COMBAT SYSTEM DESIGN STRATEGY

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ABSTRACT

In the last ten years there has been growing pressure to provide warships with complete combat systems, not a collection of different equipments. To aid in the process, two new Sea Systems Controllerate Publications are shortly to be issued covering the design strategy and human factors aspects of combat systems. These documents are supported by three MoD (PE) modelling tools. The authors' experience indicates there is a need to review the combat system procurement strategy, in the light of this whole system approach.

Introduction and Background

New Look

The requirement to procure warships, designed as complete systems, was one of the Controller of the Navy's primary objectives in bringing about the New Look reorganisation during 1983. Under this reorganisation, warship project management responsibilities were established to cover all design aspects from the hull through to the combat system. However, much of the old procurement structure was left in place with new titles, for example, responsibilities for combat equipment procurement remained within a self contained structure. Hence, the best that could be achieved in the early days of the reorganisation was combat systems based upon equipment integration, not on true system design.

Within the New Look reorganisation a new Directorate, Chief Naval Weapon System Engineer (CNWSE), was established specifically to deal with Combat System Design (CSD). CNWSE set about merging many of the activities previously undertaken as separate surface ship and submarine tasks. Typically, these were in the areas of ship weapon system engineering, documentation, standards, common services etc. One particular new activity established under New Look was that of design endorsement. The Chief Naval Architect, Chief Marine Engineer and Chief Naval Weapon System Engineer, were given responsibility for reviewing each stage of the platform design process (based upon the Downey procurement cycle)[1]. At each stage they were required to give their endorsement that designs were 'fit for purpose'.

Chief Systems Engineers Role

The methods by which such judgements would be reached was left to each Chief Systems Engineer, although it was intended that a hierarchy of interlocking standards would be produced. Within CNWSE the concept of design audit was established. Its purpose was to scrutinise the system as it evolved and to ensure that sufficient information was available at the formal endorsement reviews, to advise CNWSE on the design state and hence fitness for purpose. The particular focus within CNWSE was that of system design, not equipment design, which remained the responsibility of equipment project managers.

For proper system designs the overall characteristics and requirements need to be determined, from which the equipment specifications are derived. Undertaking the process in reverse, by designing the equipments then integrating them into a system, leads to many system problems. This was very much the general finding from the design audit work at the time.

Design Audit and Endorsement

Design audit was not viewed with much enthusiasm by project managers for obvious reasons. Projects could claim, with some justification, that system design considerations were outside their control and specifically not a requirement of their particular staff targets or requirements. Combat system project managers had the task of bringing together designs, as best they could, by seeking co-operation from individual equipment projects. They were unable to ensure sound designs from an early stage, largely because they did not have the overall authority to do so. Standards did not exist to support the objective, the MoD(PE) was not structured to facilitate direct reporting and the various participating projects had conflicting objectives. Hence, there were shortfalls in system design which were almost impossible to correct at a later stage of the procurement process. The exposure through design audit was, therefore, not welcome.

System Specifications

In considering how to judge combat system 'fitness for purpose', it became evident that specifications and standards for design were required, against which such judgements could be made. These did not exist at the time and still do not today. Much work has been put into specifying the role of the equipment project manager and providing him with the supporting documentation required for equipment procurement, post-Downey. However the continued squeeze on manpower and other resources, has prevented equivalent system design documentation being produced. In some respects there has not been an appreciation that such documentation is necessary. The current MoD(PE) procurement methods still tend to favour the approach of integrating equipment to establish combat systems. The detrimental results of not using a systems approach are not obvious in the early stages of the procurement cycle.

It only became apparent, over a considerable period, that a true systems design approach was required. At one time a command team were able to take information from each equipment and manually build the tactical picture. The continuing development, capability and sophistication of equipments, means that it is no longer possible to deal with all the data on a manual basis. A system needs to be considered from the outset as a coherent whole, with particular attention being paid to the human factors element of the design, specifically in terms of operability, inter-operability, graphical user interfaces, human computer interactions etc.

CNWSE Design Initiatives

There were a number of initiatives started within CNWSE focused upon CSD. A design workshop was established to carry out CSD work for the SSN 20. Suitable supporting methods and tools were not available, so a programme of work was put in hand to have them developed. The results of this work have been fully reported in Lionel Baker's article[2]. Concurrently two separate investigations were initiated to gain a clear understanding of what CSD was and how designs should be undertaken within the procurement process.

During 1989, the surface ship side let a contract to Frazer-Nash to produce a CSD strategy study report. This was aimed at examining the state of design knowledge and practice, with the objective of moving on to producing a full design strategy. As a composite part of the design audit and endorsement work on the submarine side, an in-house exercise was conducted to identify primary system parameters together with supporting methods and tools. A contract was subsequently let to CSC Computer Sciences Europe Ltd, in May 1991, to further research the subject. The output from this contract was a set of papers reviewing CSD principles, practice, methods, tools, risk areas etc.

The objective of the surface ship work was to produce a system design strategy to guide actual CSD. The submarine work was directed at determining precisely what CSD was, and how fitness for purpose could be judged.

CSD Strategy Steering Committee

In June 1990 a CSD strategy steering committee was established, supported by a working group. This brought the two strands together and endorsed further work. It was subsequently concluded that a formal system design strategy document was required to provide guidance to combat system and equipment project managers. A further contract was let to CSC to produce a draft CSD strategy Sea Systems Controllerate Publication (SSCP). This was reviewed by the steering committee in October 1992 and the draft endorsed in April 1993. Work is currently in progress to revise and update the SSCP in the light of comments received from the draft circulation and continued discussion with a wide range of interested people.

Design Strategy and Procurement Relationship

The following sections summarise the essential elements of the CSD strategy. In undertaking this work it has become apparent that unless an appropriate combat system procurement strategy is in place, then CSD objectives and requirements will not be met. Designs that are fit for purpose, in terms of the best balance between capability and cost, will not be realised. A brief review of alternative procurement strategies follows the design strategy section together with conclusions.

CSD Strategy

Traditional Approach

The traditional method of Royal Naval ship and submarine procurement has commonly involved the design of a hull to meet a staff requirement; followed by the selection of appropriate weapons systems to provide that hull with the required combat capability. The integration of these weapons systems, within the hull, has been regarded as primarily an interface task to resolve problems of:

- Equipment size.
- Data flows
- Weapon storage
- Environmental and human factors aspects

Current Challenges

Modern combat systems bring with them specific challenges. The system is highly interactive in nature, with each equipment having the capability to perform additional tasks beyond those initially intended. Many equipments were designed as part of other systems and are themselves evolving. There is a need to ensure rapid efficient access to common data for each equipment. Yet there is a need to segment the system to permit procurement competition. The design process is highly iterative and encompasses a wide range of engineering and management disciplines. As a minimum it should satisfy all the defined requirements, including allowing the effective integration of all combat system elements. It must ensure that the eventual combat system is:

- Safe
- Cost effective
- Procurable in the right timescales
- Will allow enhancement during the life cycle

The design strategy should enable clear visibility of trade-offs between acceptable levels of risk and capability, and critically must support MoD requirements for availability, reliability and maintainability. To meet all these challenges the combat system must be designed as a cohesive whole.

Requirements Definition and System Specification

Requirements are the origin for the design process. They can be considered as a set of statements describing that which is desired or needed from the combat system. These statements are generally unstructured, ambiguous and potentially exclusive. Requirements definition is the process of converting these general requirements into a precise, consistent and unambiguous set of statements that describe the essential nature and boundaries of the combat system.

