THE NEW ENGINEERING MANAGEMENT COURSE AT R.N.E.C.

BY

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Since the summer term in 1973, lieutenants of all three engineering sub-specializations have been returning to the R.N. Engineering College, Manadon, to study on the new course in engineering management. This is an entirely fresh course which has been designed to prepare general list engineer officers for the management tasks which they will undertake in the middle phase of their service careers. This article sets out to explain the need for the course and something of how the course is educating officers for their management roles.

THE NAVY NEEDS EFFECTIVE MANAGERS

As the resources available to the Navy are strictly limited, effective management at every level is essential if the best value in terms of maritime defence is to be obtained. To appreciate something of what this means, the Navy must be seen as an overall system working to attain its purposes.

In essence, the Navy's purpose is to carry out its maritime defence tasks using the Fleet. In the total system, the Fleet must be sustained firstly by a continuous supply of trained manpower from the shore training establishments; secondly by the material support in the form of logistic supplies and upkeep; and thirdly by a continuous flow of new ships, new aircraft and new equipments maintaining its fighting capabilities up to date. In turn, the support and procurement activities depend on a strong industrial base in

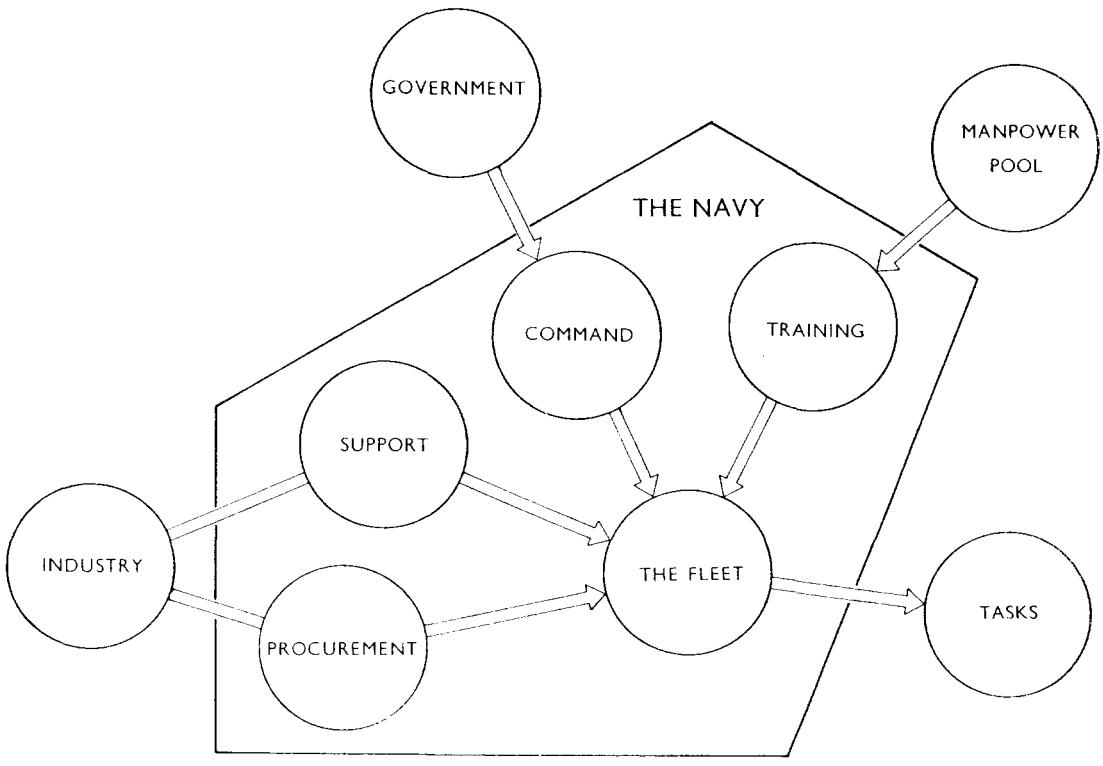


FIG. 1

this country and, to an increasing extent, in Western Europe; whilst manpower comes from the labour available to the nation. Both these elements outside the Navy are part of the country's economic system. It is the total sum of all the activities implied in this system which must be properly managed if the Navy is to continue to be able to perform its tasks effectively in future years.

