THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
AUSTRALIAN BRANCH

PROJECT CONTROL IN NAVAL SHIPBUILDING AND REPAIR

by

J.C. Jeremy, B.E., M.R.I.N.A.

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INTRODUCTION

Naval vessels in recent years have substantially increased in both complexity and cost. As a consequence there has arisen the need for close control of Naval construction and refitting projects to ensure the most effective use of available finance and resources. This requirement places a responsibility on Shipyard Management to select or devise techniques to assist them to complete these projects both on time and within cost limitations. These Project Control techniques and procedures become the tools of Managers in charge of the various projects and provide a means of measuring actual performance in order that the status of the project may be known at all times to enable any necessary action to be taken to ensure satisfactory completion.

This paper describes various aspects of Project Control and some of the techniques employed in the Naval shipbuilding and repair industry. The nature of the systems used within the various Shipyards and Dockyards varies depending upon the size and type of project undertaken, the degree of continuity of these projects, and the management structure of the Yard. In addition, control of projects within the Yard will be influenced by the degree to which control has been maintained over those activities for which organisations other than the Yard are responsible, which must be carried out both before and during the course of the project itself. Accordingly these aspects are also considered.

The Royal Australian Navy has been equipped over the years with ships and submarines of a high standard built both locally and overseas, which must be maintained and supported by Australian Dockyards. Emphasis has therefore been placed upon consideration of Project Control in Naval Shipbuilding and Repair in relation to the Australian situation. For illustration examples are given of some of the procedures used by Vickers Cockatoo Dockyard Pty. Ltd. for the construction and refit of Surface Ships and Submarines for the R.A.N.

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PROJECT CONTROL

(1) Definition of a Project

A project may be defined as a task with finite start and completion dates employing manpower, materials and plant and, of course, money. This definition is necessary to distinguish a project from tasks of a repetitive or "production line" nature which in reality may consist of a series of separate projects related by common use of the basic manufacturing resources.

A project may consist of various sub-projects. The construction of a class of ships constitutes a project for the owner of the ships. The construction of each ship of the class constitutes a project for each shipbuilder involved, and accordingly it can be said that the manufacture of the propulsion machinery is a complete project in itself for the propulsion machinery contractor.

(2) What is Project Control

Project Control may be defined as the management of the use of the money, materials, manpower and plant required to complete the project. The primary instruments in Project Control are the Managers assigned the task of satisfactorily completing the project. They must be supported with a Management information service concerned with the following:

(a) Establishment of the Work Package;

(b) Setting of the Programme Targets for
  (i) Time
  (ii) Cost

(c) Monitoring of Physical Progress;

(d) Monitoring of Actual Expenditure;

(e) Assessment of the implications of actual progress on the validity of the Programme Targets.

(3) The Requirements for Project Control

Project Control is basically a task of Management and should not need to be specified as a requirement by any customer of a Shipyard or Dockyard. The shipyard or dockyard's business is the construction and repair of ships and if the management of the yard does not satisfactorily carry out this task they should not long remain in business. The customer however has a requirement to protect his investment and needs to be assured not only of the quality of his purchase but also that it will be completed on time and within cost. The latter of course is primarily the Shipyard's problem in the case of firm fixed price contracts, however it is becoming increasingly unlikely that any yard will accept a contract without some form of escalation provision and consequently the customer retains a vital interest in the progress of the project from a financial aspect.

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For all types of shipbuilding and repair contracts customer specified requirements for Project Control are becoming increasingly common. This is particularly so for Naval contracts which involve the employment of considerable resources.

The Royal Australian Navy does not yet have a document which outlines its requirements in a general form and they are usually specified or negotiated for each individual contract. This is somewhat of a disadvantage from both the standpoint of the Navy and the Shipbuilder but does leave rather more flexibility to enable the techniques to be tailored to each individual project which may be more cost-effective where relatively little continuity is the rule rather than the exception.

In the United Kingdom the Ministry of Defence (Navy) has laid down certain requirements for Project Control in conjunction with Quality Control which lean towards programming and scheduling rather than cost control. These are outlined for surface Warships in References (1) and (2). These requirements have been used in the absence of specific R.A.N. requirements to provide a basis for the development of planning and scheduling systems at Cockatoo Dockyard and much has been learnt from the application of these requirements in U.K. Shipyards.

With Naval projects it is essential that the effective control procedures be employed within Navy Departments as well as within the production organisations as those aspects of the project under Navy Control are as vital to the satisfactory conclusion of the project as those within the control of the Shipyard or dockyard.

Notwithstanding any contractual requirement the Shipyard or Dockyard must of necessity institute Project Control Procedures adequate to realise his aim of producing a quality product within an economical and profitable timescale.

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THE NATURE OF NAVAL PROJECTS

(1) Naval Shipbuilding

Naval vessels are invariably more complex than the average commercial vessel and this complexity is increasing year by year as more sophisticated weapons and electronic systems, machinery configurations, control systems and higher standards of habitability are adopted. The need to reduce maintenance problems, reduce weight and increase operational reliability has resulted in the adoption of new materials which require improved or modified production techniques and conditions. Shipbuilding is largely an assembly task particularly with Naval Combat ships where the direct shipyard labour cost may be less than one quarter of the total cost of the ship. This labour has also a very large proportion of outfit trade content and in warships increasingly specialised labour is required to install and set to work the electronic and control systems. The outfitting period is relatively long and in many instances close control of conditions and sequences is required particularly as tests and trials are commenced.

(2) Submarine Refitting

A submarine refit involves perhaps the most thorough and complete overhaul given to a marine vehicle of any kind. The entire submarine is subjected to a complete planned maintenance routine to ensure safety and operational effectiveness. Workmanship must be of a high standard and is subject to rigorous quality control and inspection procedures.

On arrival in the dockyard the Submarine is extensively stripped of equipment, fittings and systems which are removed to the shops for cleaning, survey, repair and testing to ensure in most instances that the equipments are restored to "as new" performance and reliability. The hull of the submarine is sandblasted externally, surveyed and required as necessary. The primary aim is to ensure an efficient and safe submarine and the work content is predictable to the extent that all maintenance routines scheduled for refit will be carried out. The Main variable factor in the work load is the number of Alterations and Additions and modifications required to be completed during the refit period.

Work on board the submarine must be carried out in the correct sequence and this sequence is closely governed by the restricted space and extremely limited access available. Careful scheduling in the shops is necessary to ensure that the necessary test facilities are not overloaded and to ensure that "last out - first in" equipments are available when required.

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(3) Naval Surface Ship Refitting

A surface ship lacks most of the physical restriction of a submarine and the problems of refit are somewhat different. Planned maintenance routines and repair by survey again predominate, and with new ships the task can be relatively predictable but as ships age and the number of known defects increase, the work content becomes much more variable. Defects assume priorities and financial availability may decree that some faults have to be tolerated by Ship's Staff until next refit or even later.

Inter-relationship of tasks is far less than in a submarine and in most instances a degree of flexibility exists in the refit plan.

ACTION PRIOR TO PROJECT START

All projects for success must have a sound foundation, and the application of Project Control to those activities which must be complete prior to the start of the project itself is as important as Project Control after the start date. It is necessary therefore to discuss some aspects of these activities as they relate to subsequent satisfactory conclusion of the project as a whole.

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LONG TERM PLANNING

From the ship operator's point of view, planning of operations is greatly simplified if he can free himself from any restrictions imposed by his maintenance facilities. This however is an unreal situation, particularly in Australia where the Navy is relatively small and the refitting load is predominantly shared between three Dockyards, each of which has some degree of specialisation by way of classes of ships refitted and two of which are also involved in ship construction. Ideally, the Dockyards ought to be able to provide labour when required to suit the Fleet's needs, however each yard employs a multiplicity of trades of frequently very high specialisation and cannot tolerate successfully a high degree of fluctuation of demand when it is competing on the labour market with other industries frequently more attractive than the shipbuilding and repair industry.

Inevitably a compromise is necessary between the demands of the Fleet and the preferences of the Dockyards. An even load of work at the Dockyards must however have a high priority to ensure that flexibility exists to meet emergencies and that a satisfactory overall level of Fleet maintenance is maintained. Large peaks alternating with deep hollows in dockyard workload will inevitably result in fluctuating costs and reduced capacity for carrying out work at times of peak loading resulting in high overtime penalties, increased sub-contracting with attendant control difficulties and an overall decrease in the quality of refits.

Some degree of fluctuation despite careful forward planning is likely and in the particular situation in which we work in Australia there can be considerable advantage in sustaining a substantial Naval construction programme within the Australian dockyards. The labour requirements of shipbuilding are far more flexible than those of refitting and new construction can supply or absorb to a great extent the peaks and hollows of a Naval refitting programme.

As we must today be capable of relying increasingly upon our own resources for supply and maintenance of our defence equipment, careful and realistic planning of the forward programme of the Shipyards and Dockyards is necessary to ensure that the Fleet remains a credible force and that adequate capacity and skills will be available when required.

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THE WORK PACKAGE

(a) NAVAL SHIPBUILDING

For many years Naval Shipbuilding in Australia has followed a regular pattern. Contracts for major ships have been let on a cost plus basis, design development has occurred during the course of the building programme and construction periods have been relatively long. It has frequently been characterised by delayed completion dates and increased costs. This process tends to be demoralising for the Shipbuilder and the Navy and frequently does not improve the public image of the principal parties concerned. A change has been desirable for some time and the future should see more shipbuilding contracts on some form of fixed price basis with firm delivery dates which can be as attractive to the Shipbuilder as to the Navy. Contracts of this nature will to a very large extent depend for their ultimate satisfactory conclusion on the completeness of the work package on which the contract is founded. The price and delivery the shipbuilder will offer can be treated with a degree of confidence which is closely related to the extent that the following targets have been achieved prior to the initiation of tender action.

(1) Basic design development complete.

(2) A complete ship specification prepared which describes exactly the Navy's requirements in a clear and unambiguous manner.

(3) Adequate and complete Tender Drawings prepared to support the specification.

(4) A list of Naval Board Supply Items in sufficient detail to leave the Shipbuilder in no doubt as to what equipment he may expect to receive "in aid".

If anything less than this target is achieved, then it must be expected that price variation will occur during the course of the contract and that the programmed completion date will extend. In such cases, the Shipbuilder must clearly define the extent of his offer to ensure that a suitably well established basis exists for the control of subsequent changes.

(b) Refits

For both submarines and surface ships the traditional work list for refit has been the defect list. Prepared by the Ship's Staff assisted perhaps by the Base staff the list indicates Planned Maintenance routines due to be carried out and a list of known defects. Together with a list of Alterations and Additions and modifications approved for the ship this constitutes the Work Package.

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Whilst planned maintenance routines need only a reference in the defect list, known defects need to be adequately described either in the list or in supporting documents to enable the dockyard to reasonably assess the work required to give a reasonable estimate of cost and to ensure that the necessary labour and materials will be available when required. In this regard defect lists in the past have been of very variable quality. Figure 1 indicates two extremes found in defect lists in recent years. Example A provides minimum information and even an inspection of the ship may not reveal the full extent of the problem. Example B is far more thorough. It is logical therefore that a far better estimate of time and cost will be prepared from the Defect List prepared in the manner of Example B.

To enable the dockyard to adequately prepare for the refit, defect lists should be submitted as early as practicable. This must be weighed against the desirability of ensuring that the list is as up to date as possible in order to reduce the size of the Supplementary Defect List, normally submitted at the time of the Pre-refit Conference, which may be as late as one week prior to the refit start date.

For R.A.N. "Oberon" Class submarine refits it has been planned that the Work Package should be in the Dockyard's hands six months prior to the refit start date. This target has been achieved for the second refit. Achievement of this target is assisted by the nature of the refit where most defects will be corrected as a result of normal refitting routines and the Supplementary Defect list need not be too large.

A similar lead time is highly desirable with surface ships. Present R.A.N. procedures require Defect lists to be submitted three months before refit start date, which is a substantial improvement on the previous period of one month which was totally inadequate for estimating and planning. The three months target is currently being improved upon for Patrol Boats. This improvement is largely the result of close co-operation and mutual self help between the refitting Dockyard and the operating base. To assist both the Ship's staff and the Dockyard a standardised defect list has been prepared. This list is in pre-printed form and lists all refit planned maintenance routines, approved Alterations and Additions, class modifications and commonly occurring defects in order of the Dockyard's Cost Item number, together with space for inclusion of known defects. This document is then used by the Ship's staff as a "shopping list" enabling them to complete the task conveniently within the limited resources available to them. The dockyard is assisted as the list is closely related to standard work instructions and is in a convenient and uniform format. Experience has shown that the use of this standard list has greatly reduced the size of the Supplementary Defect list. Figure 2 illustrates the format of this standard list.

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FIGURE 1

EXAMPLE A

HOT AND COLD FRESH WATER, NO.2 DECK

Hot and cold fresh water lines on No.2 Deck to be renewed and replaced where necessary. Lines wearing thin at deckhead brackets due to vibration.

EXAMPLE B

COLD FRESH WATER MAIN

3" cold fresh water main 4K passageway between frames 123-179 aged and corroded. Dockyard to renew 45ft of 3" gal. pipe with one in No. 2½" branch line, two in No. 1½" branch lines, one in No. 1" branch line, one double offset bend and 12 in No. 3" flanges.