The end product of the design process is the system specification. This is a detailed description of the particulars of the combat system. The expansion and refinement of the system specification, during the design process, gives rise to subsystem specifications; each of which contain all the information required to enable a potential manufacturer to tender for the design and build of a specific element of the system.

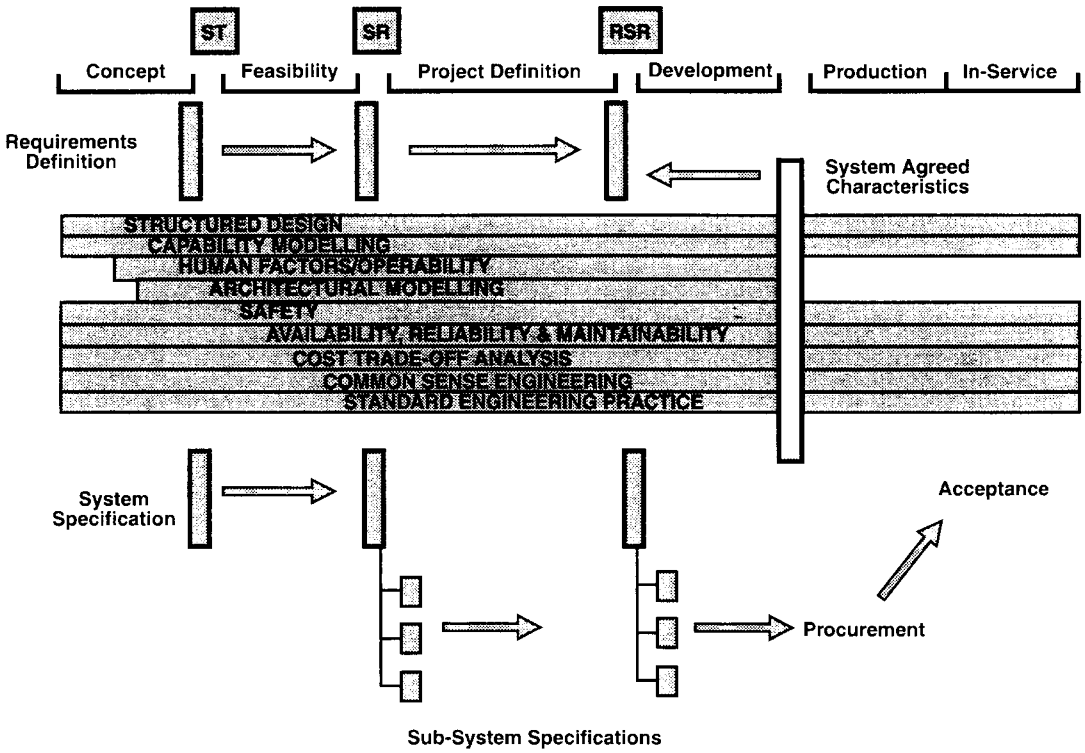


FIG. 1—COMBAT SYSTEM DESIGN STRATEGY

(FIG. 1) shows a framework and structure for the whole system design and procurement process. This is the essence of the CSD strategy which gives a set of guidelines that identify the sequence of, and relationship between, the activities.

This strategy provides many benefits. It will achieve a sound system design, ensuring integrity and compliance with technical, budget and schedule requirements. It encourages the definition and validation of clear and complete system requirements, including scenarios and operational acceptance criteria. Design visibility, traceability and control is provided through all life cycle stages. Complete system specification is derived, providing numerate statements of performance and the measures of effectiveness, with a clear assessment of risk. The strategy provides clear visibility of the cost trade-off benefits of design options and the impact of safety throughout the project design.

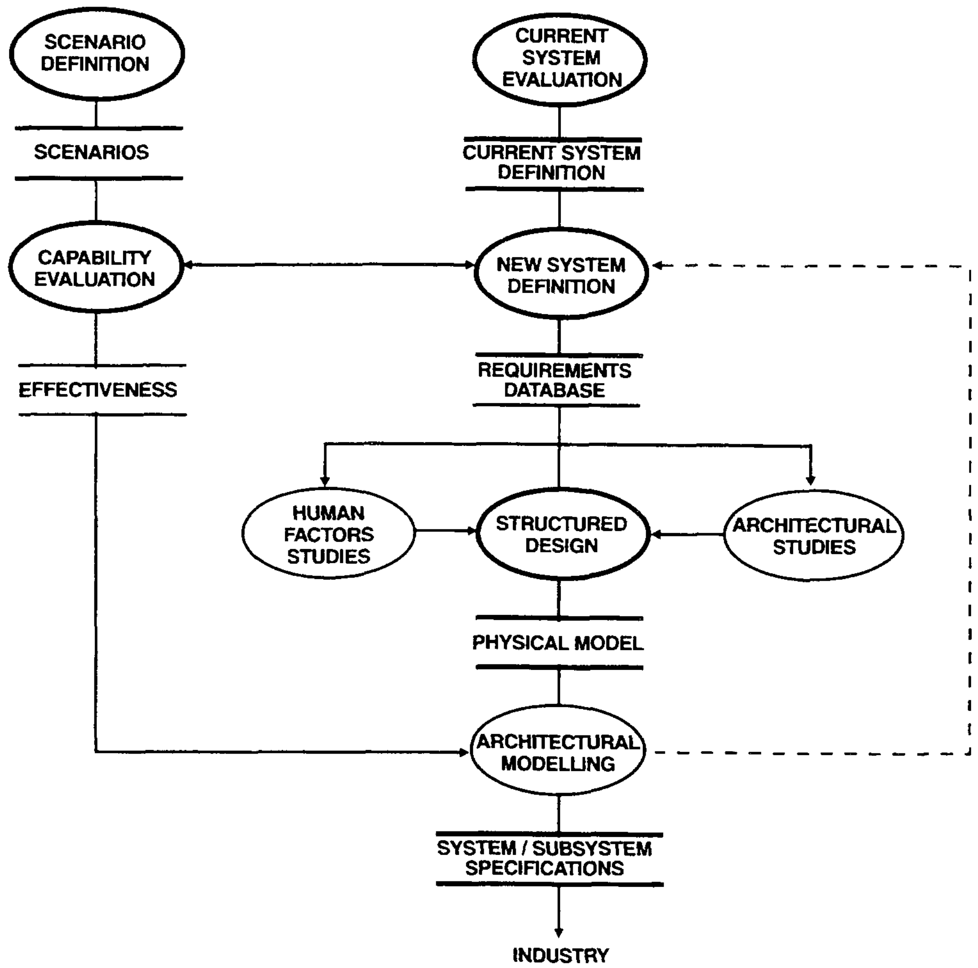


FIG. 2—COMBAT SYSTEM DESIGN PROCESS

(FIG. 2) shows the main threads of activity to be carried out throughout the CSD process. All actions are iterative in nature; the results of one process can feed back to earlier processes to cause a further review.

The starting point is to define clearly the functionality of the current system, and the operational needs of the new system, to allow the generation of the first pass requirements database. Potential design solutions are then postulated and the operational scenarios clearly defined. This should be followed by evaluation of the capability, required from the new system, in the light of the defined scenarios to reach a measure of system effectiveness.

This process generates the new system definition, the associated requirements database and the proposed solutions, in the light of the capability evaluation. Subsequently human factors, structured design and architectural studies are undertaken to generate a physical model. From this, the completed system and subsystem design specifications are produced to enable competitive procurement from industry.