Engineer officers become involved with managing the detailed business of the Service's engineering systems during the middle phase of their careers—which extends from, say, the rank of senior lieutenant to that of junior commander. The appointments filled by lieutenant-commanders are typical of the range of jobs done during this period. An analysis done early in 1973 showed that for every seven GL lieutenant-commanders of the engineering specialization two were serving at sea, three in support and procurement, one in training and one in a range of miscellaneous other jobs. Thus, five out of seven engineer officers were involved with management tasks directly associated with ships or aircraft, their support or their procurement.

Some sixty per cent. of the Navy's share of the total Defence Budget is spent on support and procurement. This fact coupled with the employment pattern already sketched indicates the vital necessity for engineers to understand how to achieve the effective management of men and other resources which the continued success of the Service demands. This also underlines the view that a major challenge in management lies in the support and procurement fields.

THE MANAGEMENT TASKS

An objective course should be derived from an analysis of the needs embodied in a job description. With the wide range of jobs open to an officer during his middle career, there is no single job description. However, typical jobs have been selected and placed in groups having similar management functions. Thus it has been possible to draw up an agreed set of 'management task descriptions' which describe the management aspects of each of the following groups of jobs:

(*a*) Head of an Engineering Department in a small ship, or Squadron Air Engineer Officer.
(*b*) Section Officer within the Procurement Executive.
(*c*) A Dockyard or Aircraft Repair Yard Officer.
(*d*) An officer on the staff of a Port Admiral, Flag Officer or Commander-in-Chief.

The themes running through these task descriptions are typified by the following examples blended from more than one group:

(*a*) Organizing a department, including specification of tasks, authority, accountability and limits of discretion.
(*b*) Controlling an authorized programme of work through either service or civilian organizations to given quality standards, to time within specified limits of resources and money.
(*c*) Co-ordination of the activities of his own department with those of other departments, service or civilian organizations, through consultations, meetings, correspondence and contracts to achieve selected goals.
(*d*) Control of work through budgetary and other financial procedures.
(*e*) Advising on upkeep, support and logistic matters to sustain availability of fleet capabilities.
(*f*) Development and training of subordinates.

These various activities are remarkably well summed up by that service definition which describes management as:

'Getting things done through people in an organization.'

An over simple definition perhaps, but one which has the virtues of being easily remembered and reminding us that the essential elements in any enterprise are:

People—Organizations—Tasks—Resources

ARE ENGINEERS EQUIPPED FOR MANAGEMENT?

The activities outlined above show that a wide range of knowledge is required by officers—a range that extends well beyond the basic concepts of systematic management itself. So it would be well to ask how well basic engineering education prepares officers for these activities. This problem also exists in the world at large, where views in answer to this question differ (as widely as they may inside the Service) extending from:

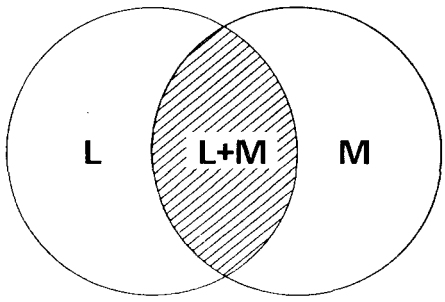
> 'Engineers have all the basic training they need for management . . . analytical and quantitative thinking, control of detail, the ability to compromise and get the job done.'

to:

> 'Take away an engineer's slide-rule, his test equipment and his proven formulae, and you take away his competence. An engineer has a passion for exact answers and unequivocal solutions . . . which ill equips him to deal with ambiguous issues, uncertain information and the subjective unpredictable tangle of human emotions that most managers inherit.'

There is more than a grain of truth in both these views. The nature of engineering education, which is concerned with the application of scientific law in explanation of how things work, is reflected in the first thought. The capacity for systematic thought inculcated in this education is clearly an asset to the manager in many activities—for example planning projects. The second thought, however, reflects the fact that the deterministic approach which is so much part of this education requires to be tempered with an understanding of how uncertainty and variety can be accounted for in scientific ways.