FIGURE 2

MAIN DEFECT LIST - HULL ITEMS

SHIPS PRIORITY NO.	SHIPS TM145 NO.	DEFECT ITEMS	REQD. (YES OR NO)	DOCKYD ITEM NO.
	ALL 70	Shell Plating (Weather Deck to Waterline)		502
9	DH 87	P.M. Sched: H.3 Item Q.1	YES	
10	DH 88	Repaint Pennant Numbers in accordance with current regulations.	YES	
		Other Defects:		
		Weather Decks		503
11	DH 89	P.M. Sched: H.4 Item Q.1	YES	
12	DH 90	H.4 Item Q.2	YES	
13	DH 91	Rocket Flare Locker doors bent and distorted and clips unserviceable. Doors to be straightened and defective clips repaired or replaced.	YES	
14	DH 92	Clean back corrosion around fuel and water filling positions. Build up with weld if necessary. Re-seal with Semtex and re-paint.	YES	
		Petrol Drum Stowage to be modified i.a.w. N.O. Drg. 249/195, Fly 1	NO Compl.	
		Safety Walk Treads -		
15	DH 93	Deck tread strips - remove and renew - represerve deck under before replacement.	YES	
		Provision Room		510
21	DH 99	P.M. Sched: H.7 Item H.1	YES	
22	DH100	H.7 Item A.1	YES	
23	DH101	Dismantle Deep Freeze Cabinet and modify bulkhead to enable Deep Freeze Cabinet to be re-sited Athwartships	YES	
24	DH102	Electrical and Freon Lines to be guarded	YES	
25	DH103	2-No. access openings to be cut in deep freeze cabinet to allow refrigerant pipework repairs.	YES	
		Other Defects:		
26	DH104	Door handle and lock defective - new handle and lock to be fitted	YES	

PROVISION OF INFORMATION

(a) Naval Shipbuilding

The work package described above for Naval Ship Construction constitutes a substantial portion of the Basic information the Shipbuilder requires. It is supplemented by Standard drawings and specifications, installation and test specifications, and Naval Board Supply equipment installation detail drawings. It is essential that the Shipbuilder receive the information as early as possible and ideally prior to him submitting his tender. This, of course, will not always be practicable however it should always be the aim to enable the Shipbuilder to complete his basic estimating with the most complete information that can be supplied. This not only simplifies his task of preparing his estimate, but reduces the likelihood of extensive qualification of his tender and later negotiation of price variations made necessary by an inadequate Tender package.

Once the Contract has been placed, the Shipbuilder is primarily responsible for ensuring that the Contract Acceptance Date is met together with a satisfactory financial outcome and accordingly information not available prior to the Contract being let must be made available on the dates specified by the Shipbuilder. Whilst a degree of flexibility can be achieved by close liaison between the parties concerned the Shipbuilder's degree of responsibility must inevitably be reduced if his specified requirements are not met.

It is therefore necessary to ensure that the preparation of detailed design drawings and specifications is planned carefully to ensure that efficient construction can be achieved. In the highly undesirable event that design development must progress concurrently with ship construction then very close co-ordination of design and construction programmes is necessary or programme slippage and increased cost will be inevitable.

(b) Refits

A naval ship or submarine refit is a relatively short period of intensive effort predominantly occupied by production activities. It is essential that work should not be delayed through lack of complete information. This information may consist of:-

(1) Refit instructions.
(2) Drawings.
(3) Specifications.

A primary requirement of any refit is an adequate definition of the standard of the finished product required by the Navy. This may take the form of a maintenance schedule or a refit instruction. In many instances however, these documents, where currently in use, only define in the broadest terms the work to be carried out and do not adequately indicate satisfactory performance figures or standards of finish, resulting in opinionative decisions being made during the course of the refit with consequent variation in the standard of the final product. The natural result of this process is a trend towards refit to "as new" performance, reliability, and appearance for all equipments. As vessels age, this approach becomes increasingly costly and unrealistic. Frequently attempts are made to restore equipments to the "as designed" condition which, it is emphasised, may radically differ from the "as new" condition, in a manner which may often be difficult or impossible to determine.

Efforts are being made by the R.A.N. to overcome this problem particularly with submarines but the task is by no means easy particularly as little historical information exists to indicate acceptable levels of deterioration in equipments as they age. Where no deterioration in performance and reliability can be accepted, refitting costs to meet this requirement should be studied and the economics of replacement of complete units during the ship's life considered. However difficult, the task is a very important one as refit instruction type documents are essential supporting information to the Work Package.

During the course of a refit reference will also need to be made to "as fitted" and makers drawings and specifications. The Dockyard must be supplied with these in a timely manner. Well before the refit commences the Dockyard should know what drawings and specifications are applicable to the particular vessel and where these may be obtained as they will be needed for material procurement and reference in the workshops as the refit progresses. The need is not as great for relatively small simple ships as for vessels such as submarines where it assumes major significance as well over one hundred thousand documents are involved and each submarine differs in detail from the others of the class.

Regrettably the control of applicable documentation has in the past, and continues, to leave much to be desired. The problem must be tackled during construction by the implementation of adequate Configuration Control procedures. Whilst some increase in first cost must be expected the provision of the correct information during refit would be greatly simplified.

For Alterations and Additions and Modifications, the provision of adequate drawings and specifications is even more important. If these documents are being provided by the Navy they may either be suitable for production purposes or may require further work by the Dockyard in its own drawing offices. In the latter case authorisation to carry out this work must be given in sufficient time to allow it to be completed before therefit commences. When all

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necessary information cannot be in the Dockyard's hands by this time, then a firm decision by the Dockyard and the Refitting Authority should be made not to undertake the work during the forthcoming refit. Whilst exceptions to this rule can be argued it must be pointed out that such exceptions introduce factors of confusion into the refit with the attendant possibilities of delays and added costs. Relatively simple tasks may also require long lead materials, the details of which may not be fully defined until all drawing preparation is complete.

MATERIAL PROCUREMENT

Together with the supply of information, the timely procurement of material is an essential prerequisite for the satisfactory progress of a project. No amount of Project Control or production control systems will correct the damage to schedules inflicted by erratic, late and incorrect material supply. For both new construction and refit timely ordering action prior to the start of the project is essential, even though the aims are somewhat different.

(a) Ship Construction

Prior to the placing of the contract, material procurement action is usually restricted to "in aid" items. These items should consist of equipments with a long lead time and specialised equipments, particularly weapons and electronics, which may require Government to Government purchasing action. "In aid" items will also include patternised items or standard Navy equipment that the Shipbuilder either could not obtain or could not purchase economically.

The satisfactory progress of shipbuilding is closely connected to the achievement of programmed equipment and material delivery dates. Accordingly, the degree of responsibility the Shipbuilder can be made to accept for the satisfactory progress of the project is linked to his extent of control over equipment suppliers. Overseas, the trend for a number of years has been to reduce the number of "in aid" supply items to a minimum, placing the responsibility for the supply of the remainder upon the Shipbuilder; in the case of a multiple ship class, often on the Lead Yard. The Shipbuilder's procurement organisation is usually far less cumbersome than the Governmental organisation, and lead times can be reduced accordingly.

The contract placed between an owner and a Shipbuilder places a responsibility on the Shipbuilder to deliver the ship on time and within the estimated cost. No contract can however be one sided, and the owner must be prepared to accept the responsibility to ensure that the information and material that he has undertaken to supply is available to the shipbuilder when he requires it. This responsibility includes:-

(a) The precise definition of the extent of "in aid" supply items. The Shipbuilder must be in no doubt as to what he may expect to receive, and to avoid inevitable disagreement this should be defined at time of Tender. The need for this precise definition cannot be over-emphasised, particularly if any form of fixed price contract is contemplated. The Shipbuilder cannot be expected to accept responsibility for the correct assumption of what the owner intends to provide.

(b) following up the contracts placed for "in aid" supply items and advising the Shipbuilder promptly if contract delivery dates cannot be met.

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(c) Being prepared to accept the cost and programme effects of the failure of equipment suppliers to meet programmed delivery targets.

(b) Refits

Materials procured prior to refits will usually include both "in aid" supply items and dockyard supply items. It is most essential that every effort be made to satisfy the anticipated refit requirements prior to the refit start as the efforts of procurement organisations both of the Navy and the Dockyard will be fully employed during the refit obtaining those requirements not definable until after survey which inevitably are by then required "yesterday".

Anticipated stores and spares requirements for refit work will normally be satisfied by the Naval Stores organisations, with the Dockyard predominantly supplying consumables. Non available items must be determined very early as they must then be manufactured by the Dockyard, or purchased from equipment manufacturers frequently from materials of special specification with a long lead time. This is particularly significant in Australia where much of our Naval equipment is imported.

Materials required for Alterations and Additions and Modifications can also fall into the two categories of "in aid" supply and Dockyard supply.

The need for careful definition of these two categories is, as mentioned above for new construction, essential. The principal items of "in aid" supply are usually self evident. Small material requirements must however not be overlooked as the Dockyard will have the greatest difficulty in supplying, for instance, one square foot of QT35 plate, one inch thick, which is totally unprocurable in Australia and only obtainable overseas in much larger quantities with an extended lead time. This comment is prompted by recent experience of this type of problem where quantitypurchase well in advance of the requirement is the only solution. This is best done by the Naval procurement organisations as the material is then available for general issue to the Fleet as required. Where, however, the requirement is more specific, as it is often for submarines, the authority can be given to the refitting Dockyard.

Delays to refits caused by lack of stores and spares when they are required can be very substantial. In refits of submarines where the work is closely sequence governed, it is possible for a very simple item such as a stud or a nut or bolt to have a very substantial effect on the refit programme. This problem is aggravated if the material is, for example, aluminium bronze to DGS 8452, unobtainable in Australia and in very short supply from overseas. It is desirable therefore that

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the provision of spares and raw materials prior to refit err on the generous side, and much time will be saved if the largest proportion possible of these items are held in the Dockyard. Where this is not possible, the demanding and issuing systems of both the Dockyard and the Navy supply organisations must be capable of rapid reaction to requirements to ensure timely provision of available parts.

There can be considerable advantage in a repair by replacement policy for Naval ship refitting to reduce refit durations and increase the availability of Fleet units. Such a policy is very expensive initially and careful control of the repair of replaced parts, which then become the spares, is essential. Where financial considerations prevent such an approach various forms of repair by replacement to overcome specific delays due to lack of spares can be adopted.

Whatever policy is adopted, money spent on the adequate and timely provision of spares and stores must be amply recovered by improved refit performance with consequent cost economies and improved Fleet availability. This aspect is particularly significant with a small Navy such as the R.A.N.

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DEFINITION OF RESPONSIBILITIES

The satisfactory execution of a Naval shipbuilding or repair project will necessitate a good working relationship between all parties concerned. If this relationship is to be established in a satisfactory manner, the individuals concerned at all levels must understand their extent of responsibility for, and degree of authority in, matters of a contractual, financial, programme and technical nature.

The Commercial Contractor undertaking Naval Construction and refit work in Australia has several authorities with which to work.

(a) The Ordering Authority, which may be the Department of the Navy, Canberra, the Department of Supply, or a Naval Dockyard.

(b) The Naval Technical Services Branch of the Department of the Navy for matters of design.

(c) The General Overseers' organisation for Quality Assurance and assistance and guidance on matters financial and technical.

(d) The Royal Australian Navy Trials' and Assessing Unit.

(e) The Australian Fleet, usually represented at the Dockyard by the Ships' Staff.

Decisions required during the course of a project are many and varied and are frequently required ofmany levels of the above organisations, from the Overseer on the job to the Naval Board in Canberra. At each level responsibilities and degree of authority require definition. To some extent these aspects are covered by existing regulations however with the increasing frequency of fixed price contracts of some type these matters must be clarified. The overseer on the job, the Ship's officers or the Trials teams must know clearly the extent to which they may act, having in mind the technical, financial and contractual implications of their decisions.

Once these authorities have been defined, the decision making process must work smoothly and quickly if programmes and budgets are not to be affected.

It is also essential that the Shipbuilder has a full understanding of the responsibilities of the various Naval Authorities. Similarly within his own organisation individuals should know the extent to which they may act. There is a considerable advantage in having a Project Management organisation with one individual having a clear cut responsibility for the cost, programme and quality aspects of a project as a whole. Without such an organisation the approach can lack cohesion with each functional supervisor concentrating on his own activities with little regard for the impact of his actions upon the activities of others. In these cases overall responsibility for the project is not vested in any individual until very high up within the Shipbuilder's organisation where day to day attention to the detailed requirements of project is impossible. Such an arrangement not only complicates the resolution of difficulties and priorities within the Shipyard but hinders a satisfactory project relationship at working levels between the Shipbuild and Naval Authorities.

SETTING THE PROGRAMME TARGETS

Rarely is the planner faced with a blank sheet of paper when establishing the programme for a project. He will usually have been given some framework within which to work, either by the customer or by his own management. With Naval projects the basic timescale for most projects, particularly refits, will be fairly well defined. If the Dockyard has been involved in the advance planning previously referred to, they will be in a position to establish an overall forward programme for the yard for some time ahead. This programme is the basis for providing management with the information they need when making decisions on future commitments.

CAPACITY PLANNING

A Shipyard or Dockyard's principal variable resource is labour. It is the planner's first task to establish the labour levels required to accomplish known and expected projects and to provide this information to management. Coupled with knowledge of the likely availability of the various trades this information enables management to set the basic targets for the yard to meet.

The raw data for the preparation of Forward Labour Loading information consists of:-

(a) Estimated manhours for projects in hand or for which a Work Package is held.

(b) Anticipated manhours for projects for which no detailed information is available, usually based upon past experience on similar projects.

The processing of this data is a relatively straight forward but tedious task to provide individual trade requirements and dockyard total labour load, and lends itself to computer processing. At Cockatoo Dockyard a series of programs have been written to carry out these calculations. The basic input data may consist of either:-

(a) Principal trade estimated manhours. A program calculates the weekly average number of men for each trade on the basis of certain specified parameters, for example manhours per week per man. This program as developed so far is suitable only for refits where the pattern of labour can be defined fairly readily.

(b) Average numbers of men for principal trades for each week of the project. This method is predominantly used for projects other than refits, the figures being calculated by hand from the estimated manhours for the principal trades.

The Forward Labour Loading program uses this data to produce the series of tables.

1. For each project, the requirement for miscellaneous trades is calculated, and the total project labour requirement tabulated.

2. For each principal trade, the individual project requirements are totalled, and a calculated figure for absentees added to provide a total of the number of men required on the books to ensure the project requirements are met.

3. Using the information calculated in 1. and 2., the total dockyard labour requirement is calculated and tabulated.

Two programs have been prepared, one for weekly labour requirements for a period of two years, and one for monthly average labour requirements for a period of ten years. No attempt is made at this stage to smooth the labour loading by these programs. It is considered that this is best accomplished by suitable modifications of the input data as individual project priorities may vary from time to time and as static allowances are made for the requirements for yard maintenance, services and minor or very short term projects which in reality may vary very considerably depending on the particular circumstances at the time.

Refinements are continually being built into these programs to produce more reliable and less coarse information.

The use of the computer enables far more comprehensive labour loading information to be maintained than previously by manual means, due to the reduced effort required to update and modify the individual project requirements. Simulation of the labour requirements for the yard for hypothetical forward programmes can also be accomplished very rapidly. For example, the dockyard labour required to carry out a new construction programme of several ships over a number of years in conjunction with other commitments can be determined within one working day, assuming immediate computer availability when required.