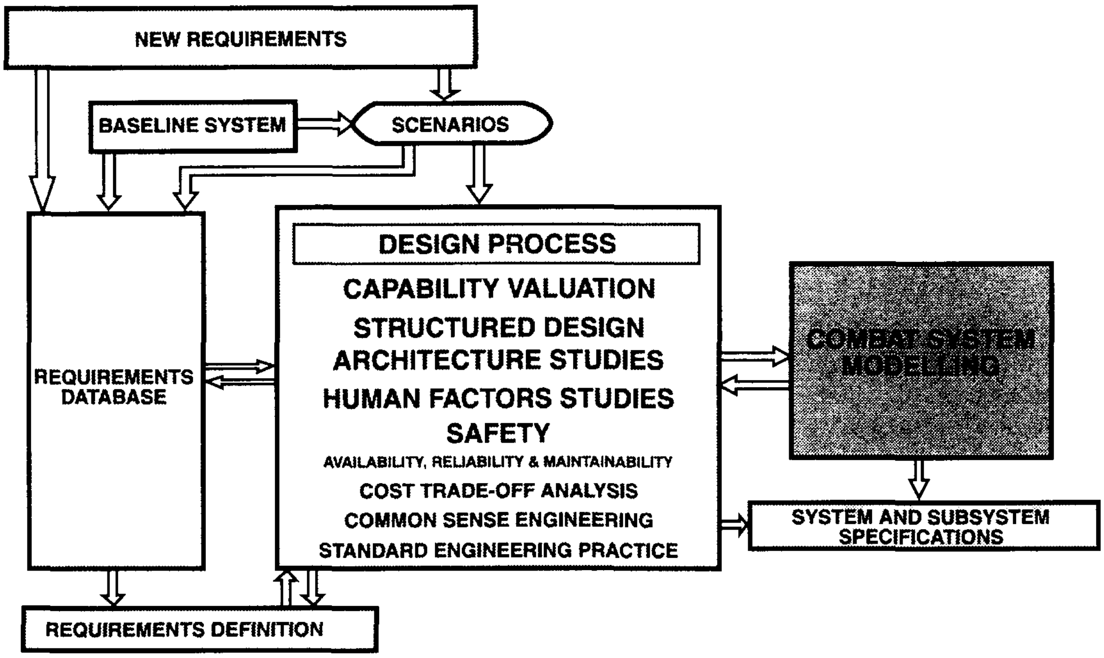


FIG. 3—COMBAT SYSTEM DESIGN PROCESS—ALTERNATIVE VIEW

(FIG. 3) shows an alternative view of the same process carried out during the CSD. New requirements and details of the baseline system are used to create the requirements database. The requirements definition is a documentary summary of the contents of the database. Scenarios, provided by the user/sponsor, are used as an input to the requirements database and the structured design.

The design process involves a continuous iteration of activities within the areas of:

- Function.
- Architecture.
- Human factors.
- Capability required.
- Cost trade-off.
- Safety and standard engineering practice.

All of these depend on common sense engineering and include the key component of availability, reliability and maintainability.

The design process results in the creation of the physical model and an output of the system and subsystem specifications. It starts during concept and is repeated during feasibility and project definition.

SSCP 59

Introduction

The CSD Strategy—Project Manager's Guide (SSCP 59), is in the final stages of editing. It will be issued in the late autumn of 1993. This section provides a brief overview of the guide.

Combat system project managers in the MoD(PE) have a complex task. To produce computer systems to time and to budget is not easy. To manage the design of what could be argued to be the most complex computer system anywhere, puts a severe strain on even the most technically and commercially skilled engineer. When this is combined with the impact of the MoD appointing cycle and the present uncertainties in the Defence arena, the task becomes a very interesting challenge! SSCP 59 has been written to help the combat system project manager meet this challenge. The document is not intended to identify precisely 'How' a particular activity is to be carried out, this will depend on many factors, and a multitude of associated documents, particularly the new range of Chief of Defence Procurement Instructions (CDPIs), exist to explain 'How'. SSCP 59 is intended to remind the project manager, at every stage, 'What' needs to be done to ensure a successful completion. The document has been written to try to answer many questions that the project manager may not readily be able to ask others.

SSCP 59 contains three main sections:

(*a*) The design chapters cover the activities required during the three main stages of concept, feasibility and project definition.

(*b*) A comprehensive chapter is provided to identify those project management tasks that are common to the whole design evolution.

(*c*) A series of annexes are provided that include references to other related documents and guidelines on specific methods and tools that may be applicable for the project.

The Concept Stage

The aim of the concept stage (FIG. 4), is to get the project off to the correct start. The primary task during this stage of the CSD process is to produce a very clear definition of the combat system requirements. This will involve the operational 'needs', appropriate policies, objectives and constraints. Clear documentation is required of the operational scenarios against which the capability of the design options will be evaluated.

During the concept stage the first version of the requirements database will be created. This will be followed by a first pass logical/functional model of the proposed combat system. Initial risk assessment will be carried out during this stage to focus activities and make the most cost-effective use of resources. The final outputs will include the provision of comprehensive documentation to support the generation of the staff target, feasibility stage and invitation to tender documentation.