The second quotation also underlines the need for an understanding of human nature. Although this subject does not figure in an engineering degree, the general naval training given to all officers lays stress on the leading of people and points officers to the qualities required in successful leadership. While not everyone would distinguish between leadership and management, there are aspects of each which are not common to the other. Their relationship can best be expressed diagrammatically, thus:



LEADERSHIP — MANAGEMENT

FIG. 2—LEADERSHIP AND MANAGEMENT

Although general naval training and early experience should have brought an officer to some basic understanding of sailors, there is a great deal more that he needs to know if he is to be fully effective in his mid career. So, whilst his initial education in this area has been sufficient for his early needs, it is not enough for all time.

Engineer officers also benefit from the mid career education offered on the Lieutenants' Greenwich Course and the Naval Staff Course. However, each of these excellent courses are directed towards the management of the Navy's operational tasks and neither covers the ground of material management in the depth required by engineers. The Engineering Management Course is really complementary to these two courses which lay stress on other characteristics and qualities that are wholly relevant to the complete naval officer. For this reason, officers are currently being appointed to do the LGC and the EMC sequentially at the same period of their career.

THE DEVELOPMENT OF THE COURSE

Management is not a new field for the R.N. Engineering College, as those who studied the subject in order to qualify for membership of the Institution of Mechanical Engineers may recall. In 1968, due to the shortage of sea-training billets for marine engineers in the Fleet, a sea-training phase was introduced into the ME Application Course. To make time for this period spent in the sea-training ship, the subject 'Management and Economics' was dropped from the course.

This was a good development as officers were much more interested in getting to sea and doing some *real* engineering than they were in extending their time in the College studying a subject which did not appear to be immediately useful. A management course given later in their careers would be more relevant and also provide the opportunity for all three engineering sub-specializations to partake. Furthermore, experience gained in two or three junior appointments would provide a sound foundation on which further education could build. Thus, approval was given in 1969 for the College to run a career course in management for senior lieutenants who had graduated in 1968 or later years.

Outside the Service, management education is usually given through a series of short courses as a man's career develops. Such a scheme, however desirable, does not fit with the naval appointing system. A single course has the advantage of being able to present an integrated view of material management. In preparing the initial ideas for the course, the College consulted all the Service authorities employing engineer officers in order to establish a list of topics for which there was a wide demand.

In 1972, the Management Studies Section was set up, staffed by a Lieutenant-Commander E (ME), a Lieutenant E (WE) and an Instructor Lieutenant. The former two had each just completed a post-graduate year on management, one at Manchester and the other at Southampton University; and the latter had graduated in industrial economics, undertaken further management studies and gone on to work in industry for several years. This inter-disciplinary staff worked closely together to develop an integrated approach to the course, pruning and developing the initial syllabus ideas.

In May 1973, the first Engineering Management Course started. Since then, between 15 and 25 students have been on each of the successive $12\frac{1}{2}$-week courses which have been run each term. The course has been of interest to others: two project engineers from Vickers Ltd., and one foreign officer have attended courses during 1974.