Forward Loading information of this nature is not only valuable to top management for "strategic" planning, but should form the basis for tactical planning information for issue to yard supervisors. This information should indicate the planned allocation of labour to individual projects to meet their programmes, and may well indicate past performance, say for the previous month, of actual labour allocation against planned; information which is complementary to costing records. The planned labour allocation information must be used with care. The individual supervisors must retain the responsibility for the efficient use of labour, and it must be recognised that it will rarely be possible to predict labour availability and hence its allocation accurately on a day-to-day or week-to-week basis in view of the many complex interacting factors involved. The information should however be regarded as management intent and deviations from the planned figures should be investigated.

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REQUIREMENTS OF THE PROJECT PROGRAMMES

Within the limits set by owner's requirements, management policy and available labour, the time oriented work programme must be formulated. This programme serves to provide both the plan of action for the yard and a means of assessing the implications of actual progress for management.

The requirements of each level of management differ with respect to this programme. Top management does not require great detail. They need to know the most significant milestones within the programme and achievement related to these milestones. Middle management requires more detail in order to co-ordinate the activities of the various functional departments of the yard, however their requirement is similar to top management in that neither should be swamped by detail from which the significant factors have to be extracted. Neither level will have the time to do this with consequent reduction in the value to them of the programme, and accordingly the Planning organisation should do it for them. Programmes at these two levels of management should therefore predominantly highlight those activities and events which will provide a satisfactory overall picture of the project as a whole.

It is considered that emphasis should be placed on readily measurable events in management programmes rather than activities. Achievement of events can be easily assessed on a "yes-no" basis and provides a more concise means of progress assessment than activities, which unless they are very finely detailed usually leave some doubt as to exactly what work is entailed by each with consequent difficulty in determining exactly when it is started and when it is completed.

Programmes and schedules for use at the work face must of necessity be more detailed and oriented towards production activities rather than events. These activities should bear as close a resemblance as possible to the work instruction or should at least be capable of relation to it. This is not always easy, as indicated later in this paper, particularly as individual requirements of detailed work schedules may vary.

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PREPARATION OF THE OVERALL PROGRAMME

The technique of Network Analysis is now well established in the Shipbuilding and Repair Industry both overseas and in this country, and it is not intended in this paper to outline its principles, which have been well described previously in papers before this Institution (References 3, 4, 5). Reference 6 provides an outline of the technique in a readily useable form.

It is logical that this technique would figure prominently in Project control of Naval Projects and its use is usually a Naval requirement. However, care must be taken in its application for while it is a very useful technique its use slavishly for all manner of programming tasks can introduce substantial difficulties and in many instances other, often simple techniques will function more satisfactorily.

For preparation of the overall project programme, network analysis is, however, a most useful tool. The desirability of programming by milestone events is readily accommodated, indeed this method is the basis of PERT as originally developed. Networks which are wholly event oriented are however difficult to prepare and follow, and an activity based network is far simpler for the planner to draw. It is considered that a combination of both types of network is a very practicable compromise and provides a very useful Project Control document. In the preparation of these networks, a number of factors should be kept in mind.

(1) Activities should be kept reasonably broad throughout the network, which should show that logic which is essential for the satisfactory progress of the project. Accordingly, it will be more detailed for machinery spaces, weapons, electronic and control spaces than for accommodation spaces. Activities relating to the supply of information and materials must not be left out.

(2) Milestone events must be readily measurable events for which the state of achievement can be unambiguously defined. For example, events such as "Start shipping main engines", "Commence flushing Lub. oil" are satisfactory, but "Lub. oil system 50% complete" is not.

(3) Overall networks should not be too large. It is considered that ideally they should not exceed approximately 3,000 activities and 500 milestone events. This may sound large, but such a network will be relatively coarse in detail when applied to the construction or refit of a modern naval ship. More will be said of network size later.

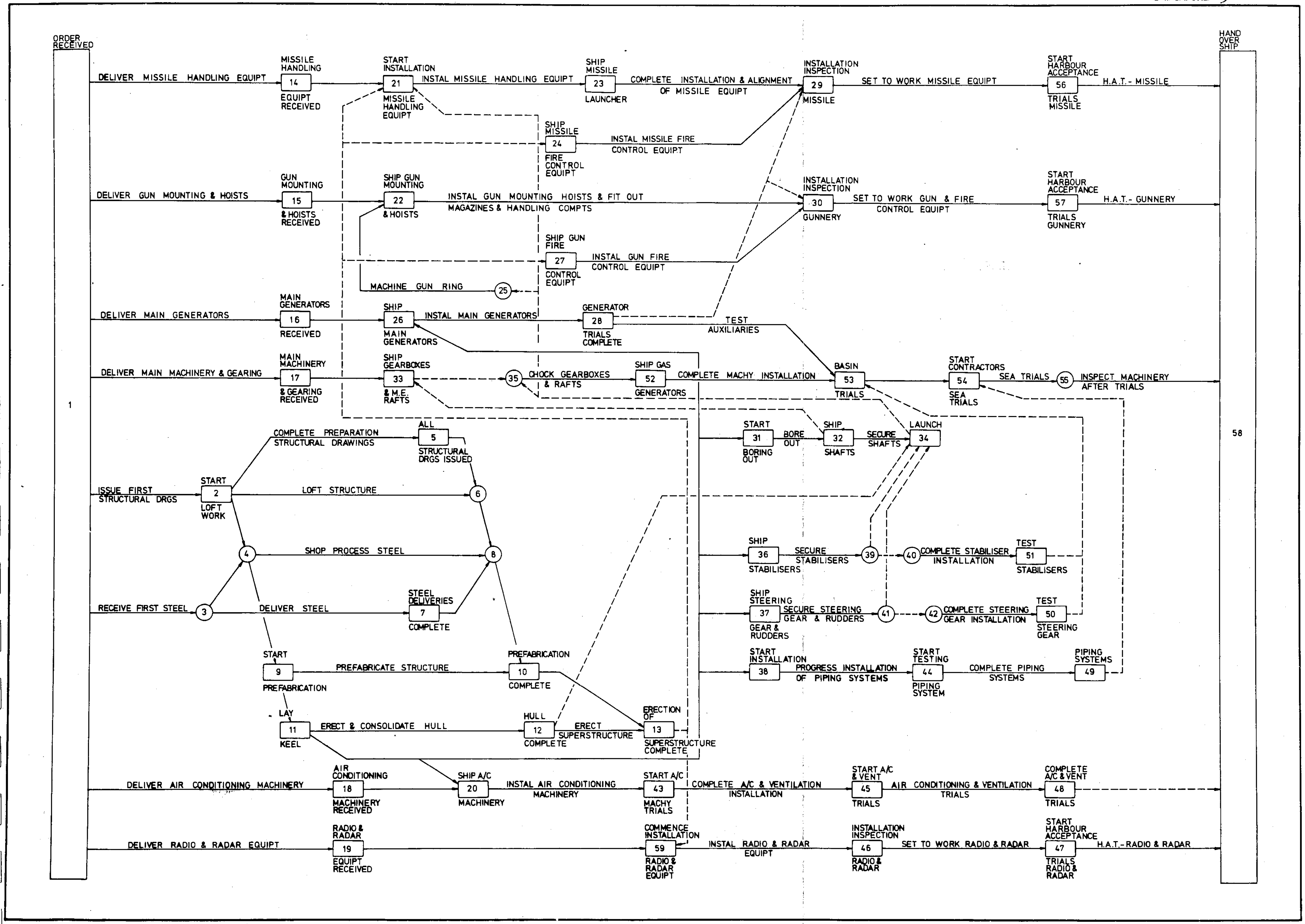
Figure 3 illustrates a network constructed as described above. This example is a very simple network drawn to illustrate the principles involved and of necessity activities and events are very broad. Figures 4 and 5 illustrate event and activity lists produced following computer analysis of the network. This example is of new construction, but the same principle is applied to refit networks.

GENERAL COMMENTS ON THE USE OF NETWORKS

Before outlining methods of presentation of programme information both for management and production use, it is considered desirable to comment further on some of the advantages and disadvantages of using networks for Naval Construction and Repair, together with remarks on their use prompted by experience.

(a) By definition a network assumes that there exists a unique or best sequence of activities for a project, for which activity times may be varied. Indeed, one of the primary advantages of network analysis is its ability to highlight the inter-relationships between activities, and it is this advantage which should be exploited. Mention has already been made of the fact that many activities in shipbuilding and repair do not have a specific inter-relationship unless each task is analysed in the greatest of detail. Even then a part from a number of major constraints, there will frequently be many satisfactory ways of accomplishing the tasks. Coupled with the difficulty of precisely defining many activities without recourse to great detail, it is easy to produce very large networks which become difficult to handle. These networks may show one preferred sequence of activities, carefully worked out, however in these cases individual tasks will be accomplished in an order far more likely to be dictated by availability of material than by network logic. Whilst networks confer a commendable degree of flexibility to the overall plan, substantial changes of logic to accommodate actual progress can be very difficult to arrange particularly of the network is large. Experience with the network for the first refit of H.M.A.S. "Oxley", which consisted of some 8,000 activities, confirmed the difficulty of controlling a very large network with many activities in a preferred sequence rather than a strictly essential sequence when factors beyond the networks control forced substantial deviation from the original plan. Accordingly it is essential to ensure that the level of detail of each network is suited to its

FIGURE 3



ORDER RECEIVED
1
HAND OVER SHIP
58
DELIVER MISSILE HANDLING EQUIPT
MISSILE HANDLING 14 EQUIPT RECEIVED
START INSTALLATION 21 MISSILE HANDLING EQUIPT
INSTAL MISSILE HANDLING EQUIPT
SHIP MISSILE 23 LAUNCHER
COMPLETE INSTALLATION & ALIGNMENT OF MISSILE EQUIPT
INSTALLATION INSPECTION 29 MISSILE
SET TO WORK MISSILE EQUIPT
START HARBOUR ACCEPTANCE 56 TRIALS MISSILE
H.A.T.- MISSILE
SHIP MISSILE 24 FIRE CONTROL EQUIPT
INSTAL MISSILE FIRE CONTROL EQUIPT
DELIVER GUN MOUNTING & HOISTS
GUN MOUNTING 15 & HOISTS RECEIVED
SHIP GUN MOUNTING 22 & HOISTS
INSTAL GUN MOUNTING HOISTS & FIT OUT MAGAZINES & HANDLING COMPTS
INSTALLATION INSPECTION 30 GUNNERY
SET TO WORK GUN & FIRE CONTROL EQUIPT
START HARBOUR ACCEPTANCE 57 TRIALS GUNNERY
H.A.T.- GUNNERY
SHIP GUN FIRE 27 CONTROL EQUIPT
INSTAL GUN FIRE CONTROL EQUIPT
MACHINE GUN RING
25
DELIVER MAIN GENERATORS
MAIN GENERATORS 16 RECEIVED
SHIP 26 MAIN GENERATORS
INSTAL MAIN GENERATORS
GENERATOR 28 TRIALS COMPLETE
TEST AUXILIARIES
DELIVER MAIN MACHINERY & GEARING
MAIN MACHINERY 17 & GEARING RECEIVED
SHIP GEARBOXES 33 & M.E. RAFTS
35
CHOCK GEARBOXES & RAFTS
SHIP GAS 52 GENERATORS
COMPLETE MACHY INSTALLATION
BASIN 53 TRIALS
START CONTRACTORS 54 SEA TRIALS
SEA TRIALS
55
INSPECT MACHINERY AFTER TRIALS
START 31 BORING OUT
BORE OUT
SHIP 32 SHAFTS
SECURE SHAFTS
LAUNCH 34
COMPLETE PREPARATION STRUCTURAL DRAWINGS
ALL 5 STRUCTURAL DRGS ISSUED
ISSUE FIRST STRUCTURAL DRGS
START 2 LOFT WORK
LOFT STRUCTURE
6
4
SHOP PROCESS STEEL
8
RECEIVE FIRST STEEL
3
DELIVER STEEL
STEEL DELIVERIES 7 COMPLETE
START 9 PREFABRICATION
PREFABRICATE STRUCTURE
PREFABRICATION 10 COMPLETE
LAY 11 KEEL
ERECT & CONSOLIDATE HULL
HULL 12 COMPLETE
ERECT SUPERSTRUCTURE
ERECTION OF 13 SUPERSTRUCTURE COMPLETE
SHIP 36 STABILISERS
SECURE STABILISERS
39
40
COMPLETE STABILISER INSTALLATION
TEST 51 STABILISERS
SHIP STEERING 37 GEAR & RUDDERS
SECURE STEERING GEAR & RUDDERS
41
42
COMPLETE STEERING GEAR INSTALLATION
TEST 50 STEERING GEAR
START INSTALLATION 38
PROGRESS INSTALLATION OF PIPING SYSTEMS
START TESTING 44 PIPING SYSTEM
COMPLETE PIPING SYSTEMS
PIPING SYSTEMS 49
DELIVER AIR CONDITIONING MACHINERY
AIR CONDITIONING 18 MACHINERY RECEIVED
SHIP A/C 20 MACHINERY
INSTAL AIR CONDITIONING MACHINERY
START A/C 43 MACHY TRIALS
COMPLETE A/C & VENTILATION INSTALLATION
START A/C & VENT 45 TRIALS
AIR CONDITIONING & VENTILATION TRIALS
COMPLETE A/C & VENT 48 TRIALS
DELIVER RADIO & RADAR EQUIPT
RADIO & RADAR 19 EQUIPT RECEIVED
COMMENCE INSTALLATION 59 RADIO & RADAR EQUIPT
INSTAL RADIO & RADAR EQUIPT
INSTALLATION INSPECTION 46 RADIO & RADAR
SET TO WORK RADIO & RADAR
START HARBOUR ACCEPTANCE 47 TRIALS RADIO & RADAR
H.A.T.-RADIO & RADAR