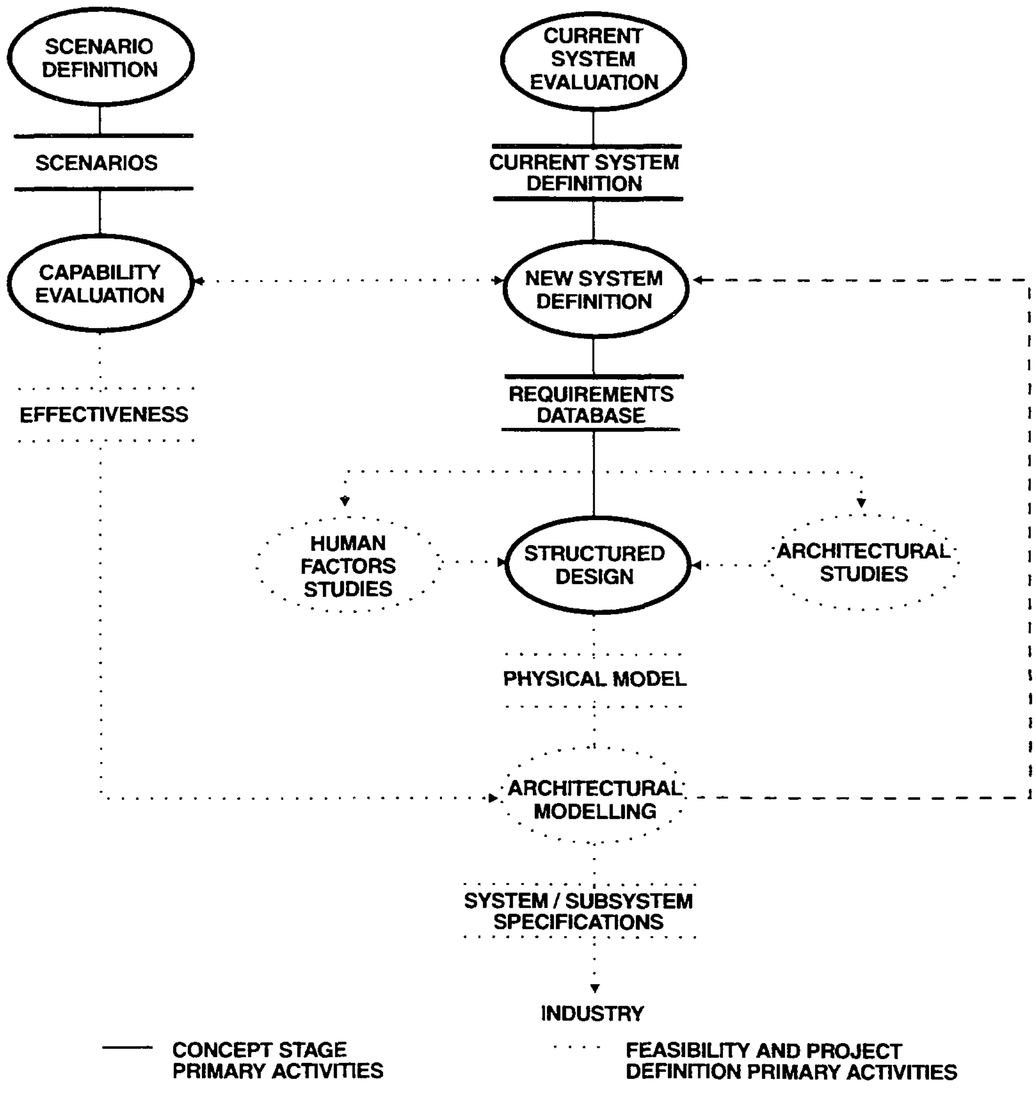


FIG. 4—CONCEPT STAGE ACTIVITY

Feasibility Stage

The feasibility stage aims to identify and reduce the risk in the CSD (FIG. 5). This involves producing credible system solutions, functionally capable of meeting the requirements, and which will be reliable and maintainable in operation. These solutions require validation through extensive modelling. All applicable risks require identification, as do the actions required to manage them. On completion of the design work, it is necessary to document the implications in revisions to the requirements definition and enhancement to the system specification. The data produced during feasibility will enable the completion of the staff requirement.

If more than one competing feasibility study has been carried out, a consolidation exercise will be required on completion. This task, to rationalise all the output products into one cohesive set of documents for competitive project definition, will be carried out by the MoD project team as a formal activity.

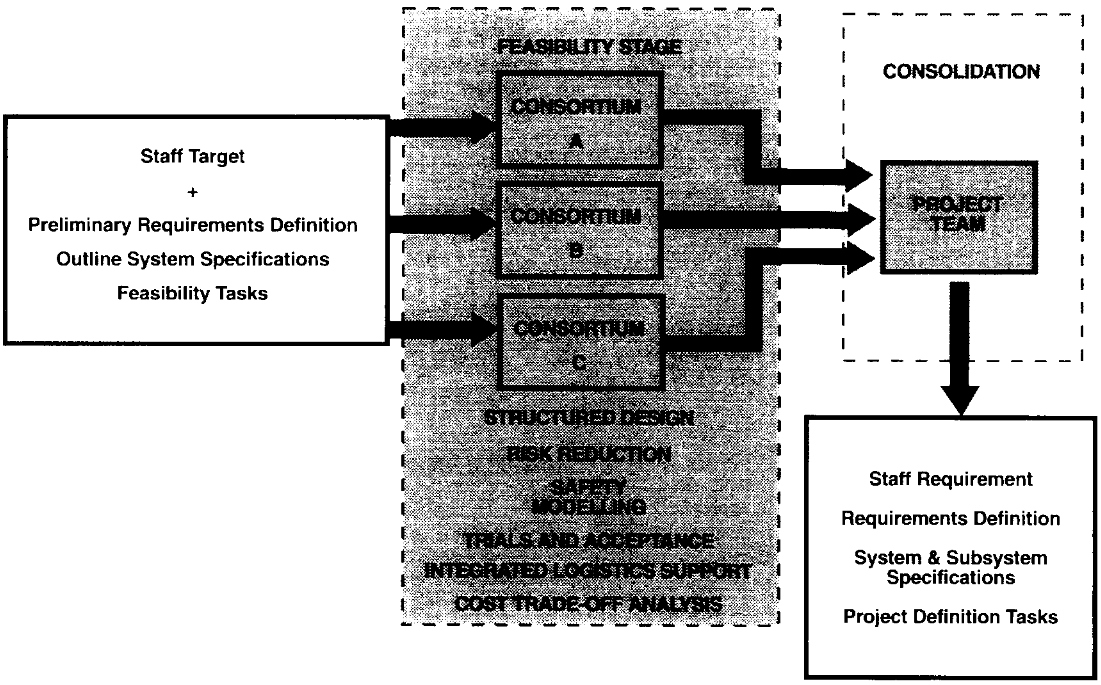


FIG. 5—FEASIBILITY STAGE ACTIVITIES

Project Definition

It is common for a majority of the technical work, during project definition (FIG. 6), to be carried out by industrial consortia. For the MoD(PE) project management team, this stage of the contract is almost a repeat of the feasibility stage. However the design will be to a greater level of detail, the output products generated at the end will be more comprehensive, and the cost estimates will be more accurate.

During project definition the competing consortia will be required to take the outputs from the feasibility consolidation stage and produce their best system solution that meets the requirements definition.

On completion of project definition the MoD(PE) staff will be required to 'consolidate' the final system and subsystem specifications for the competitive development and production contract.

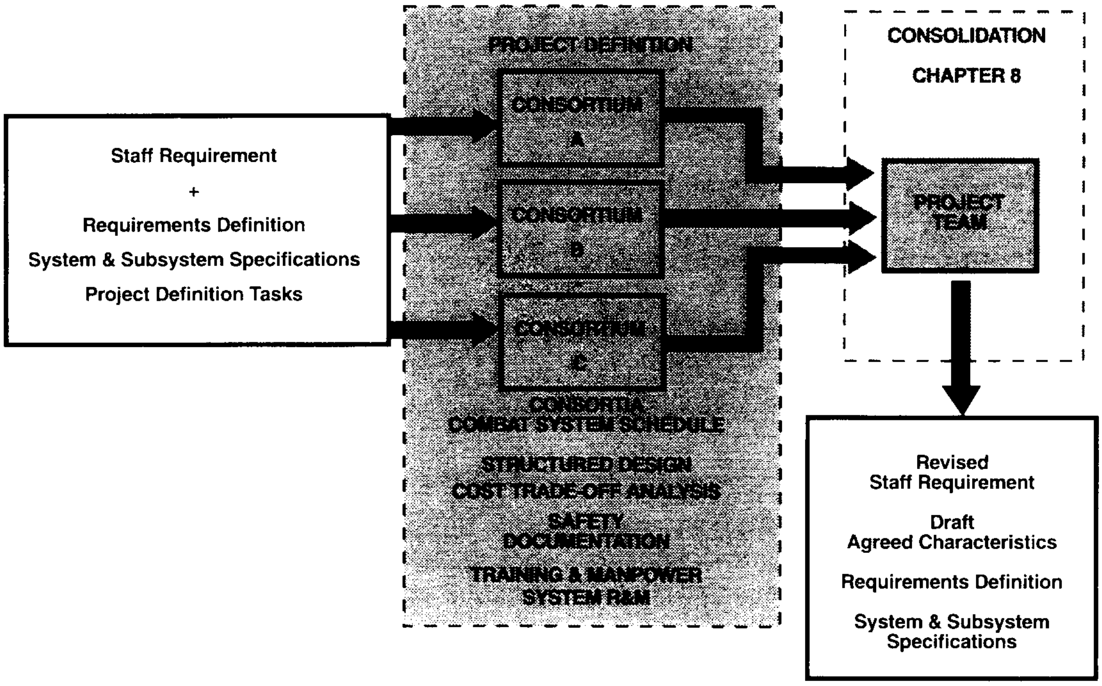


FIG. 6—PROJECT DEFINITION STAGE

Project Management

SSCP 59 provides a comprehensive guide to the project management activities that are common throughout the three stages of the CSD. The disciplines are set in place during concept and the early months of the feasibility stage. The only real difference at each stage is the relative amount of effort expended on a particular task.