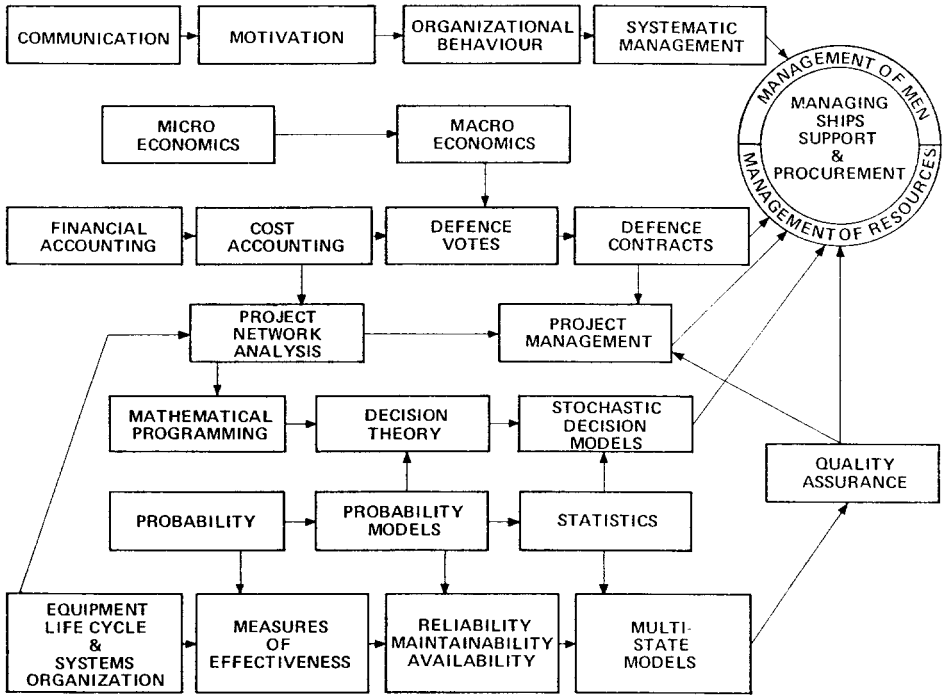


FIG. 3—BREAKDOWN OF THE COURSE

THE CURRICULUM

The purpose of the course is to provide an education and not to give instruction on specific administrative procedures. Thus, the course aims:

> 'To ground engineer officers in modern teachings and techniques of management so that in subsequent appointments they can develop their own managerial skills quickly.'

The curriculum is divided into five main subjects, each taken by an individual member of the staff with the support of other sections:

Personnel and Management
Operational Studies
Systems Behaviour and Quality Assurance
Probability and Statistics
Financial Control and Economics.

These subjects are related to the elements of management referred to earlier thus: 'people and organizations' are dealt with in the first subject, the 'task' is considered in the middle three, the 'resources' are covered by the last. A more detailed breakdown of the course into individual topics is shown in FIG 3, which illustrates some of the links between the sections in the integrated view of material management. This subdivision does not attempt to show the time devoted to each topic, so the individual headings do not carry equal weighting as far as time is concerned.

In the succeeding paragraphs, this article gives something of the flavour of the course without cataloguing every topic in the syllabus.

Personnel and Management

This key subject, taken by the Head of the Management Studies section, aims to promote a deeper understanding of the many human factors which affect management in either the Service or an industrial environment. From this foundation, the principles of systematic management are elucidated. The

subject is divided into four sections, namely: communication, motivation, organizational behaviour, and development of a management system.

Communication

The problem of communication is one that is easy to demonstrate to people, and it therefore makes a good introduction to the subject of personnel. It is obvious that good communications between everyone concerned in any enterprise is an essential requirement for success, but the problem is that all too often these communications either do not exist or they have, for one reason or another, broken down. Officers study for themselves the factors which lead to communication blocks or which inhibit creative thinking when fresh ideas are needed. They go on to suggest ways in which good links between individuals or groups can with care be promoted.

The concepts of communication are extended when officers study the key points to be observed in the organization and conducting of meetings. They participate in simulated meetings of different types and learn how to ensure that the meeting achieves the particular sort of purpose for which it was called.

Motivation

Motivation is another essential requirement in the success of an enterprise. Well-motivated people work willingly and take a pride in a job well done. The various factors in motivation are discussed in lectures and tutorial groups and the development of current theories is considered. No particular theory is advocated exclusively as there is no absolute strategy which has universal application or permanence in any one situation. Officers are encouraged to relate these theories to their own experiences and to develop an awareness of their relevance to their future work.

Job enrichment, for example, is a topic which is discussed within this section. A short case study examines the problem of motivation for people who have monotonous and dirty jobs in which there is little intrinsic satisfaction. Ways of making jobs more worthwhile for people are discussed in tutorial groups. More money for the job or more time off are popular panaceas offered by students. The many other things to which people will respond and ways of using these factors are discussed.

Organizational Behaviour

The natural reactions and behaviour of people when working together in groups often leads to problems if their needs are not recognized and remedial measures are not taken. The course traces the growth of an industrial enterprise from the one-man-band stage through the intermediate stages in which simple structured organizations become necessary to the final stage in which complex structures are employed. The aspirations, fears and loyalties typically possessed by people in any organization can be readily seen by studying their reactions within an expanding enterprise of this nature. The relationships between a manager and his subordinates, his superiors and peers are considered.

Several typical problems are discussed in this section. For example a contrast is drawn between managing to maintain an existing situation and managing to achieve change. Whilst the steps in the former can usefully be compared to those in a feedback control system, the latter calls for careful appraisal of the strategy to be adopted. The natural resistance to change must be overcome; the co-operation of those who are in a position to block change must be won—patience, persuasion and tact are needed.