I C L 1900 SERIES PERT 01/03/72

PROJECT ES EXAMPLE SHIP CONSTRUCTION PROGRAMME

MILESTONE EVENT LIST

D E S C R I P T I O N	EARLIEST DATE	LATEST DATE
ORDER RECEIVED	7MAY73T	7MAY73T
START LOFT WORK	3DEC73	18FEB74
START PREFABRICATION	21JAN74	1APR74
LAY KEEL	4MAR74	20MAY74
START INSTALLATION PIPING SYSTEMS	29JUL74	3FEB75
AIR CONDITIONING MACHINERY RECEIVED	28OCT74	5MAY75
ALL STRUCTURAL DRAWINGS ISSUED	2DEC74	16JUN75
MAIN GENERATORS RECEIVED	2DEC74	18AUG75
SHIP AIR CONDITIONING MACHINERY	27JAN75	28JUL75
START BORING OUT	3MAR75	14JUL75
START TESTING PIPING SYSTEMS	14APR75	13OCT75
SHIP SHAFTS	21APR75	25AUG75
STEEL DELIVERIES COMPLETE	5MAY75	8SEP75
SHIP STEERING GEAR & RUDDERS	19MAY75	22SEP75
SHIP STABILISERS	23JUN75	22SEP75
SHIP MAIN GENERATORS	23JUN75	10NOV75
MAIN MACHINERY & GEARING RECEIVED	14JUL75	14JUL75
MISSILE HANDLING EQUIPMENT RECEIVED	14JUL75	3NOV75
HULL COMPLETE	28JUL75	6OCT75
LAUNCH	28JUL75	6OCT75
PREFABRICATION COMPLETE	25AUG75	17NOV75
GUN MOUNTING & HOISTS RECEIVED	22SEP75	26JAN76
SHIP GEARBOXES & MAIN ENGINE RAFTS	6OCT75	6OCT75
ERECTION OF SUPERSTRUCTURE COMPLETE	3NOV75	2FEB76
START INSTALLATION MISSILE HANDLING EQUIPMENT	3NOV75	2FEB76
SHIP MISSILE FIRE CONTROL EQUIPMENT	3NOV75	8MAR76
SHIP GUN FIRE CONTROL EQUIPMENT	3NOV75	31MAY76
RADIO & RADAR EQUIPMENT RECEIVED	1DEC75	22MAR76
SHIP GUN MOUNTING & HOISTS	15DEC75	26APR76
SHIP GAS GENERATORS	26JAN76	26JAN76
COMMENCE INSTALLATION RADIO & RADAR EQUIPMENT	1MAR76	21JUN76
SHIP MISSILE LAUNCHER	29MAR76	28JUN76
GENERATOR TRIALS COMPLETE	12APR76	30AUG76
START AIR CONDITIONING MACHINERY TRIALS	12APR76	4OCT76
TEST STEERING GEAR	17MAY76	8NOV76
TEST STABILISERS	21JUN76	8NOV76
PIPING SYSTEM TRIALS COMPLETE	21JUN76	20DEC76
INSTALLATION INSPECTION - MISSILE	19JUL76	11OCT76
INSTALLATION INSPECTION - GUNNERY	26JUL76	22NOV76
START AIR CONDITIONING & VENTILATION TRIALS	26JUL76	24JAN77
INSTALLATION INSPECTION - RADIO & RADAR	30AUG76	13DEC76
COMPLETE AIR CONDITIONING & VENTILATION TRIALS	4OCT76	11APR77
BASIN TRIALS	8NOV76	8NOV76
START HARBOUR ACCEPTANCE TRIALS - GUNNERY	15NOV76	21MAR77
START HATS - RADIO & RADAR	22NOV76	14MAR77
START HARBOUR ACCEPTANCE TRIALS - MISSILE	6DEC76	7MAR77
START CONTRACTORS SEA TRIALS	20DEC76	20DEC76
HAND OVER SHIP	11APR77	11APR77

FIGURE 5

I C L 1900 SERIES PERT 01/03/72 OUTPUT SHEET NUMBER 7

PROJECT ES EXAMPLE SHIP CONSTRUCTION PROGRAMME RUN 1 TIME NOW 7MAY73 PAGE 1

ACTIVITY LIST

PREC EVENT	SUCC EVENT	U I	DESCRIPTION	DUR	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT
1	17		DELIVER MAIN MACHINERY & GEARING	110	7MAY73T	14JUL75	7MAY73T	14JUL75	
35	52		CHOCK GEARBOXES & RAFTS	15	6OCT75	26JAN76	6OCT75	26JAN76	
52	53		COMPLETE MACHINERY INSTALLATION	40	26JAN76	8NOV76	26JAN76	8NOV76	
54	55		SEA TRIALS	2	20DEC76	10JAN77	20DEC76	10JAN77	
55	58		INSPECT MACHINERY AFTER TRIALS	12	10JAN77	11APR77	10JAN77	11APR77	
1	2		ISSUE FIRST STRUCTURAL DRAWINGS	30	7MAY73T	3DEC73	16JUL73	18FEB74	10
1	3		RECEIVE FIRST STEEL	30	7MAY73T	3DEC73	16JUL73	18FEB74	10
62	6		LOFT STRUCTURE	52	3DEC73	20JAN75	18FEB74	28JUL75	10
3	7		DELIVER STEEL	70	3DEC73	5MAY75	18FEB74	8SEP75	10
4	8		SHOP PROCESS STEEL	60	17DEC73	19MAY75	4MAR74	22SEP75	10
9	10		PREFABRICATE STRUCTURE	80	21JAN74	25AUG75	1APR74	17NOV75	10
11	12		ERECT & CONSOLIDATE HULL	70	4MAR74	28JUL75	20MAY74	6OCT75	10
21	23		INSTAL MISSILE HANDLING EQUIPMENT	20	3NOV75	29MAR76	2FEB76	28JUN76	12
23	29		COMPLETE INSTALLATION & ALIGNMENT OF MISSILE EQUIPMENT	15	29MAR76	19JUL76	28JUN76	11OCT76	12
29	56		SET TO WORK MISSILE EQUIPMENT	20	19JUL76	6DEC76	11OCT76	7MAR77	12
56	58		HAT - MISSILE	4	6DEC76	10JAN77	7MAR77	11APR77	12
36	39		SECURE STABILISERS	2	23JUN75	7JUL75	22SEP75	6OCT75	13
1	19		DELIVER RADIO & RADAR EQUIPMENT	130	7MAY73T	1DEC75	20AUG73	22MAR76	15
59	46		INSTAL RADIO & RADAR EQUIPMENT	25	1MAR76	30AUG76	21JUN76	13DEC76	15
46	47		SET TO WORK RADIO & RADAR	12	30AUG76	22NOV76	13DEC76	14MAR77	15
47	58		HAT - RADIO & RADAR	3	22NOV76	13DEC76	14MAR77	11APR77	15
1	14		DELIVER MISSILE HANDLING EQUIPMENT	110	7MAY73T	14JUL75	27AUG73	3NOV75	16
12	13		ERECT SUPERSTRUCTURE	10	28JUL75	6OCT75	17NOV75	2FEB76	16
1	15		DELIVER GUN MOUNTING & HOISTS	120	7MAY73T	22SEP75	3SEP73	26JAN76	17
24	29		INSTAL MISSILE FIRE CONTROL EQUIPMENT	30	3NOV75	14JUN76	8MAR76	11OCT76	17
22	30		INSTAL GUN MOUNTING,HOISTS & FIT OUT MAGAZINES & HANDLING COMPARTMENTS	30	15DEC75	26JUL76	26APR76	22NOV76	17
30	57		SET TO WORK GUN & FIRE CONTROL EQUIPMENT	16	26JUL76	15NOV76	22NOV76	21MAR77	17
57	58		HAT - GUNNERY	2	15NOV76	29NOV76	21MAR77	11APR77	17
31	32		BORE OUT	6	3MAR75	21APR75	14JUL75	25AUG75	18
32	34		SECURE SHAFTS	6	21APR75	2JUN75	25AUG75	6OCT75	18
37	41		SECURE STEERING GEAR & RUDDERS	2	19MAY75	2JUN75	22SEP75	6OCT75	18
26	28		INSTAL MAIN GENERATORS	40	23JUN75	12APR76	10NOV75	30AUG76	20
40	51		COMPLETE STABILISER INSTALLATION	45	28JUL75	21JUN76	15DEC75	8NOV76	20

intended purpose. The overall refit network for the second "Oberon" class submarine refit has been re-drawn to include fewer than 3,000 activities, which are far broader than before.

Where more detail is required, detailed sub-networks of individual parts of the task can be drawn. These networks are more readily controlled and are in use for a shorter period of time.

(b) In the early stages of network preparation, the basic overall approach to a project should be defined. At this stage it is very helpful for the person who will be responsible for controlling the work in the yard to have some involvement in planning. Very frequently failure to conform to programme sequence and time is brought about by a lack of understanding of the thinking behind the programme. Good communications are required at all times.

(c) Most networks will be computer processed. With large networks in particular, much time and money can be lost if errors are made in preparing data for the computer. Good training of planning staff is necessary to ensure that errors are minimised. Careful checking of data is advisable before card punching as many mistakes are more simply corrected on paper than later when the mistakes have been added to magnetic tape. The establishment of network presentation standards and a degree of quality control within the Planning Department will help. When data is being prepared for update runs, it must be very carefully checked, particularly when changes of logic are being made.

(d) The application of network analysis is hindered if the computer program used is not adequate. It should not unduly restrict the flexibility of the technique and it should be able to produce print-out tailored to suit the needs of its users. Good relations with the computer are also necessary. A protracted turn-around time can out-date an up-date before it is even run. Delays in computer processing can be very costly in wasted time and in reduced validity of the output.

(e) Networks encourage forward thinking and the consideration of alternatives. Potential bottlenecks are highlighted before they occur and proposed solutions can be tested. Critical and sub-critical activities are highlighted and available labour can be directed where it will do the most good. Above all, programmes produced from networks are soundly based and can be treated with much more confidence than those prepared by less rigorous means.

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RESOURCE ALLOCATION BY COMPUTER

The achievement of a work schedule requires the timely allocation of the correct resources, usually manpower, when required by the project programme. The linking of network activities with resources and the scheduling of these activities within available resources is a very desirable aim. Several computer programs available today have highly developed facilities for resource analysis of this nature.

The International Computers Ltd 1900 Series PERT program which is used by both Cockatoo and Williamstown Dockyards has an excellent resource allocation segment with a capacity and flexibility to suit most requirements. Its practical use in the real situation does however present some difficulties, and input data of a higher standard than that required for time analysis is required.

Activity durations must be carefully calculated. For normal time analysis, activity durations are frequently the allowable time for the activity rather than the required time. This usually results in the first completion date determined being much later than acceptable. Activities on critical and near critical paths are then reduced in time towards the minimum required time in order to complete the project within an acceptable period. This process soon highlights the need for overtime or changed logic. Resource analysis by computer requires manpower requirements for activities to be specified with some precision requiring activity durations to be refined to maintain a viable relationship. These activities will then be scheduled having in mind their criticality determined by time analysis of the network and the availability of their required resources using certain decision criteria specified by the planner. This tends to reduce the flexibility of the resulting programme as the activities will be closely scheduled within the resource availability known at the time of preparation of data for the computer run. In the real situation this availability will vary from day to day and the reduced programme flexibility will inevitably tend to increase deviations from the schedule.

Resource analysis absorbs a great deal of computer time and involves substantial quantities of input data. Increased emphasis must be placed upon accurate activity durations and resource estimating but even more important is a full understanding of the many combinations of available decision criteria. These factors, which are costly, must be weighed against the benefits of a schedule of improved accuracy - at the time it is prepared.

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Production departments can control the availability of manpower but they cannot control the availability of information and material. Experience indicates that the latter affects programmes as frequently as the former. Resource allocation by computer is a very desirable aim, and as means are developed to control the supply of information and material, its use is likely to increase.

PRESENTATION OF PROGRAMME INFORMATION

Overall Programmes

Computer print-out is not always the most convenient form in which to present programme information. Particular activities or events are not always easy to find and the volume of information provided tends to discourage close study. Some form of Bar Chart remains a very convenient way of presenting programmes, particularly those of an overall nature.

The overall project programme, if oriented towards events as recommended, can be presented as indicated in figure 6. This format permits float to be allocated and the most significant aspects of the programme highlighted. It is similar to that of the Cardinal Date Programme referred to in references 1 and 2 and in general use for Naval projects in the United Kingdom. The bar chart is divided horizontally to indicate part of ship or system, for which milestone events are represented by small boxes.

This format permits the programme's use to illustrate actual progress, in conjunction with a milestone reporting procedure described later, by means of colour coding of those events which have been scheduled to be completed by the report date. This system is as follows:

(a) Milestones which have been achieved by the report date are coloured green.

(b) Milestones scheduled to be achieved by the report date, but not achieved, where the delay will not prejudice the completion date, are coloured yellow (milestones with float).

(c) Milestones scheduled to be achieved by the report date, but not achieved, where the delay will prejudice the completion date, are coloured red (milestones which are critical, or have become critical or near critical).

An assessment of relative progress between the events can be indicated by small arrowheads, similarly coloured, placed against the bar at the report date.

This means of progress indication gives a rapid impression of the state of progress of the project and immediately highlights problem areas, however is rather tedious to employ and tends to be used only to a limited extent.