In addition to the activities identified earlier, the project management section addresses:

- Organisation.
- Planning.
- Total quality and configuration management.
- Security and technical documents.

Methods and Tools

Introduction

The cost of building modern combat systems makes production of experimental prototypes an almost impossible task. However modern computer systems offer a cost-effective alternative by providing the means to 'model' the system. Modelling is the science of representing the desired system, from one or more viewpoints, to validate and verify some specific aspects of system functionality. Modelling during CSD is essential and is the only present means to minimise development risks.

It would be expected that to meet the need, models could be chosen either from commercial or MoD sources. Commercial models tend to have an advantage of price and breadth of use but rarely meet specific CSD needs. The MoD developed or sponsored modelling tools are tailored to the specific requirements of CSD, but are generally expensive in development and upkeep. There is also an issue of credibility. There has to be adequate demonstration that MoD models are fit for purpose. For these reasons it would be preferable to use suitable modelling tools from commercial sources. As these are not readily available or always appropriate, it has been necessary for the MoD to sponsor the development of a set to support CSD. Other models are available from various authorities for cost-trade-off analysis, Integrated Logistics Support (ILS) and safety design work and are not further addressed here.

The modelling methods and tools required to support CSD are identified in FIG. 2. They comprise:

- Requirements definition (current system evaluation and new system definition).
- Effectiveness modelling (capability evaluation).
- Structured design.
- Human factors requirements (architectural studies and human factors studies).
- System performance (architectural modelling).

An adequate tool to support requirements definition is currently not available from any source. Work in this area was undertaken as part of the SSN 20 development programme. A product termed Logical System Description was developed in embryo form. It utilised soft systems methods and domain modelling to aid the creation of object based requirements definition. The approach held much promise as a viable method, but the creation of a practical tool and its use was likely to be very expensive. As a result further work has not been undertaken. The specification of clear cut, well balanced, unambiguous requirements is fundamental to system design. This is, therefore, an area that needs addressing as a matter of some urgency.

WSDEM (Weapon System Design Effectiveness Model), IME (Integrated Modelling Environment) and COSAT (Combat System Analysis Tool) have been produced to support effectiveness modelling, structured design/system performance and human factors respectively. IME uses a YOURDON functional approach to structured design. An alternative could be through an object oriented approach. There is some movement currently in this direction, which will need to be kept under review for its applicability to CSD. The tools listed here are sponsored by Director General Submarines SM823 and further described below.

A Human Factors Guide for Management and Design in Royal Navy Combat Systems (SSCP11), also sponsored by SM823, has been produced in response to, and in recognition of the need to give as much consideration to the system users as to the design of the equipment. This guide is reviewed below.

An area that remains without tool support is that of a data repository. Ideally, all CSD data, including management data, should be stored in a common data store. All tools would have an interface with the repository and hence help to maintain a common database. This would ensure availability of the latest relevant data to all authorised users. The establishment of tools to support a data repository (not to be confused with a relational database) is of course a complex undertaking, that has as much relevance in the commercial world as that of the military. Thus far there is no solution available from either source.

Modelling Process

The modelling process involves viewing the evolving design from different perspectives. The modelling activities involved within CSD include structured design, effectiveness and capability modelling, human factors, and models used to support these activities can be drawn from several different methodologies. The two most common ones currently applicable for CSD are 'object oriented' and 'functional' modelling (which uses a YOURDON notation). Traditionally, the functional YOURDON-based approach has involved the creation of logical and physical models. The logical model is a comprehensive representation of what the system has to do, but is implementation independent. A model of this type, would

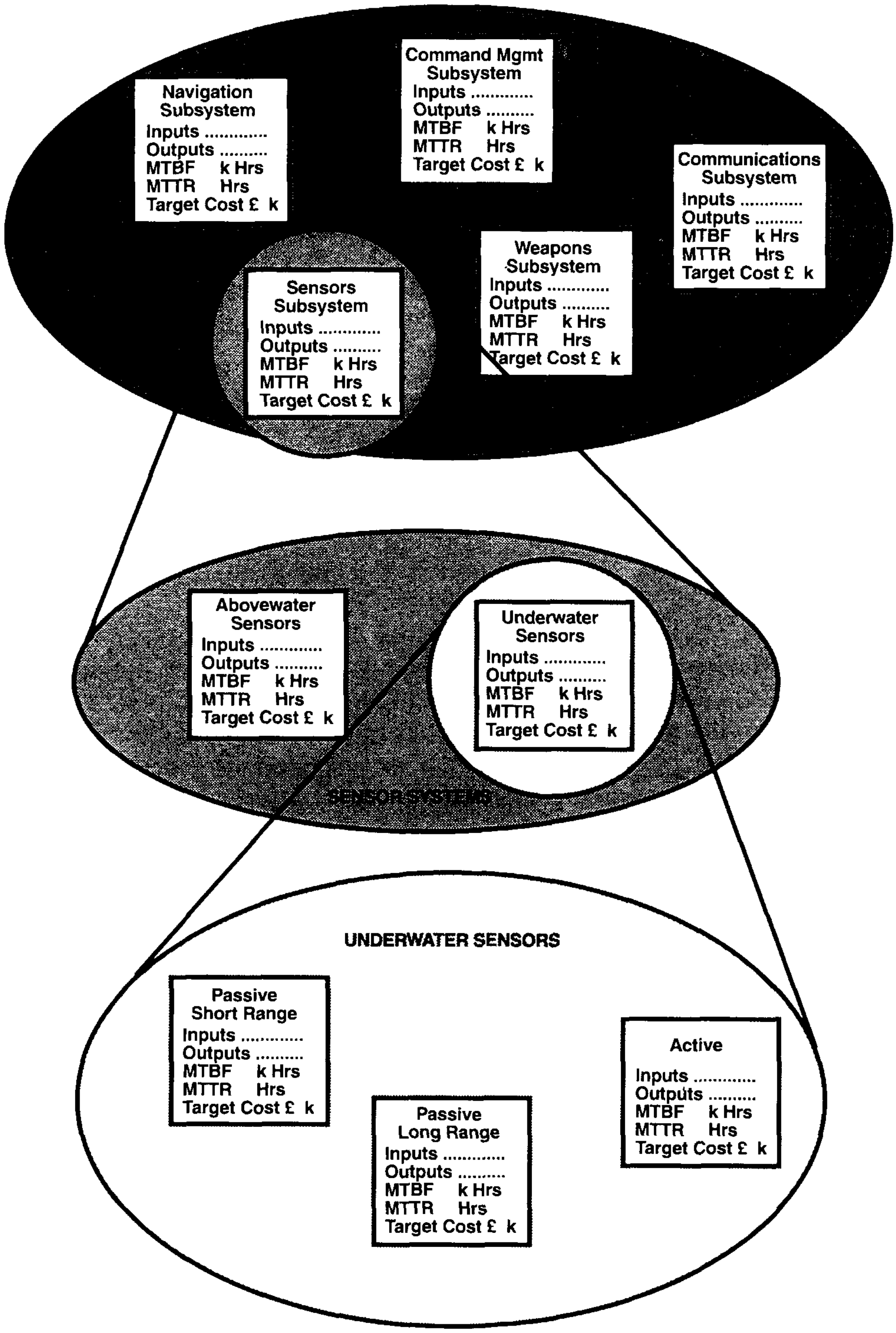


FIG. 7—COMBAT SYSTEM OBJECTS

be defined at a high level in the concept stage and progressively refined during feasibility and project definition. The physical model is a "real world" representation of a logical model, and would be developed during the feasibility and project definition stages.