Development of a Management System

This section aims to bring the many ingredients of an effective management system into a clear focus. The key principles—clarity of purpose, economy of effort, delegation of authority, and motivation—are shown to be common to all systems in vogue today. Systematic management exists when all the parts necessary for success in any enterprise are there by the conscious intent of management and not simply due to chance. The main emphasis is placed on explaining 'Systematic Management', but the Louis Allen system, which has been adopted within the Dockyards, and Management-by-Objectives are also discussed.

At a more detailed level, this section touches upon several matters which have not arisen previously, such as: terms or reference and managerial guides, job appraisal interviews, and uniformed and civilian staff reporting procedures.

The Task

The purpose of management is to get things done—the 'task'. Planning, allocating resources, and controlling are some of the activities concerned. Although many of the abilities required are better acquired by experience, the clear thinking and analytical powers needed can be extended more effectively through further education.

Work study, which has been in use for a long time, teaches the basic questions which must be asked about any job:

What is to be done?
How is it to be done?
By whom is it to be done?

But the more difficult problems associated with the whole life cycle of naval ships and equipments do not always yield to simple questioning; more powerful techniques of analysis are needed. There are many methods of modelling the complex situations which face managers to render clear options as a basis for decisions. Although decisions based upon subjective assessment or rules of thumb are easier to make, the underlying assumptions are often obscure so that the full implications of the decision may not be recognized in time to forestall further difficulties. A more thorough analysis may generate more options so making decision less easy; but the pay-off lies in the deeper understanding of the situation that results. Thus, the manager is better equipped to plan fully for the implications of any decision he makes.

Operational studies, system behaviour, and the supporting subject of probability and statistics combine to give an officer a grasp of the powerful methods of analysis and modelling which are available. They encourage a 'systems' approach in which the requirements are deduced from an analysis of the objective—an approach which focuses the attention on the 'ends' and not the 'means'. They help in developing the ability for methodical analysis and synthesis. Specific techniques are taught in some detail to enable officers to acquire a grasp of the principles for themselves and to achieve a degree of numeracy in the areas concerned. The course is not trying to turn out 'technicians'; its educational aims would not be achieved, however, by a short and superficial survey of these fields. This is important as the length of the course stems from this policy.

Operational Studies

Operational Studies is the name given within the Ministry of Defence to what is more widely known as Operational Research (OR). OR developed rapidly during World War II as scientific methods were employed to solve

many operational problems—hence its name. Today it is widely used outside the Services to enable managerial, organizational, or man/machine situations to be represented in ways that are amenable to logical and quantitative analysis. It is often considered as a set of mathematical techniques of interest only to the deep specialist; but this overlooks two points. Firstly, they are not esoteric techniques but merely extensions of the scientific methods already familiar to engineers. Secondly, there is great value in understanding the powerful conceptual models which result from applying scientific methods to problems not governed by physical laws. In addition to this educational value, a knowledge of OR will enable an engineer to recognize the potential of the OR specialist to help solve complex problems and so to work in closer partnership with this specialist.

Operational studies include:

(*a*) *Project Network Analysis (PNA)*

PNA is used as the introduction to this section because it is both readily understood and exemplifies many of the principles of problem solving. Not every officer has met PNA before, but a quick review of the techniques employed provides him with an adequate grasp. These are applied in a three-day case study in which a hypothetical development project is planned and controlled using a computer-based network. The use of PNA, whether it is in support of a ship's refit or a development project, gives rise to a number of difficulties. The case study illustrates such problems as activity times (which are no more than best guesses); the difficulty of obtaining accurate and up-to-date information on progress; and the question of how to correlate actual progress with that obtained from cost and expenditure data. The case study also provides a vehicle for introducing the Downey procedures for costing and controlling development projects in the procurement field.

(*b*) *Linear Programming*

Mathematically speaking, linear programming is simply an algebraic method of solving a set of linear inequalities—equations in which one side can only be expressed as being 'less than or equal to' the other side. Educationally, however, the interest lies in the logic of formulating the equations rather than the techniques of their solution. In developing an understanding of how a certain type of problem can be modelled by such equations, many of the essential elements of scientific problem-solving are exemplified. Stating objectives; selecting criteria; identifying constraints; distinguishing between controllable factors and ones which are not; analysing the sensitivity of solutions to the variables—all emerge in association with linear programming problems.