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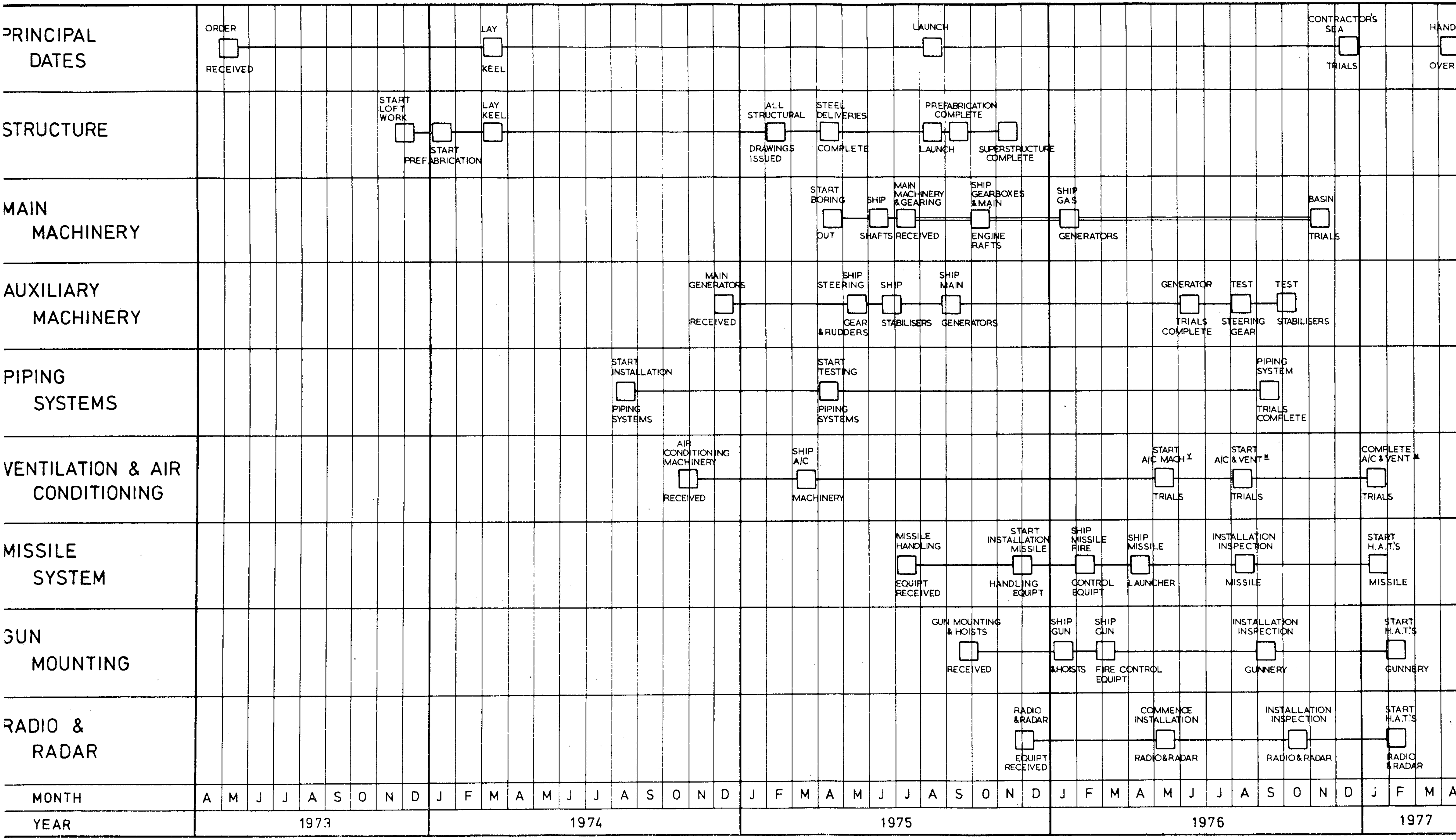

PRINCIPAL DATES
ORDER RECEIVED
LAY KEEL
LAUNCH
CONTRACTOR'S SEA TRIALS
HAND OVER
STRUCTURE
START LOFT WORK
START PREFABRICATION
LAY KEEL
ALL STRUCTURAL DRAWINGS ISSUED
STEEL DELIVERIES COMPLETE
PREFABRICATION COMPLETE
LAUNCH
SUPERSTRUCTURE COMPLETE
MAIN MACHINERY
START BORING OUT
SHIP SHAFTS
MAIN MACHINERY & GEARING RECEIVED
SHIP GEARBOXES & MAIN ENGINE RAFTS
SHIP GAS GENERATORS
BASIN TRIALS
AUXILIARY MACHINERY
MAIN GENERATORS RECEIVED
SHIP STEERING GEAR & RUDDERS
SHIP STABILISERS
SHIP MAIN GENERATORS
GENERATOR TRIALS COMPLETE
TEST STEERING GEAR
TEST STABILISERS
PIPING SYSTEMS
START INSTALLATION PIPING SYSTEMS
START TESTING PIPING SYSTEMS
PIPING SYSTEM TRIALS COMPLETE
VENTILATION & AIR CONDITIONING
AIR CONDITIONING MACHINERY RECEIVED
SHIP A/C MACHINERY
START A/C MACH. TRIALS
START A/C & VENT. TRIALS
COMPLETE A/C & VENT. TRIALS
MISSILE SYSTEM
MISSILE HANDLING EQUIPT RECEIVED
START INSTALLATION MISSILE HANDLING EQUIPT
SHIP MISSILE FIRE CONTROL EQUIPT
SHIP MISSILE LAUNCHER
INSTALLATION INSPECTION MISSILE
START H.A.T.'S MISSILE
GUN MOUNTING
GUN MOUNTING & HOISTS RECEIVED
SHIP GUN & HOISTS
SHIP GUN FIRE CONTROL EQUIPT
INSTALLATION INSPECTION GUNNERY
START H.A.T.'S GUNNERY
RADIO & RADAR
RADIO & RADAR EQUIPT RECEIVED
COMMENCE INSTALLATION RADIO & RADAR
INSTALLATION INSPECTION RADIO & RADAR
START H.A.T.'S RADIO & RADAR
MONTH
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
YEAR
1973
1974
1975
1976
1977

Production Programmes

The format and presentation of production programmes may vary greatly depending on the nature of the project, the timescale of the programme and the preferences of the users. Despite the introduction of new planning techniques, the simple bar chart remains a much favoured means of presentation. These charts may be produced by part of ship, system, trade responsibility, or for a combination of factors. This presentation, however, despite its familiarity to many, cannot overcome its disadvantages. It is impossible to indicate the inter-relationship of activities, and reasonable representation of actual progress in relation to the programme is very difficult.

With the introduction of the computer as a planning tool, it is natural that it should be increasingly used as a means of actually producing the production programme. Indeed, if it is not so used, then a great deal of its advantage is being lost, as the transcription of information to other forms from computer print-out is costly and time consuming. This has, however, been frequently done in the past and in some instances continues to be done. The reason for this often lies in the limitations of a line printer which restricts to some extent the format of the programme which can be produced. Most commercially available network programmes until recently did not allow the user much opportunity to adjust the format of print outs, resulting in the production of complicated and unfamiliar layouts which when coupled with the average man's suspicion of anything produced by a computer was a powerful argument against its everyday use.

The programs in use at the three dockyards primarily involved in Naval work in Australia have either been specifically tailored to the Dockyards' requirements (NAVNET) or are readily adaptable to the varying requirements of the particular user (1900 Series PERT). Increasing use of this facility is being made.

Mention has been made of the necessity of presenting the programmes to suit the preferences of the work force user, and they can be produced by the computer as bar charts (figure 7) or in a tabular form. Figure 8 indicates a format which has proved very acceptable for one particular application at Cockatoo Dockyard.

Produced for Patrol Boat refits, the schedule is presented as an activity listing, in two priorities, for each trade. Priority one activities are those activities with less than nine days float. All networking information of no use to the Yard is suppressed and the activities are listed in start date order with the earliest dates printed as planned dates. Priority two activities are similarly listed. However the planned dates printed are not the earliest dates, but dates set a pre-determined time earlier than the latest dates, thus delaying their scheduled start but ensuring that some float is preserved.

.../27

FIGURE 7

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I C L  1900 SERIES PERT                              15/02/72                                   OUTPUT SHEET NUMBER   19