Object Oriented Modelling

Object oriented modelling (FIG. 7), divides a whole system into a series of smaller objects. Each object can contain a number of functions. The combination of all the objects provides the functionality of the whole system. Each object can be thought of as a 'black box' with input, function, and output. Every object can be subdivided into further objects. During the concept stage, objects can be used as a representation of a requirement. This generic statement can then have particular data values (range, frequency etc.) associated with it to enable interactions with other objects. As the overall model develops and the project life cycle progresses, the objects relate increasingly to real physical equipments as they become specific representations of the real world.

Object oriented modelling provides the capability to include numeracy into the specifications and hence enables the trade-off analysis of different data values. This gives a clear understanding of the impact of requirement and application on design. Projects within the MoD are generating libraries of model objects representative of combat system equipments. These library of objects are re-usable and hence progressively reduce the cost of future modelling.

YOURDON

The YOURDON method (FIG. 8), splits the functionality of the system into various views. These include context diagrams showing the boundary of the system and the interfaces; event lists showing stimuli produced by the environment and appropriate responses.

Data Flow Diagrams model the system as a network of processes that accept and produce data, and control messages taking an information flow view of the system.

State Transition Diagrams model the different states that sections of the system can be found in, and detail the sets of conditions required to cause the operating state of the system to change.

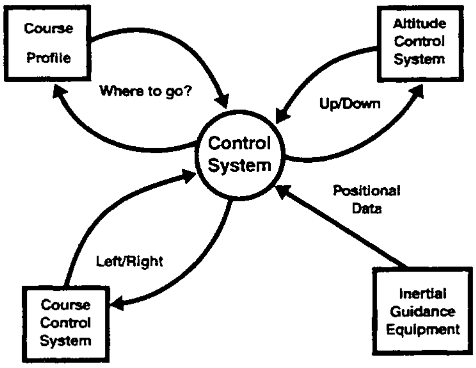
Entity Relationship Diagrams model the stored data in the system as a collection of objects and their relationship with each other.

The Weapons System Design Effectiveness Model (WSDEM)

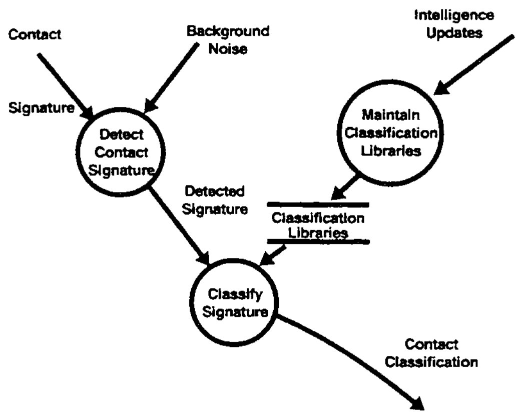
WSDEM is an object-oriented system effectiveness assessment facility, applicable throughout the life cycle from early design assessment to supporting fleet weapon acceptance and subsequent service. The models relate system design parameters to mission effectiveness, via simulation. The facility provides the means of effectiveness and capability modelling. The analysis of study results provides an understanding of the capability of an overall design as well as the ability to assess the relative merits of different (competing) equipments.

Models are constructed from a collection of real world objects, which represent the various elements of the system to be modelled. These contain all the necessary interface protocols and communication details, appropriate real world algorithms, and attributes for data output and results analysis.

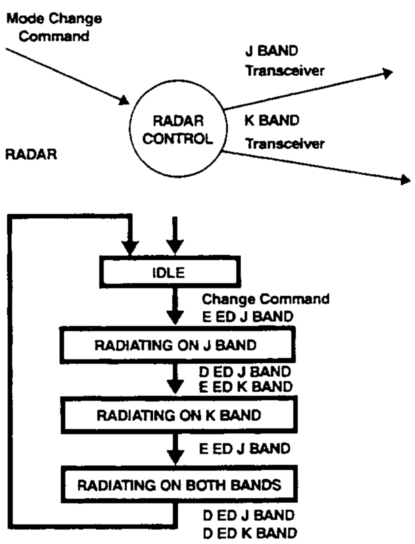
WSDEM facility outputs are study reports, containing detailed statistics concerning the effectiveness and capability of the modelled system in response to the tactics employed within the specified scenario. The analysis of these statistics can provide evidence of comparative equipment performance, as well as general assessments of the current state of a CSD.



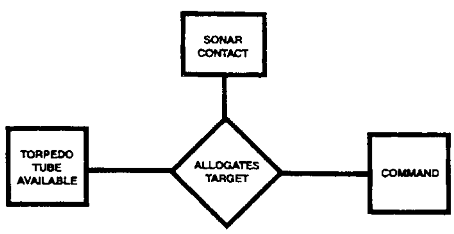
Yourdon Context Diagram for a Missile Control System



Yourdon Data Flow Diagram for EW Analysis Function



Yourdon State Transition Diagram for Radar Control



Yourdon Entity Relationship Diagram for Target Allocation

FIG. 8—YOURDON MODEL VIEWS

The facility is fully functional, and the current upgrade programme will add to its capability, especially in productivity and ease of use.

The Integrated Modelling Environment (IME)

The IME is an environment designed specifically for the modelling of large combat systems throughout their life. Based upon Yourdon, it supports the structured analysis and design of complex systems.

The combat system is described in terms of logical and physical functions, which are represented diagrammatically and enable the presentation of multiple views of the design. The modelling process involves the capture and analysis of the user requirement and its translation into various models which represent the required functionality. The logical model is translated into a physical implementation of the system using pre-defined architectural guidelines.

The IME also encompasses an Architectural Modelling Tool (AMT), which allows the dynamic modelling of subsets of the physical model to assess performance. The AMT provides facilities to exercise and investigate a system design at an early stage in the life cycle. The detailed behaviour of the system, in response to internal and external stimuli, can be explored and displayed graphically. The processes are capable of representing the real functions performed by weapon system equipments.

IME is an operational tool and is being used on a number of design projects. Further development is under way at the time of writing.

Combat System Analysis Tool (COSAT)

The study of the impact of human factors on combat system effectiveness and performance, is recognised as deserving far higher priority than has been traditional. To enable design options to be considered, a prototyping system is required early in the project life-cycle.

COSAT is a flexible prototyping system for evaluating elements of, or the whole combat system. It enables issues such as Graphical User Interactions (GUI), operability and inter-operability to be modelled. COSAT may also be used for combat system architecture evaluation and potentially for operator training.

Combat system architecture models, software and process models, GUI screens and scenarios are used to construct representations of the system to be simulated. All these elements are constructed through graphical editors. Outputs from COSAT are directed to the screens for real-time use and to a data file for post-simulation analysis.

COSAT is currently being updated from a demonstrator to a full system. The current implementation has the capability of building, editing and executing all the necessary and appropriate models for human factors investigations and is in practical use.

Human Factors Guide—SSCP 11

Introduction

In January 1990, the MoD instigated an initiative to advise and promote the implementation of human factors in the design of warships and their systems. This resulted in the establishment of a human factors steering group under the Directorate Operational Requirements (Sea), with supporting working groups. The major thrust of the initiative was to ensure that greater account was taken of the human element in generating staff targets and requirements.