One of the linear programming case studies investigates the selection of the site for a new industrial plant for blending fuel. The exercise requires the problem to be formulated in terms of different fuel blends and operating costs. The resulting equations are solved on the computer using a packaged programme. This enables the sensitivity of the solution to the variables to be explored easily. In doing this, officers find that they have acquired a considerable insight into the real problem. Factors have emerged which are found to have an important bearing on the best solution; factors which would not have been recognized by a qualitative analysis.

(*c*) *Decision Theory*

Managers are expected to make decisions about the future; and decisions imply choice. Decision theory attempts to show the underly-

ing structures and strategies of various decision problems. It introduces ways of handling methodically the uncertainty and risk. While the use of such models does not necessarily ensure a better decision, it does, for instance, enable the manager to check the subjective estimates which people unconsciously build into their thinking about the future.

(*d*) *Simulations*

The provision of a service to a customer, using limited resources, when the demand for the service is outside the provider's control is one of the more difficult problems facing managers. Everyone has experienced the frustration of finding all the telephone lines engaged, or has been stymied when that urgently required spare part is not available in the ship's stores. The basic elements of the overall problem are described in terms of *queueing* and *inventory* theory in which mathematical analysis yields simple models.

However, the total problem, of which specific services or individual stores are only elements, usually requires to be modelled by a simulation technique. Discrete event simulation is used to provide an understanding of simulation and to illustrate the strengths and weaknesses of the process. Mathematical models generate answers from single values given to each of the variables. Such models are quite satisfactory when little variation is expected from the selected value of each parameter. However, in cases where there is a wider distribution of values, answers based on averages may be misleading. Simulation models enable actual or predicted distributions to be taken into account and may yield answers in the form of probabilities. However plausible a model may appear, it may have overlooked a significant factor. In all modelling—and rules of thumb are simple models—the results of the model must be validated before too much reliance is placed in them.

Systems Behaviour

The 'Systems Behaviour' section of the course is primarily concerned with the concepts and practical implications of modelling the behaviour of engineering systems in terms of reliability, availability, effectiveness and similar indices of performance.

Reliability theory is often discarded as having no practical use because little confidence can be placed in performance predictions based on limited data. Both in the early design stages and in post-design work, however, there is a great deal of value to be gained by the systematic analysis of system behaviour inculcated by the process of defining reliability and similar indices of performance. Furthermore, a more meaningful dialogue between the operator and the designer results when the behaviour of the system is quantified and the implications of the numbers are understood.

To quantify these concepts, the engineer is forced once again to think clearly about the real objectives for which the system is built. He has to start by defining what constitutes *success* and *failure* in each context. He is forced to face up to the implications of failure and to devise means of minimizing their adverse effects. Most engineers are familiar with such terms as 'mean time between failures' and 'mean time to repair', but they also need to be conversant with the statistical implications of the data from which any quantitative values have been derived, and which are vital to their proper interpretation.

Inevitably the absolute value of the quantitative measures depends upon the quality of the data in the analysis. Here, the topic of 'Management Information' systems is introduced to highlight the principles beginning to

emerge from the work that has been going on in the Ship Maintenance Authority and the Ship Upkeep Information Centre. This is another area in which there are few, if any, black and white answers and engineers must learn to make good use of the information that is available. The Ship Maintenance Authority's 'Reliability/Maintainability/Logistics' system affords a good working example of how the ideas of system behaviour are being deployed to advantage in actual practice.

Quality Assurance

Today *quality assurance* is far more than a set of statistical techniques or shop floor tests. It is a management system in its own right, affecting every department of a firm from the drawing office to the after-sales service. So *quality assurance* is a very good example of *systematic management* calling for well-defined procedures, strict discipline and a high standard of mutual understanding and confidence between the parties concerned. The range of activities necessary in such a system is derived, and the way these are embodied in the new Defence Quality Assurance System is studied. These are illustrated by looking at the organization in any typical naval shipbuilding yard.

Quality assurance contains principles and concepts which have a wider application than production engineering, and officers are encouraged to view conventional Service procedures such as 'rounds' or 'staff inspections' as part of quality assurance in the fleet. So this subject is food for thought for those officers who may not become directly involved with industry.