                   PROJECT  C2   MASTER CONSTRUCTION PROGRAMME                        RUN  16  TIME NOW  7FEB72  PAGE   1

 PRIORITY 1 SCHEDULE ON CRANE/STORES LIGHTER 234  FOR FT

 COST     D E S C R I P T I O N          DUR      7        21        6         20         3         17
NUMBER                                          FEB72     FEB72     MAR72     MAR72      APR72     APR72
       MANUFACTURE MANHOLE HATCHES ETC     40   -AAAAAAAAAAI    *    I    *    I    *    I    *    I    *
       MANUFACTURE SHAFT BRACKETS &        15    AAAAAAAAAAAAAAA*    I    *    I    *    I    *    I    *
       STERN TUBES                               X    *    I    *    I    *    I    *    I    *    I    *
       MANUFACTURE SHAFTS & KEYS           30    X AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA   *    I    *    I    *
       FIT BULKHEAD FITTINGS               15   -H    * AAAAAAAAAA   I    *    I    *    I    *    I    *
       BORE OUT A BRACKETS                  6    X    *    I    *    I    *  AAAAAA *    I    *    I    *
       SHOP FIT PROPELLERS TO SHAFTS       10    X    *    I    *    I    *    I AAAAAAAAAA   *    I    *
       INITIAL OUTFIT OF WHEELHOUSE        15   -H    *    I    *    I    *    I    *   AA    *    I    *
       FIT RUDDERS                         10    X    *    I    *    I    *    I    *   AAAAAAAAAAI    *
       SHIP,ALIGN & SECURE SHAFTS           5    X    *    I    *    I    *    I    *    I   AAAAA I    *
       OUTFIT WHEELHOUSE & MESS SPACE      25    X    *    I    *    I    *    I    *    I    *   AAAAAAAAAAA+
       FIT PROPELLERS                       4    X    *    I    *    I    *    I    *    I    *   AAAA  *
       FIT OUT ENGINE SYSTEMS              20    X    *    I    *    I    *    I    *    I    *    AAAAAAAAAA+
       FIT STEERING GEAR                   20    X    *    I    *    I    *    I    *    I    *    AAAAAAAAAA+
       SHIP MAIN ENGINES                    2    X    *    I    *    I    *    I    *    I    *    AA   *
       FIT OUT & FIT CONTROLS TO MAIN      15    X    *    I    *    I    *    I    *    I    *    I AAAAAAAA+
       ENGINES                                   X    *    I    *    I    *    I    *    I    *    I    *
       FLOAT HULL                           1    X    *    I    *    I    *    I    *    I    *    I  A *
       LINE UP ENGINES & SHAFTS             5    X    *    I    *    I    *    I    *    I    *    I   AAAAA
       SHIP CRANE                           1    X    *    I    *    I    *    I    *    I    *    I    *   A
       CHOCK MAIN ENGINES                  10    X    *    I    *    I    *    I    *    I    *    I    *   A+
       SECURE CRANE                         5    X    *    I    *    I    *    I    *    I    *    I    *    +
```

I C L 1900 SERIES PERT 14/10/71

TRADE SCHEDULE PROJECT PB PATROL BOATS REFIT PROGRAMME.

PRIORITY 1 WORK FOR FITTER ON HMAS AWARE JOB NO 2091

COST NO.	DESCRIPTION OF WORK	COMMENCE DATE	COMPLETE DATE
5130H	SURVEY WTIGHT DOORS SCUTTLES AND HATCHES	5OCT71	18OCT71
6280H	REMOVE STEERING PUMP	5OCT71	5OCT71
5320P	REMOVE WINDLASS	5OCT71	7OCT71
6100D	REMOVE GALLEY S WATER VALVES	6OCT71	19OCT71
6080H	REMOVE STEERING RAM HOSES GEARBOX	6OCT71	8OCT71
6080H	REMOVE STEERING PUMP	6OCT71	7OCT71
5320P	STRIP & SURVEY WINDLASS	7OCT71	14OCT71
6160E	REMOVE AFT SULLAGE PUMP	8OCT71	18OCT71
6110H	REMOVE FRESH WATER PUMP	8OCT71	18OCT71
6130P	REMOVE GENERAL SERVICE PUMP	8OCT71	18OCT71
6120L	REMOVE DIESO TRANSFER PUMP	8OCT71	18OCT71
6070D	REMOVE LUB OIL CIRC PUMPS	8OCT71	18OCT71
6140A	REMOVE AUX GEN SERVICE PUMP	8OCT71	18OCT71
6150C	REMOVE FRD SULLAGE PUMP	8OCT71	18OCT71
6032N	CARRY OUT TOP OVERHAUL MAIN GENS IN ACCORDANCE WITH SEPARATE SHEET ATTACHED	12OCT71	16NOV71
6012E	CARRY OUT TOP OVERHAUL MAIN ENGINES IN ACCORDANCE WITH SEPARATE SHEETS ATTACHED.	12OCT71	23NOV71
5060N	CHECK CONTENTS GAUGES RU TKS	12OCT71	2NOV71
6060B	REMOVE DIESEL FUEL TANK CONTENTS GAUGES	12OCT71	18OCT71
5133N	REPAIR AS DIRECTED WTIGHT DOORS SCUTTLES AND HATCHES	18OCT71	29NOV71
6060B	DISPATCH DIESEL FUEL TANK CONTENTS GAUGES TO SUBCONTRACTOR	18OCT71	21OCT71
6120L	DISPATCH DIESO TRANSFER PUMP TO SUB CONTRACTOR	18OCT71	21OCT71
6140A	DISPATCH AUX GEN SERVICE PUMP TO SUB CONTRACTOR	18OCT71	21OCT71
6110H	DISPATCH FRESH WATER PUMP TO SUB CONTRACTOR	18OCT71	21OCT71
6070D	DISPATCH LUB OIL CIRC PUMPS TO SUBCONTRACTOR	18OCT71	21OCT71
6130P	DISPATCH GEN SERVICE PUMP TO SUB CONTRACTOR	18OCT71	21OCT71
6103J	REFIT GALLEY S WATER VALVES	19OCT71	16NOV71
5263J	REFIT GALLEY FRESH WATER VALVES	19OCT71	16NOV71
0560C	CHECK P BRACKET & STERN TUBECLEARANCES	26OCT71	27OCT71
0560C	REMOVE PROPELLERS	27OCT71	27OCT71
0560C	BREAK INTERMEDIATE SHAFT COUPLINGS	27OCT71	28OCT71
0560C	REMOVE P BRACKET BUSHES	27OCT71	28OCT71
0560C	BREAK TAILSHAFT COUPLINGS PORT & STBD	27OCT71	28OCT71
0560C	REMOVE TAILSHAFTS	28OCT71	28OCT71
0560C	REMOVE INTERMEDIATE SHAFTS &STERN TUBE BUSHES	28OCT71	29OCT71
0560C	SURVEY P BRACKETS	28OCT71	1NOV71
9100E	TRANSPORT TAILSHAFTS PROPELLERS BUSHES & COUPLINGS TO TURBINE SHOP	28OCT71	29OCT71
0560C	GAUGE TAILSHAFTS	29OCT71	29OCT71
0563N	REPAIR TAILSHAFTS	29OCT71	3NOV71
0560C	FIT PROPELLERS & COUPLINGS TO TAILSHAFTS	3NOV71	4NOV71
5060N	RECONNECT RU FUEL TKS	4NOV71	8NOV71
9100E	DELIVER PROPELLERS TAILSHAFTS & COUPLINGS TO SHIP	4NOV71	4NOV71

These programmes are produced for each Patrol Boat refit using a standard refit network retained on magnetic tape, which can be rapidly reproduced to suit the parameters of the particular refit. This approach is a substantial time saver; however two factors frequently complicate its application, resulting in considerable extra work and delays to the issue of the programme:

(a) Occasional incomplete work package (usually followed by large Supplementary Defect Lists) which prevent early release of much work on the network with the consequent need to delete it from the computer file for early runs, and to add it later as the work is released.

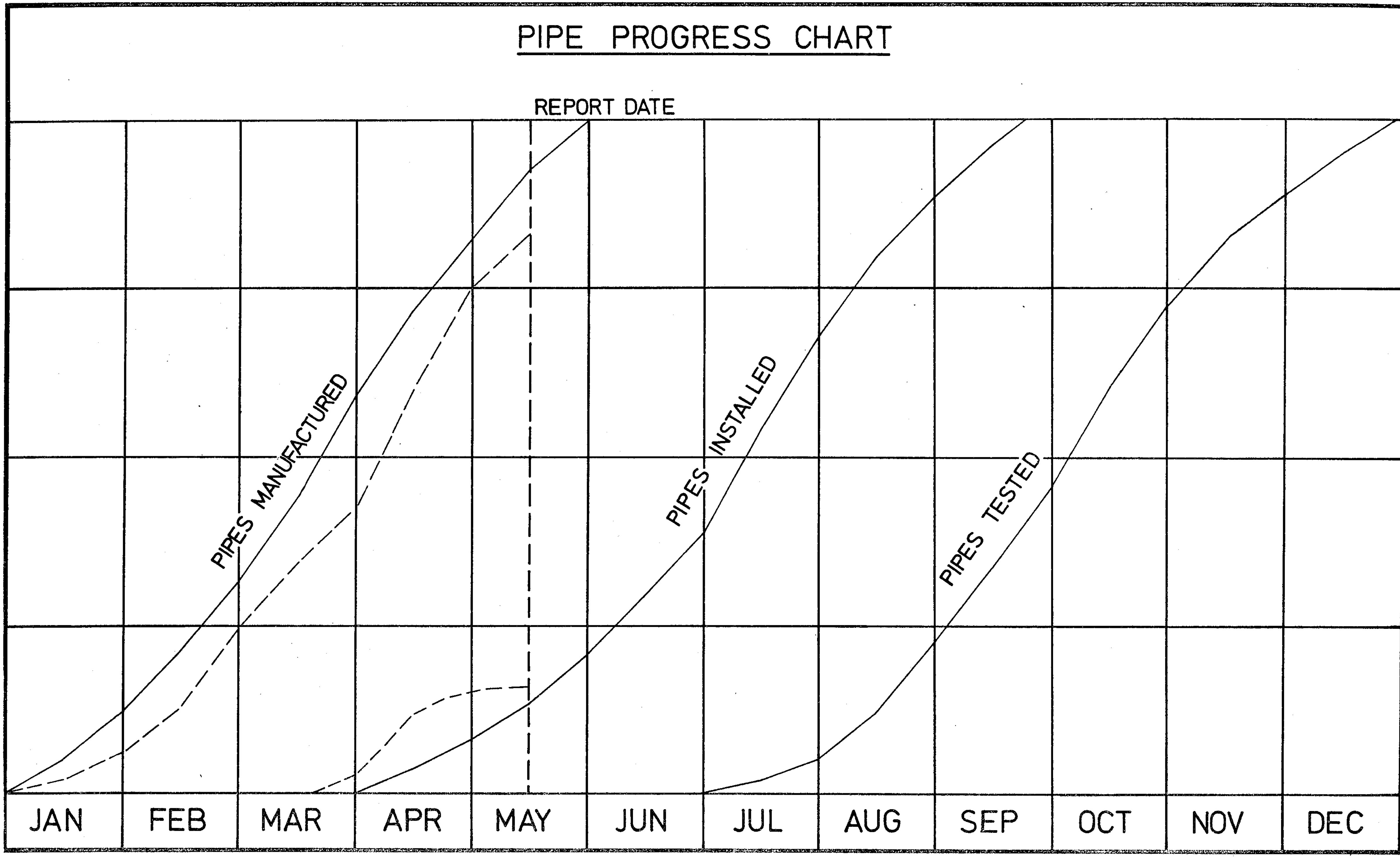
(b) Financial restrictions which may prevent release of the full work package requiring similar deletions from the programme.

It is emphasised that the above approach is one solution to a particular problem. Regrettably, it is not always, if at all frequently, so simple. The network approach can be a disadvantage for some types of activities. The repair of sea valves in refit, the installation of pipes, valves, ventilation, deck coverings, etc. in new construction are examples. In these cases the particular sequence in which they are completed is not very significant, and although they may be represented on a network as a series of fairly broad activities for various parts of the ship, these activities may encompass much work over a protracted period of time. Attempts to increase network detail for these types of activity can result in immensely complicated networks suffering from the previously mentioned problems of preferred rather than necessary sequence with consequent progressing difficulties.

For these activities, rate of achievement is more significant than the order in which they are completed. For a part of ship, for a piping system, for example, it is possible to determine reasonably easily when manufacture, installation and testing of pipes and fittings can commence and should be completed. An analysis of the numbers of pipes and fittings involved enables a determination of a planned rate of achievement of each process, and it is possible to assess progress and indicate it in a graphical manner, as indicated in figure 9. From this chart, progress trends can be observed and remedial action taken.

Group Systems

The above method of planning and progressing work is an attempt to reduce the shipbuilding or repair task to packages of work (in the example, individual pipes) of basically similar work content which can be monitored by statistical means. Whilst the approach has value for progress monitoring, it does not provide a



PIPE PROGRESS CHART
REPORT DATE
PIPES MANUFACTURED
PIPES INSTALLED
PIPES TESTED
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

FIGURE 9

useful production programme. For work to proceed at the planned rate, each package must be identified and scheduled in some manner. If one is considering individual pipes, the task assumed mammoth proportions. However, if individual pipes and fittings are grouped into larger packages the task is more feasible.

During the construction of H.M.A.S. TORRENS at Cockatoo Dockyard, it became necessary to devise a means of controlling the manufacture and installation of auxiliary machinery seats and pipes and fittings in the main machinery spaces as the very broad programmes produced were failing to provide sufficient detail for the co-ordination of the various production shops. Accordingly a system was developed of dividing the task into small groups of work of defined content which was then scheduled using information derived from a fairly broad installation network. Each group was described on a group sheet which listed applicable drawings, the detailed contents of the group, together with scheduled dates (figure 10). Schedules for the installation of groups were also prepared (figure 11).

The system used for "Torrens" was essentially simple and whilst not wholly successful as a schedule, it was of great assistance for the production of parts and monitoring of installation progress. Group sheets and schedules were prepared by hand and as would be expected, the volume of paper produced was substantial. The principal employed was consciously borrowed from systems used overseas for the control of the installation of outfit equipments and materials which were considered too complicated and expensive for application to this particular task. Experience proved however that these systems are a logical progression from simple approaches such as the "Torrens" group system.

Use of group systems gradually encourages the reduction of the size of groups to more finite work packages, and the extension of the system throughout the ship. This inevitably results in many thousands of groups being scheduled with the attendant problem of control of the schedule. The use of a computer then becomes essential.

One such system in use overseas is the Installation Group System used by Vickers in the U.K. for the planning and control of the outfit of Nuclear Submarines. It is a version of a system developed in the United States for the same purpose. In this system, a Group is defined as a batch of related materials which is installed:

(a) in one continuous operation or series of operations,

(b) in one compact part of the ship,

(c) By one trade with the assistance of one or more support trades. Each group is defined on a group sheet which lists all the items required to install a particular group, their sources of supply, order number, and other necessary information.

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FIGURE 10

H.M.A.S. "TORRENS". SHIP NO. 224

COMPARTMENT: Boiler Room SYSTEM: Aux. Saturated Steam A.S.

GROUP NO.	DRG NO.	GROUP	PIPES	FITTINGS	BOLTS & NUTS	FLANGES	PROG. INST. DATE	ACTUAL DATE	TEST DATE	REMARKS
ASG.501		A.S. Range	501,502,508,509	501,502,503,556			Oct. 68			
ASG.502		H.P. Steam to E.R. & Aft Ejector	503,504,505	528,551			Oct/Nov 68			
ASG.503		H.P. Steam to Ford Bilge Ejector	506,507	529			Nov 68			
ASG.504		L.P. Sat. Steam Range	510,511,512	504,505,506,507 508,509,534,535			Nov 68			
ASG.505		L.P. Steam to Evaps.	513,514	531,532			Nov 68			
ASG.506		L.P. Sat. Steam to E.R.	515	530			Nov 68			
ASG.507		H.P. Steam Drenching	516,517,518,519 520	510,552,553			Nov 68			
ASG.508		L.P. Steam to Exhaust Range	521,522	523,524,525,526 527			Dec 68			
ASG.509		L.P. Steam to T.G. Glands	523	533			Nov 68			
ASG.510		H.P. Sat. Steam to O/B Fuel Pump and Heater	524,526	511,513,515,517 521			Jan 69			
ASG.511		H.P. Sat. Steam to I/B Fuel Pump and Heater	525,527	512,514,516,518 522			Jan 69			
ASG.512		L.P. Steam from Aux.Blr to Range and Siren	528,529,530,531 532	536,538			Nov 68			
ASG.513		L.P. Steam to Waste Steam		543			Nov 68			
ASG.514		L.P. Steam to O.M.S. Ford.	534,536,546	539,540,541,542 558			Dec 68			

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SHIP 224 H.M.A.S. TORRENS

PIPE INSTALLATION SCHEDULE Boiler Room

PIPES SCHEDULED FOR INSTALLATION IN THE MONTH OF DECEMBER, 1968

SYSTEM	GROUP NO.	PIPE NO.	REMARKS
Main Steam	G.501	3.	
	G.502	4.	
Superheated Steam	G.501	503.504	
	G.502	505.506.508.513	
	G.503	507.	
Saturated Steam	G.508	521.522	
	G.514	534.536.546	
	G.515	536,537.538.539.540 541.542.543.544.545	
	G.516	547.548.549	
Aux. Exhaust	G.504	507.508	
	G.504	544.552	
Oil Stripping	G.505	517.518.519.520.521 546.547.548.549.550.551	
	G.506	537.540.541.542	
	G.507	523.524.525.526	
Diesel Suctions	G.501	527.528	
	G.502	501.502.503.504 505.554	
	G.503	506.507.508.555	
Aux.Circulating	G.502	502.503.504.505 532.536	
	G.503	506.507	
	G.504	517	
	G.506	518.519.520.524 526.534	
Fire and Bilge	G.504	516.517	
	G.505	518.519.536.593	
	G.506	520.	
	G.517	572.573.	

Each group is identified by a unique number which includes the appropriate cost code and a part of ship code, and has associated with it production information such as:

(1) Trade responsible for installation.

(2) Drawing number.

(3) Installation constraint codes (i.e. before launching or in dock, etc.)

(4) Scheduled dates for:

Drawings available.
Material available.
Start installation.
Complete installation.
Test.

This latter information can be stored on magnetic tape and facilities provided for the receipt of progress information. The information can be sorted into various sequences and tabulations produced listing groups scheduled for starting or completing installation, delinquent groups, groups by trade responsibility etc. Progress information can be analysed statistically and presented graphically in a similar manner to that illustrated for pipes in figure 9.

Control of installation and feedback of progress is achieved by means of material and production cards (printed by the computer) with tear-off tags providing the means of feedback of actual achievement.

When it is considered that for a Nuclear submarine some 12,000 groups may be scheduled it can be seen that the system requires considerable effort and dedication to its application. Experience in its use has indicated a number of advantages and problems. Its major impact has been in the area of material collection and distribution. However as a planning tool it has been less than fully successful due basically to its relative inflexibility. The problems associated with re-scheduling uncompleted groups following a major programme revision are substantial, particularly bearing in mind the fact that there may be several satisfactory alternative installation schedules to satisfy the overall programme.

The Installation Group System is designed primarily for use on New Construction projects. It is interesting to note that a very similar system is in use in the U.K. to control the refits of the Royal Navy's Polaris submarines (The Progress Monitoring and Management Information System).

Group systems such as these are a logical extension of the "hand operated" system used for "Torrens". With such applications in mind, a simpler version of the Installation Group System is being

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developed by Vickers Cockatoo for possible use on future complex Naval projects. Figure 12 illustrates the format of a typical tabulation produced by the system. Its application is being approached with caution however, as the operation of such a system affects many functional departments if its use is to be of real value and its operation is not inexpensive.

Reference (7) describes a related system of Group Control of installation parts used by Yarrow in the U.K. This Assembly Parts List system is very detailed and lists individual items required for each installation package in computer tabulations providing references to arrangement and detail drawings, purchase orders, anticipated and required delivery dates, source of supply and other relevant information.

Most planning and progressing systems of this type place emphasis on the timely supply of materials and information which are continually evident as critical factors in the success of any programme. Indeed, planning and control of drawing production and material procurement are as essential as planning and control of production.

Production Control

So far mention has been made primarily of project and outfit programmes. No less important is the scheduling of the manufacture of the component parts which comprise a ship or the repair of items removed during refit. These processes will involve work in many shops using a wide variety of machine tools. The systems used for the control of these production activities vary depending on the requirements of the particular organisation employing them, and a description of these systems is beyond the scope of this paper, which is predominantly intended to discuss the control of projects as a whole. It is frequently apparent however, that more attention is given to project control than production control, when in reality the extent to which the former is achieved depends to a large extent on the effectiveness of the latter. Too often, during a refit for example, there exists a "limbo" phase when most equipment is in the shops and at a time when the most co-ordinated effort should be made to ensure programme achievement the least seems to be known of actual progress. To the supervisor of the ship it may seem a miracle if a piece of equipment appears on time, marvellous if the shop will give a firm, if late, completion date, and normal if neither equipment nor information is seen on the horizon for an apparently indefinite period.

The shops at this time require sound systems to assist and control their activities to meet required dates for equipment particularly as refitting shops are likely to be beset with the usual spare gear problems and be competing with others for the use of manufacturing facilities. Control of priorities within these shops is essential or the age old system of "he who shouts loudest gets best service" will prevail.

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FIGURE 12

INSTALLATION GROUP SYSTEM   RUN DATE 30/09/71

TRADE SCHEDULE - COMPLETE INSTALLATION

SHIP	GROUP	DESCRIPTION	LEAD TRADE	CONSTRAINTS LCH.	CONSTRAINTS DOCK	COMMENCE SCHED.	COMMENCE ACT.	COMPLETE SCHED.	COMPLETE ACT.	TEST SCHED.	TEST ACT.
233	1105010503	WIRE & FITTINGS FOR GUARD RAIL	03	L		208		210		214	
233	1105101504	WIRE & FITTINGS FOR GUARD RAIL	03	L		208		210		214	
233	1002101202	HYDROSTATIC RELEASE FOR LIFE RAFT	03			215		215		216	
233	1003100301	LIFE JACKETS 8 OFF	03			215		215		216	
233	1004101402	LIFE BUOYS 2 OFF	03			215		215		216	
233	1004101404	MAN OVERBOARD MARKER	03			215		215		216	
233	0702010208	WOOD GRATING	04			150		206		213	
233	0609203901	SPAR FLOORING AFT HOLD STB	04			206		209		212	