The initiative resulted in the decision to produce a hierarchy of human factors guides as shown in (FIG. 9). SSCP 11 is the guide appropriate to combat systems.

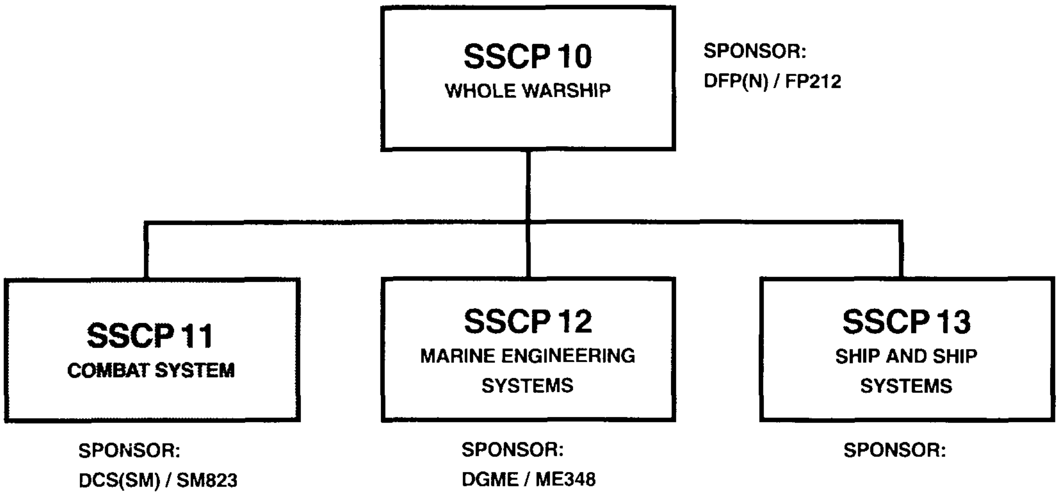


FIG. 9—HUMAN FACTORS GUIDES—SSCPII

Contents of SSCP 11

SSCP 11 addresses and interrelates specific human factors issues and design activities within the overall CSD process. The intent is to generate a clear understanding of the extent to which human factors design procedures and activities should be undertaken, during each of the CSD stages.

'Human Factors' is defined as:

> "The interdisciplinary science concerned with influencing the design of manned systems, equipments and operational environments so as to promote safe, efficient and reliable total system performance."

SSCP 11 provides a structured approach to enable the following objectives to be reached:

(*a*) To define the overall human factors requirements for inclusion in the combat system Staff Requirement.

(*b*) To define the tasks, roles and jobs of the personnel involved with the combat system, thereby specifying the required characteristics of the system itself.

(*c*) To ensure that the defined tasks, roles and jobs are compatible with the current and future personnel characteristics, qualifications and branch structures of the Royal Navy.

(*d*) To define manpower levels and organisation required to meet the system functional requirements and performance targets.

(*e*) To ensure that the combat system, comprised of its constituent equipments, is designed to take full account of the appropriate human factors design practices.

(*f*) To define the training facilities ashore and afloat to support the defined manpower.

To provide the structured approach, SSCP 11 identifies five main Human Factors Design Areas, (HFDAs). These are:

User tasks and workload. This assists in the analysis of operational tasks, workloads and maintenance.

Personnel. Addresses the human activities at a number of different levels; the final output, the Quarter Bill covers the manning required for the combat system at different action states.

The work space and equipment. These activities focus on the design of the human computer interactions; this includes design for operability and maintainability, taking due account of health and safety requirements.

The work environment. Focuses on the human factor requirements for the surroundings; this includes platform motion, noise vibration, temperature, ventilation, lighting and radiation.

Training. Embraces both training requirements and the resulting equipment and facilities required.

Human Factors Plan

The human factors integration plan covers all the activities identified above, and allies closely with the stages of the CSD amplified under SSCP 59. Essentially the plan identifies what needs to be done and when within the overall design process.

An essential component of the CSD is the related cost trade-off analysis. SSCP 11 provides a disciplined framework for the analysis of potentially conflicting requirements and design options, to enable the optimum system to be specified.

Many of the human factors topics identified, have been addressed previously within the scope of ILS. SSCP 11 clearly explains the additional activities required to meet the human factors plans, and identifies those ILS activities that still require to be carried out. For example in the case of test equipment, SSCP 11 lists the design activities concerned with the operability and safety of the test equipment. The document also lists those relating to rationalisation, scaling, costing etc. that remain ILS activities.

Summary

SSCP 11 is a comprehensive new guide to assist project staff in the complex task of ensuring that the combat system has been designed such that it can eventually be operated to its maximum capability by trained Royal Navy personnel.

Strategies for Combat System Procurement

Introduction

Present combat systems tend to be purchased by MoD(PE) using a 'conventional' fixed price procurement strategy. The work on SSCP 59, and other related initiatives has caused the authors to review the implications of the procurement methodology on the design and development process.

Procurement Strategy

A clear procurement strategy is required to define 'who' will carry out the various functions between concept and fleet acceptance, and the contractual relationships between the parties.

The aims of an ideal procurement strategy should be to ensure, that using the skills and expertise available from all parties, the user will be provided with a combat system that meets the requirements and is delivered to time and budget. It should support competitive procurement and provide clear break-points at which the continuing viability of the project can be reviewed. This also provides a solid bedrock for foreign collaborative negotiations.

Constraints on the Procurement Process

In the present operational environment, it is much easier for the target cost of a warship to be specified than for an exact definition of the functionality to be agreed. However 'cost' is itself far from absolute.

A genuinely competitive market exists when multiple sellers and buyers come together. The multiple sellers compete to provide each buyer with his needs. The multiple buyers encourage the existence of more than one seller, and ensure that the chosen seller retains his price and quality advantage for a significant period. In the UK defence industry it is very difficult to argue that a genuine market exists. Generally there is only one buyer. The complexity and cost of modern combat systems, defence industry consolidation and the scarcity of orders has significantly reduced the number of qualified sellers.

The Royal Navy has shown itself to be capable of building and commissioning the best integrated warships in the world. However any valid procurement strategy must recognise the technical demands placed on the system designers. There is no other system that is as complex as a warship combat system. The only possible equivalent is the space shuttle, which was not built to a fixed price. A combat system is one of the rare examples of a system that cannot fail safe. In wartime, a failure of the combat system to fire on demand is a greater safety threat than if a missile is fired inadvertently.

There is a belief that 'off-the-shelf combat systems' can be utilised in Royal Navy warships. These are available, but are generally limited to a single weapon, the associated fire control system and a relatively simple Command, Control and Communication system. To be commercially available they need to be in fleet service, and have a downrated capability that meets the technology export restrictions. This implies that the system will have been designed up to 10 years previously.

Significant dependencies exist between the CSD and the evolution of the platform. Not least of these is that the platform, being simpler to design and build, will normally be ready for fleet acceptance up to 2 years before the combat system. The procurement strategy must encourage cost trade-off analysis, between changes to the platform verses changes to the combat system.

As noted earlier there are very significant difficulties in documenting the sponsor's actual minimum operational requirements. This is due to many factors including the difficulty of predicting warship roles several years before acceptance, and the fear that if the needs are too well defined, only the lowest common factor will be agreed. Perceived wisdom indicates that ill defined wishes often become mandated requirements, increasing warship functionality as the project progresses. In this case sponsor and industry can unconsciously collude to increase the scope of the project.