Probability and Statistics

Both the 'Operational Studies' and the 'Systems Behaviour' sections of the course apply the 'Probability and Statistics' provided by the Mathematics section. This part of the course is a fairly intensive 36 periods on the subject, starting with a revision of the basic ideas and moving on to deal with more advanced methods such as the analysis of variance, and also such matters as the use of probability papers and ranking procedures for data analysis.

Resources

No enterprise can exist without the basic resources of which money is an essential one in all cases. In this final subject, economics and financial control are studied.

Economics

Naval engineering has large interfaces with industry and engineers should, therefore, be familiar with the economic system in which both the Service and industry have to work. The military problem is one in which limited quantities of men, ships, weapons, bases and support facilities have to be combined to produce an effective defence force that will provide a credible deterrent against attack. This is just as much an economic problem as, say, combining limited quantities of coke, iron ore, blast furnaces and mill facilities to produce the maximum profit from steel production. Economics is relevant!

The subject is divided into microeconomics—studying the actions of individuals and groups—and macroeconomics—studying the national aggregates in such terms as total employment and gross national product. The first explains how industrial firms operate and business decisions are influenced by economic considerations. The second discusses the factors affecting Government policies and the national budget and, in particular, the defence budget.

Financial Control

Naval officers must be *au fait* with accountants' procedures and terminology as they become more involved with accountability for the money they are spending. A working knowledge of financial and cost control procedures is needed. The accountancy taught includes both financial accounting—that is the study of money accounts compiled historically, the balance sheet—and cost accounting—the calculation and comparison of real costs for control and decision making purposes: combined, these form management accountancy. These studies should enable officers to understand and use accounts and to participate in cost accounting and control work. He should not only be capable of defending his work on its technical merits but also be capable of deploying financial arguments in its support.

THE PROGRAMME

If this summary makes the subject matter appear a little heavy, it should be remembered that it is spread over $12\frac{1}{2}$ weeks, and this gives students sufficient time to acquire a good grasp of the overall field. There is plenty of variety in the course; each week is separately programmed. As far as possible, mornings are given to lectures and example periods where needed, and afternoons are given to tutorial group discussions, case-studies and private studies. On several occasions, whole days are given to particular case-studies in which continuity of thought is important. During the term, a number of eminent people from various Service authorities, from industry, and from universities are invited to talk to the course about their work. These lectures give the students a broader view of the Navy as well as helping them to see the relevance of the subjects being studied.

Ideally, students should study management in a fully participative course in which they read the subject for themselves, learn experience from case-studies and clear their thoughts in group discussions with both staff and other students. However, a course of such a nature requires a great deal of staff design work if it is to succeed; it also assumes a highly-motivated student! Regrettably, the staff effort to prepare the case-studies, direct the discussion groups and monitor the students progress is insufficient to approach this ideal. Nevertheless, each successive course has increased the degree of student participation. With time and experience, case-studies are being refined and improved. Each course has given a number of very constructive ideas on detailed improvements which have been incorporated wherever possible.

A long-term aim is to build up a series of case-studies set in a naval scenario and pertinent to the tasks officers are likely to perform. Because it is often difficult to wean people from their preconceived ideas when set problems in familiar settings, not all the case-studies should be service orientated. The non-service setting encourages an open-minded approach. Students often find them more interesting and challenging and thus gain more from them.

Students prepare essays or papers on certain aspects of their work and this enables them to practise service writing. Several project schemes are being introduced which will encourage students to do further reading, to delve in the library, and also to go out on field work in search of information or data to a limited extent. These schemes are aimed at getting groups of officers to think through some management problems in greater depth among themselves, and to present their answers to the rest of the course. In this way they will acquire a deeper understanding of what management is about.

CONCLUSION

The start of the Engineering Management Course has been an exciting adventure in education. As it is aiming at extending the capacity for management in the long run, it is far too early yet to judge its success. So far, initial reports have been encouraging; officers, after a few months in a subsequent appointment, have been finding that they have learnt far more than they had realized at first. The course has much to offer to all who will be engaged in the management of the Navy's tail. As the course continues to develop, it is believed that it will be seen to be making a valuable contribution to the quality of naval management.

Acknowledgements

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