233	0609205902	SPAR FLOORING FRD HOLD STB	04			206		209		212	
233	0609211903	SPAR FLOORING AFT HOLD PT	04			206		209		212	
233	0609213904	SPAR FLOORING FRD HOLD PT	04			206		209		212	
233	1008010841	FIRE EXTINGUISHER BRIDGE	04			212		212		216	
233	1008010842	FIRE EXTINGUISHER REFILLS BRIDGE	04			212		212		216	
233	1008100840	FIRE EXTINGUISHERS MESS SPACE 2 OFF	04			212		212		216	
233	1008202838	FIRE EXTINGUISHERS MACHINERY SPACE	04			212		212		216	
233	1008210839	FIRE EXTINGUISHERS MACHINERY SPACE	04			212		212		216	
233	0226000001	SPONSONS P & S HULLS	04	L		208		213		214	
233	1008101846	HOSE 2 OFF	04			215		215		216	
233	1002101201	6 MAN LIFE RAFT	04			215		215		216	
233	0213202301	SHAFT TUBE STB	05	L		202		208		214	
233	0213210304	SHAFT TUBE PT	05	L		202		208		214	
233	0702010211	ALARM BELL	06			150		206		213	
233	0702010202	SWITCHES ELECTRICAL PANEL	06			150		206		213	
233	0702010203	AN URC/58 RADIO	06			150		206		213	
233	0702010206	CHART TABLE LIGHT	06			150		206		213	
233	0213209303	A BRACKET PT	07	L		202		208		214	
233	0213201302	A BRACKET STB	07	L		202		208		214	
233	1103101102	FAIRLEADS 6 OFF	07	L		204		209		214	
233	1102101101	ANCHOR 1 OFF	07			215		215		216	
233	1102101102	ANCHOR CABLE 100 FATHOMS	07			215		215		216	
233	1105101501	STANCHIONS FOR GUARD RAIL AFT	10			208		210		214	
233	1105010502	STANCHIONS FOR GUARD RAIL AFT BRIDGE	10			208		210		214	
233	0702010201	INSTRUMENT CONSOLE & PANEL BRIDGE	14			150		206		213	
233	0702010209	WINDOW WIPERS	14			150		206		213	
233	0218010804	BRIDGE WINDOWS 7 OFF	14			151		208		215	
233	0218100801	SIDELIGHT AFT BHD 3 OFF ACCOMMODATION	14			151		208		215	

The raw materials for ship construction are the materials for the manufacturing shops. The products of the manufacturing shops are the materials for the outfitters. In yards where new construction and refit are proceeding concurrently, good production control is necessary to ensure the requirements of each are met. In these instances, the production control systems need to be sufficiently flexible to ensure that the urgent demands of ship repair can be readily accommodated by the system to prevent its destruction by continuous short-cutting.

Refitting shops in particular must have rapid reaction service in the areas of work authorisation and spares and material provision or any degree of control obtained may be frustrated simply because the shops are choked with items awaiting the necessary paperwork or the supply of spares.

Tests and Trials Programmes

A major Naval construction or refit project may involve several hundred inspections, tests and trials as it approaches completion, many of which will be inter-related in a complex manner. In many instances the exact time required for equipment setting to work and trials will depend on a number of variable factors which require that a degree of flexibility be built into the trials programme to accommodate failures and to provide time for occasional re-trial. Unfortunately however, experience indicates that it is inevitably the Tests and Trials period which suffers most when programme slippage occurs and the time available for trials is reduced towards, and sometimes below, the minimum. This process tends to result in late programme extensions or pressure for acceptance of less than satisfactory performance.

It is for planning the Tests and Trials phase that the use of networks can produce substantial dividends. They greatly assist co-ordination of the various parties concerned with trials and reduce trial failure due to lack of completed pre-requisites. The trials programme itself is usually a day by day programme and as the project draws to a close will become the primary project control document. It is in essence a milestone programme to which all are working, and consequently as a programme document tends to be amongst the most successful. The extent to which it is achieved will however be a function of the extent of thought and co-operation which has gone into its formulation and the care that has been taken to adequately complete all pre-trial activities

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SETTING THE COST TARGETS

Long before modern management techniques were directed towards the programme aspects of projects, Managers were faced with the requirement of performing work within financial limitations. The profitability of so many Companies for so many years indicates that management skills in this direction have not however been lacking. In recent years it has become necessary for the Shipbuilding and Repair industry to adopt more rigorous cost control procedures to complement the increased complexity the products of the industry. For Naval work in Australia, good cost control will ensure better value for the relatively little money which is available for an increasingly complex and costly service.

THE COST LIST AND ITS RELATION TO THE WORK PACKAGE AND PROGRAMME

For many years the control of costs within the Shipbuilding and Repair industry has been oriented around control by trade, shop or department. The rate of expenditure was within the control of the functional departmental managers and the techniques required were relatively simple. The need to obtain better historical records and greater control in detail has resulted in a trend over the last twenty years or so towards costing on a ship system basis with work lists standardised to ensure that costs can be compared by studying the relative work content of individual ships. Resulting units of work are relatively large and represent activities spread over much of the building or repair period, presenting difficulties in determining the value of work achieved for comparison against actual progressive expenditure. This deficiency can result in trends of over expenditure not being evident until it is too late for corrective action to be taken. To achieve a more satisfactory degree of control it is possible to outline certain requirements for the definition of satisfactory work units for cost recording.

(1) The total content of the work package should be divided into readily identifiable units of work.

(2) Each work unit should be performed predominantly by one trade to ensure functional departmental cost responsibility.

(3) Each work unit should be so defined that its limits are clearly understood by both estimators and workmen. It may however, consist of a number of individual operations.

(4) To enable satisfactory progress monitoring with a minimum of opinionative progress assessment, work units should not require more than a few weeks for their completion. Similarly they should not be too small, or the number accomplished at any one time will prevent adequate control.

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(5) To enable the comparison of progressive expenditure with planned expenditure the work unit should be capable of direct relationship to the activities in the work programme. If the work programme is co-ordinated with the supply of information and material, achievement of each work unit within its planned cost and the project within its overall cost plan should be possible.

(6) Each work unit should be related to a particular part of ship or system to enable cost comparison between different ships.

The above criteria would perhaps establish the ideal relationship of work package, work units, work plan and cost plan. In practice however it is much easier to define these requirements than to apply them to the real project within a real shipyard environment. The extent to which they are achieved will be a compromise based upon the nature of the project, the Shipyard's management systems, and the degree of financial risk associated with the project. The latter has a substantial bearing upon the economics of using a highly complex work definition and costing system as the effort expended on the system must be reflected in cost benefits in excess of the extra cost of the system or its application would not be warranted.

The difficulty of defining and scheduling the activities in the construction of a modern Naval vessel has been mentioned in relation to the use of Network analysis techniques. Ideally, each work unit should constitute one activity on the network, or have a positive relationship to these activities. Many of the work units will have little significance in relation to the overall programme whereas the individual operations comprising others may need to be closely scheduled. Accordingly the resulting network is likely to be very large and complex with the resulting limitations and difficulties previously mentioned.

It is not suggested that this reason alone should deter attempts to achieve the criteria outlined above. There are however the factors which should be taken into consideration:

(a) Each work unit must be defined very early in the construction programme. Ideally this should be done when the first estimate of cost is being prepared, and accordingly the degree to which this may be achieved is dependent on the detail contained within the work package.

(b) Each work unit must have an estimated cost. These estimated costs will usually be dependent to some extent on historical data relating to similar ships previously built and a known level of productivity. In Australia particularly, with small Naval Shipbuilding programmes this historical data accumulates very slowly, and may be rendered obsolete by changes in productivity and the introduction of new production techniques. Historical data is second best to estimating data prepared as a result of work study, however in the absence of the latter, must be used despite its disadvantages. For it to be of real value, it is necessary however to have a history of the previous projects from which it has been derived in order to assess the affect on the cost of those projects of late materials, information or equipment, bad weather or strikes etc. The quantitative assessment of these factors is extremely difficult.

(c) For actual cost records for each work unit to be of value the booking of time to each work unit must be accurate. Cost numbers should be simple, as the workman himself is often the primary instrument of cost recording. Frequently cost records are derived from the same documents from which a man's pay is calculated, necessitating rapid handling from the shop floor to the accounting department, with consequently little time for checking of cost numbers. When this number must be correctly selected (and for each individual it may change frequently) and must then be accurately written, there are many opportunities for error. The larger the number and complexity of cost numbers, the greater the likelihood of these errors occurring.

(d) Many activities in a production programme can be considered complete for the purpose of logically permitting the start of subsequent activities in the programme or network, whilst not in actual fact being 100% complete in themselves. In these cases 'completed' work units may incur legitimate costs, although small, for some time after having been reported logically complete. This problem may perhaps be overcome by accepting these charges against subsequent activities if the principal of "work unit finished - cost number closed" is to be rigidly enforced.

ACHIEVING THE IDEAL

There is a great similarity in concept between the "group" for scheduling and the "work unit" for costing. It would be possible then to devise a system where, by application of a group system to all aspects of a project, the complete interrelationship of work definition, information and material to production programme and cost target could be achieved. Such a step would be a very bold one for a Shipyard to take, as it would require a substantial re-thinking of traditional methods of work authorisation, cost and progress reporting to achieve

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control of many thousands of individually costed tasks in place of the fairly flexible programme activity definitions and few hundred cost numbers used to date. It is considered that the success of such a system would necessitate complete work authorisation by production control work cards with pre-printed group/cost numbers enabling a system of feedback of actual costs against each group by filled in pre-printed cards entirely separated from the attendance manhour return used for the calculation of wages. This approach, when carefully applied, would also enable a progressive and continuous record of the ratio of productive and non-productive manhours to be maintained.

Such a system of production and cost control would necessitate extensive use of electronic data processing, and a large and highly trained planning, estimating and production control staff. Its cost effectiveness would need close examination before adoption for new ship construction. It would however, be less difficult to apply it to refit work.

PRACTICAL COST LISTS

In devising cost lists for use on shipbuilding and repair projects, the ultimate use to which resulting costing information will be put and the ease with which the cost list may be used in the yard must be considered. The ability of the yards costing procedures to cope with the task of accurate charging, estimate updating, and interpretation of data will largely dictate the degree of detail adopted.

For new ship construction there exists the difficult task of deciding to what extent to subdivide firstly the systems and secondly the processes involved. Division of the Cost List on a ship system basis directly relates the work units to physical jobs, and is a relatively straight forward operation. The establishment of time limited tasks can be achieved to some extent by division of these systems by part of ship - the size of the individual parts determined by the degree of detail required. A further division by function, for example, process for hull construction, and separation of shop work from work on the berth or afloat, can also be achieved.

Refit work has traditionally been costed on an equipment or system basis. The charging of all work for one particular equipment or system to one item number prevents a ready assessment of the comparative costs of planned maintenance, repair of defects, and modifications. Work of this nature does however lend itself to division into functional units within the basic system division. This approach has been adopted by Vickers Cockatoo for the costing of Submarine refits, and the system used is outlined below to illustrate this type of approach.

The cost list for an "O" class refit consists of approximately 1,000 cost numbers. Each number is made up of five digits; the first three being a system identification number, the fourth a function number, and the fifth an alphabetic check digit. The system identification number is a cross reference to the Planned Maintenance schedule and hence the work package. It is also used on Quality Control documentation, as part of an equipment identification numbering system, and for identification of spare gear within the dockyard. The function number may be as follows:

0 - A dockyard service item or an item for a system for which it is not desired to charge work to individual functions (used particularly when total system work content is small).

1 - Removal from Ship.

2 - Stripping, cleaning and dimensional inspection.

3 - Refit, repair, re-assembly and shop test.

4 - Replacement in ship and reconnection or re-establishment of system.

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5 - Testing and Trials onboard, Routine Maintenance after re-installation.

6 - Specific Alterations and Additions.

7 - Class Modifications.

This system is intended to have the following advantages.

(a) Each cost item can be related to the programme to a reasonable extent.

(b) As work completes on each function, item numbers can be closed enabling the finalisation of costs for that item. This suffers somewhat from the previously mentioned problem of precisely defining when work is 100% complete from the point of view of incurring legitimate charges.

(c) Charges on functions 1, 2, 4 and 5 should remain relatively constant from refit to refit enabling comparative repair costs to be assessed.

(d) The uniformity and logic of the system should assist its understanding and consequently decrease the possibility of incorrect charging. Whilst this is a definite advantage in practice the relationship of the cost number to equipment identification numbers has resulted in instances where the latter has been used as a cost number.

Figure 13 illustrates a typical section of a Submarine refit cost list prepared in this manner.

VICKERS COCKATOO DOCKYARD PTY. LIMITED **JOB Nº 3004**

H.M.A.S. OTWAY MAIN REFIT 1972-73

EQUIPMENT : MAIN GENERATOR AND MOTOR ROOM
EDP Nº : 064
P.M. SCHED. REF. : E214 **INSPECTION:** P.O.C.

COST HEADING	WORK DESCRIPTION
0911H	Remove as necessary for survey and access lockers, ladders, sections of cork insulation, floor plates and supporting structure.
0912L	Dismantle clean and gauge as required for survey bulkhead 103 watertight door and communication cock. Clean and scrape as necessary for survey bulkheads, flats, bilges, floor plates and supporting structure. Clean and survey lockers and ladders. Clean and examine for mould growth cork insulation.
0913P	Repair as per survey bulkhead 103 watertight door and communication cock, lockers, ladders, floor plates and supporting structure, bulkheads, flats, and bilges. Paint main generator and motor room.
0914A	Replace ladders, lockers, floor plates and supporting structure and sections of cork insulation. Reassemble bulkhead 103 watertight door and communication cock.
0915C	Check impression bulkhead 103 watertight door. Test main generator and motor room in accordance with trials agenda H2.
0917J	RAN "O" Class Modification No. 152 - W.T. door handles - manufacture and fit replacement handles as per drawing No. 246/332 sheet two. RAN "O" Class modification No. 610 - engine room floorplates - synthetic rubber compound to be applied to underside of deck plate in contact with supporting structure in accordance with Tech. Addenda No.3.

MONITORING AND REPORTING PROGRESS

Programmes and schedules produced for a project should progressively reflect actual progress in order that they may provide a valid representation of the means of achieving the target. To do this a regular and reliable feed-back of actual progress to the planning organisation is required. There are several ways by which this may be achieved; the method used will depend upon the place of planning within the yard's organisation and the types of planning system employed.

