to them, in order to reduce any downstream effects on ships 02, 03, 04, etc.

No doubt special reporting will be set up for the first of class. As it is essential to gain the information while it is relatively 'fresh', we believe that the Company should have a guarantee chief engineer or manager or board for the first twelve months, to make sure that the Navy looks after our equipment properly.

References

1. Jennings, R. E.: The Type 23 combined test facility part I: development and installation; *Journal of Naval Engineering*, vol. 29, no. 3, June 1986, pp. 500–508.
2. Jennings, R. E.: The Type 23 combined test facility part II: instrumentation and results; *Journal of Naval Engineering*, vol. 30, no. 1, Dec. 1986, pp. 184–192.