Where the sponsor's requirement does not contain simple, clearly worded specifications, including absolute measurable figures, there is little hope of sustaining a legal battle. It is almost impossible, during combat system fleet acceptance, to prove legally, whether or not a system has met its staff requirement. This is due to the short periods available for trials, the scarcity of other ships and the variability of environmental conditions. The use of sponsor maintenance staff, gives industry a very solid let-out for failure to meet availability targets.

Risks are faced by all three parties, the sponsor, MoD(PE) and industry. Their effects, however, can be reduced by identifying them early, and structuring the project accordingly. A risk 'transferred' from one party to another is not automatically reduced unless the recipient is empowered, and funded, to mitigate that risk.

Competitive bidding costs the particular company between 4 and 10% of the value of the contract. The winner will expect to recover this money on the project and losers will need to build it into the price of subsequent contracts. In either case, for a four contractor competition, the MoD should expect to be eventually charged approximately 25% of the project value for the privilege of conducting a competition. These factors and the need to win work in the shrinking defence business, means that almost all fixed price competitive contracts will start at a loss. The industry project manager will be judged on his ability to recover this loss over the lifetime of the project.

Conventional Procurement

In the conventional procurement process, the feasibility stage is generally carried out by competing industrial consortia. From these contractors, one or more are selected to carry out project definition. A final winner is selected for development. This consortia will normally carry the system into production. Up to the start of development, the MoD is intimately involved in the design and will endorse the detailed subsystem specifications for development.

The conventional procurement has several advantages that make it superficially attractive. The most significant are that it is well understood, and it produces an eventual system that can be made to mimic closely the sponsors technical requirements as they evolve.

The disadvantages of this procurement strategy include high cost and timescale risk. This arises from MoD endorsement. The contract will require strict compliance with the subsystem specifications, which cannot be absolutely correct. As soon as the contract is let, industry will be interested in locating errors to justify either additional funding, extension to contract, or both. As time elapses the scope for these additional work items increases. There is almost nothing that can be done to protect against this unless MoD undertakes more design work than industry, which is counter productive.

Cardinal Point Specification (CPS)

In cardinal point procurement, the concept stage is used to define in very straightforward terms the actual requirements for the system, documented in the CPS. Thereafter selection of the supplying consortium can be done on a basis of lowest cost compliancy. From completion of the CPS, the MoD must refrain from interference in the evolution of the system; and remain only as an intelligent customer, withholding payment for provable lack of achievement.

The most significant perceived advantage of this procurement strategy is reduction in cost risk. The risk to capability is seen to be low as the supplier will be held to meeting clearly defined functional 'hoops'. Fleet acceptance trials can be used to trigger final payment.

The most obvious disadvantage of this procurement is the impossibility of defining, in concrete, the absolute operational requirements of the combat system. Unless they are defined in exact, unambiguous, unchanging terms no court action will be possible to justify withholding payment. Also it would be politically unacceptable, to reject a warship and its combat system complete, at the end of fleet acceptance and start again. The eventual 'get-well' programme will be at MoD risk. During the bidding procedure, potentially qualified suppliers are encouraged to bring their designs up to technical compliance to enable objective lowest cost selection. To achieve this they will rely on the results of modelling. If the contractor's own sets of models are used, the judgement is not independent. If common models are mandated for all bidders, this potentially puts the cost, timescale and technical risks back onto MoD shoulders. Should the eventual system not meet the CPS requirements, the contractor has a claim that the problem arose in the model deficiencies.

Partnership Procurement

In the procurement of large tankers and container ships, partnership procurement is used. A concept study is carried out by the customer's own technical staff. This confirms the operational requirements which are passed to potential suppliers for a feasibility study. This results in competitive designs, fixed price proposals for the chosen design, and fixed prices for labour rates and materials mark-up for subsequent design changes. The customer selects one of the competing designs based on a combination of technical quality, suitability for purpose, company pedigree and cost. The customer's own staff then work with the chosen contractor to adjust the design and to develop the final detailed specifications. On completion of the design, both parties sign-off a mutually agreed specification. The contractor will then be responsible for delivering the ship to this specification. Any agreed changes to the design, will result in adjustments to the contract price at the fixed rates quoted in the original proposal.

The principles of partnership procurement could be applied to the MoD(Navy) combat system evolution. Many possible options exist as to how each contract stage would be managed. However, the common thread is that the eventual design will be signed off as being correct by both MoD and the contractor, and will be the result of mutual partnership design effort. The chosen contractor will still be held to producing the combat system to time and to budget in accordance with the production contract.

If a reasonable measure of trust can be established by the parties in the CSD process, the partnership procurement strategy offers many advantages. The risks of cost and technical capability are shared, and can be allocated to the party best able to manage these risks. In a climate of mutual interest, it is in the interest of all parties to identify and resolve problems as they arise. There is still significant pressure on industry to get the price right at the beginning, as latterly there will only be scope for agreed fixed price changes. However there is not the same pressure to justify changes, to compensate for reduced profit levels to the original contract. The system modelling can be totally within MoD control using the 'best' models available. The impossibility of exactly defining operational requirements is addressed.

The partnership procurement process has one major disadvantage. It relies on a measure of trust and mutual self interest between the sponsor, MoD(PE) and industry. If it is considered that this trust cannot be established, it is impossible to conceive of a written contract that could adequately cover the iterative team efforts required during project definition and development. Other disadvantages include the need for somewhat complex incentive contract terms, to provide industry with the motivation to design for minimum cost compliancy.

Facility Procurement

The term 'Facility Procurement', and the concept behind it, is gaining currency in industry and commerce. In simple terms, the customer 'rents' the use of a capability rather than buying the equipment itself. Certain large MoD computer systems, some training, maintenance and Fishery Protection facilities are already provided by this means. It is possible to solve several of the procurement challenges identified earlier, by renting the facilities provided by a warship complete with combat system. This offers the ultimate in cost and technical risk reduction. Maintenance and long term support would be the responsibility of the supplier. The navy would devote itself to operating ships owned by industry.

In the present climate of uncertainty, it is impossible to rule out any option. Whole ship facility procurement may be a practicable approach in the future. However the implications on the RN engineering branch would need very careful study!

Choice of Procurement Strategy

The Treasury has seen significant short term cost reductions using the 'conventional' fixed price procurement and will take some convincing that a change is needed. That the major result of this procedure is lack of capability for the user over the life of the combat system, appears to be of little concern. The fault is seen to be in the MoD's ability to manage the procurement and the Navy's subsequent use—not in the procurement strategy itself. The modern CSD process is complex and prone to high risks. It is difficult to see how a system can be procured without a partnership of common interest, involving the very best skills and capabilities available. It is not immediately obvious how incorporating a conflict situation at the start, and sidelining much of the available expertise, reduces these risks.

Conclusions

The principle of whole system design was a primary objective of the New Look reorganisation in 1983. Since then the implications on warship design have resulted in a gradual evolution of a comprehensive system design strategy. This is particularly critical for the complex modern combat system.

The CSD strategy has been evolved to handle the challenges of modern integrated computer systems, where each elemental equipment affects others, and the system as a whole. The strategy is to evolve a comprehensive set of specifications for a cohesive system that will meet the user's operational requirements.

A Guide (SSCP 59), is shortly to be published that will assist the CSD project manager in his task of deciding what needs to be done at each stage of the project.

The design task is supported by three MoD sponsored computer tools that cover the combat system structured design, effectiveness modelling and the human/computer interface.

The human factors requirements of the design process are comprehensively described in SSCP 11, a complementary guide for the project manager.

The work on CSD has emphasised the need for a review of the applicability of procurement strategies to ensure that the present day realities of MoD/industrial relations are correctly managed.

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