(1) Reporting of progress may be made by the production departments themselves. This may be by means of a routine report on work in progress or a more formalised report directly related to scheduled work units. This method may suffer from problems of fluctuating reliability caused by the work load of the production department restricting the amount of time available for reporting of progress, particularly as it will be required in all probability in two directions, to the functional departmental supervisor and to the planning department. It does have the advantage that the departments reporting are in a good position to know actual progress, however progress information may tend to be optimistic and the precision of reporting required by modern planning techniques may not always be satisfactory resulting in delays in the effective use of the information.

Production control techniques with fairly rigid documentation procedures for use within production shops normally incorporate automatic progress feedback facilities.

(2) Reporting of progress by progress chasers. This means is the most reliable, however there are again two alternative approaches. The progress chasers may be responsible to the production departments or to the planning department. The former have some of the disadvantages mentioned above, but as they will probably be required by the functional departmental supervisors in any case, their initiation of progress information makes good use of available resources. Chasers responsible to the planning department have the advantage of impartiality and familiarity with the programme in detail, however they must obtain their information from production departments and require their co-operation and acceptance. Reporting by this means may also tend to be pessimistic.

Information on actual progress will provide the means of reviewing the programme and providing management and the Navy with progress reports indicating the overall project status. It would be usual for such reporting to be carried out at monthly intervals. More frequent reporting presents problems with data handling and network updating in short periods of time with an increase in the likelihood of error, and is likely to be employed only on relatively small projects of short duration.

It is considered that progress reports provided to the Shipyard management and the Navy as the result of monthly progress reviews should be as concise as possible and should avoid large quantities of information which requires interpretation. In this context computer print-out is not ideally suitable as very frequently minor errors may appear in an update run which whilst readily understood by the planning department could be very misleading to others.

The use of milestones for project programmes as previously described, permits the use of a milestone reporting system which can present the information obtained on actual progress and its implications on the programme in a concise manner. Each month, a report can be given, listing the following:

(1) Those milestones achieved since the previous report;

(2) Those milestones scheduled for achievement but not achieved, together with reasons for non-achievement in two categories

(a) Where the delay will not necessarily affect the project completion date (i.e. the milestones have float)

(b) Where the delay is likely to affect the project completion date (i.e. the milestones are critical or near critical)

(3) Those significant milestones not yet scheduled to be achieved, which may be delayed as a result of progress to date, or for other reasons.

For each milestone, the planned, and actual or likely achievement dates would be specified. This method of reporting makes it very difficult for the true situation to be disguised, although it is possible of course that the likely dates may be over optimistic.

At various levels within the Shipyard or dockyard management more detailed reports will be required. The system should be so designed that these reports are produced as a matter of routine, and accordingly it is desirable that some care be taken to ensure that the reports produced suit the requirements of the users. Most important amongst these reports are actual and likely dates for issue of drawings and specifications and the availability of materials. In this respect the Navy has a responsibility to not only expect due reports from the Shipyard but to report to the Shipyard progress on those aspects of the project under Navy control. Statistical reports similar to figure

9 are also useful to indicate trends and can provide back up information to the milestone report.

PROGRESS MEETINGS

The progress meeting is the medium by which many problems can be resolved by the simple expedient of bringing all the principal parties concerned face to face. In this manner, they can constitute a useful means of assisting control of projects. They can, however, tend to become a burden upon the Shipyard and Navy staffs and can fail to achieve their purpose unless carefully controlled.

Short informal daily meetings on the job can be very useful as a means of ironing out day to day problems, but formal meetings can absorb many valuable managerial manhours. This is particularly so when many projects are running concurrently. Meetings which are held at too short an interval tend to become sessions at which matters which should be dealt with on a day to day basis are raised, with consequent delays and frustration of the real purpose of the meeting. Also, they frequently become involved in assessing what has actually happened rather than deciding the course of future actions.

It is considered that the following criteria should be applied to progress meetings.

(a) For major projects, formal progress meetings should not be held more frequently than once a month. Should a higher frequency prove necessary then it is likely that normal communications have broken down and the project has degenerated to management by crisis.

(b) The meetings should be conducted to a formal Agenda, known well in advance to all those attending. The Chairman bears a substantial responsibility to ensure that the meeting proceeds to this Agenda and does not become involved in trivia. The Agenda should not be too broad so that the Chairman can reasonably expect representatives attending to have specific contributions ready for the meeting.

(c) Representation at formal progress meetings should not be too diverse. Large attendance inevitably means a small individual contribution with consequent waste of valuable time. Each authority represented ideally should have one spokesman, adequately prepared to discuss the matters on the agenda. He should have adequate authority to make the decisions which may reasonably be expected to be made at such a meeting. He may bring others to the meeting for support on specific matters or for observation, however they should be kept to a minimum.

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(d) When progress is discussed, it should be considered in relation to the programme. The programme exists partly for this purpose and by so doing its use as a day to day control document is greatly encouraged.

(e) Minutes of meetings should be promptly distributed. They are a useful reminder to those responsible to take action following the meeting. Regretably experience has shown too often that some action is frequently not taken until the individual responsible is studying the minutes he has just received on the eve of the next meeting.

CONFIGURATION CONTROL

Many of the problems experienced with Naval projects stem from less than adequate Configuration Control. These problems are particularly severe with complex projects such as submarine refits where large quantities of data are used for reference for the determination of refitting standards and the ordering or manufacture of spare parts.

Configuration Control is a process which must be commenced during design and construction. Its basic purpose is to define ships and the equipment fitted in them accurately, so that after they are built they may be operated and maintained in an efficient manner. The process is concerned with two forms of ship definition.

(a) Hardware definition. This involves the definition of the ship and the equipments and systems in that ship, and how these equipments and systems are installed. This definition is in terms of equipment drawing numbers, reference or serial numbers, modification state, etc.

(b) Documentation definition. This definition is in terms of technical documentation, Books of Reference, handbooks, test specifications, Parts Identification and Equipment Lists, as applicable to the equipments and systems fitted in the ship.

Basically, there is nothing new in Configuration Control. Experience has shown however that it has not been efficiently applied in the past, as manifested by inabilities to obtain information, problems associated with the identification and demanding of spare parts, with the consequent disruption to refitting schedules and increased refit cost. "As Fitted" drawings are found to be "As Might have been Fitted" drawings, and spares ordered from Parts Identification Lists turn out to be the wrong size or a different item altogether.

Modern Configuration Control procedures to establish a complete ship definition during construction must increase to some extent the first cost of the ship. The reduced difficulties experienced during refit should amply repay these costs, however the ship definition must be kept up to date. This is the responsibility of both the Navy and the Dockyards. The Navy must ensure that all documentation held by all authorities is amended as necessary sufficiently promptly to ensure that it can be used with confidence. Similarly the Dockyards must ensure that the effects of alterations and additions and class modifications are fed back into the system.

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CHANGE CONTROL

During the course of a project, changes are likely to be made to the content of the work package. These changes, which may in many cases be minor in themselves, can have a substantial effect on the cost of the project or its time for completion. They may result from

(a) Changes to the requirements, specifications or drawings constituting the original work package supplied to the Shipyard or Dockyard.

(b) Modifications to drawings which have been submitted for approval.

(c) Modifications to approved compartment layouts or system designs in order to make an arrangement or system workable.

(d) Departures made at the ship from approved drawings.

(e) Requests for modifications or extras by Overseers, Ship's staff or Trials Teams during the course of the project or at time of Trials.

(f) In refit, additional work or "growth" on existing items in the Work Package.

(g) Proposals by the Shipyard or Dockyard which could improve the suitability of an arrangement or system or which may result in cost benefits.

In each case the change may require modifications to drawings or re-work of manufactured components or onboard installations with consequent cost and time penalties. The acceptance and implementation of these changes must be closely controlled in order that the project is not overburdened by modification work and to ensure that no additional work is undertaken without suitable contractual coverage.

Change Control should not be considered to be a part time job for any individual or department. If so treated, it is likely that many changes will pass unnoticed. It is particularly difficult to control changes which may be implemented at the work face in either the Drawing Offices or in the yard as a result of person-to-person discussion between the parties involved either on site or by telephone. In these instances there is likely to be no record of reason for or source of the change and consequently little chance for adequate financial or programme adjustment. Education of all persons involved in the project to understand the need for Change Control is essential, particularly for Naval projects where the Yard is frequently used to giving the customer what he wants rather than only that for which he has specifically asked.

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Good definition of the task in the Work Package is basic starting point for an effective change control procedure. Work packages containing such expressions as "generally in accordance with", "as necessary", "as required", "as may be directed", "to the satisfaction of" prevent precise definition of changes with the consequent difficulty of obtaining approval for extra cost or delays.

Ideally, no change should be implemented until it has been approved as an extra (or perhaps even a reduction in price) following a thorough investigation of its implication in respect to drawings, re-work, materials and programme delay or disruption. In many cases however changes will be mandatory or suspension of work whilst awaiting approval could be more costly or disruptive than the change itself. In these cases, machinery should be established for rapid local approval.

PROJECT CONTROL WITHIN THE SHIPYARD ORGANISATION

Project Control is the task of every person within the Shipyard or Dockyard, to a degree which is dependent on their position within the organisation. There is usually however a Planning Department which is responsible for defining the goals and monitoring progress. The position this Department will occupy within the yard's organisation will vary depending on the size of the yard and the nature of its management structure. It can be argued that planning should form part of the Production organisation in order that the greatest benefits can be gained as a result of direct involvement in the task. This approach does however threaten one of the essential features of a planning organisation, which is vitally necessary if it is to fully perform its task, namely neutrality. This problem may be overcome by placing the planning department within the Technical organisation, or alternatively on its own as a separate Planning Division. This latter approach, more feasible in very large organisations, may be desirable when it is realised that the Technical Departments are in themselves production departments for an essential and controlling aspect of any project, the preparation of information and the purchasing of material and equipment. When this latter approach is adopted, it is usually desirable for the Production control aspects of planning as distinct from Project planning to be the responsibility of departments within the Technical and Production divisions.

It must be emphasised that the establishment of an organisation and the implementation of various systems for the control of the various activities of the yard do not in themselves guarantee satisfactory Project Control. This will only be achieved if these facilities are correctly used, and this is dependent on several factors.

(1) The degree to which Top Management support, use and trust the Project Control organisation. This management backing must not only exist, but be seen to exist.

(2) The skills and experience of Planning, progressing, costing and production control departments' personnel. The persons responsible for setting the target and monitoring progress must have adequate training and suitable experience in order that production and technical departments will have confidence in their ability.

(3) The degree to which the systems being employed are defined and understood by all who have an involvement in their use. This is a function of firstly, good systems design, and secondly, training. Systems which depend for

their success on the discipline of their application must not be introduced until all details of their operation have been well defined and all users understand fully their method of operation, and perhaps most important of all, what the system is intended to achieve.

(4) The efficiency of the supporting services within the yard. These services will be used by many departments within the organisation and Project and Production control departments should not be treated as second priority. These services include a rapid and efficient computer service and good internal communications, both of which are essential for systems handling information which becomes rapidly out of date and hence useless if excessively delayed. Delays in these services can also result in significant delays to production.

CONCLUSIONS

Project Control in Naval Shipbuilding and repair is a Management process using a series of related but basically separate management information and control systems and techniques. These systems and techniques have been developed to assist a number of functions.

(a) Forward planning.
(b) Task Definition
(c) Project planning and scheduling
(d) Production control
(e) Cost control and recording
(f) Control of Changes
(g) Configuration Control and Information Management
(h) Material Control.

In many instances, much work has been done to develop these systems and techniques and to apply them, both within the industry as a whole and in individual yards. However, the systems and techniques in reality form part of what should be an integrated management information and control system designed to provide managers with the information they need to enable them to effectively use their time as managers of the human and physical resources of the industry. In this respect the Shipbuilding and repair industry may be said to lag behind other industries. This criticism is often countered by the remark that the industry is different from all others, has special problems, requires unique skills, and requires different methods of management. Whilst this is to some extent true, it may be that the industry is in reality somewhat isolated from experience in and the development of other industries. Such an isolation would tend to encourage a traditional approach to management problems in a world of rapidly changing technology, and when this isolation is coupled with a situation where management is so busy coping with the immediate problems of the present that they can spare little time to consider the approach to problems of the future, the development of modern management systems to effectively handle the complexities of the particular industry is likely to be slow. Development of such systems also requires money, which in this industry particularly, is not readily forthcoming. Available finance has usually been directed to capital investment in plant and machinery. Whilst this has been essential, it is considered desirable that a similar boost be given to investment in the management of the industry. The amount of money involved would probably seem insignificant when compared to the potential gains.

In closing, one factor must be kept foremost in mind when considering or developing any form of system to assist management in project control. The industry is a human enterprise whose prime

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purpose is the efficient construction and repair of ships. Accordingly systems should function to assist management in their task, and should never be allowed to become a controlling factor in themselves.

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