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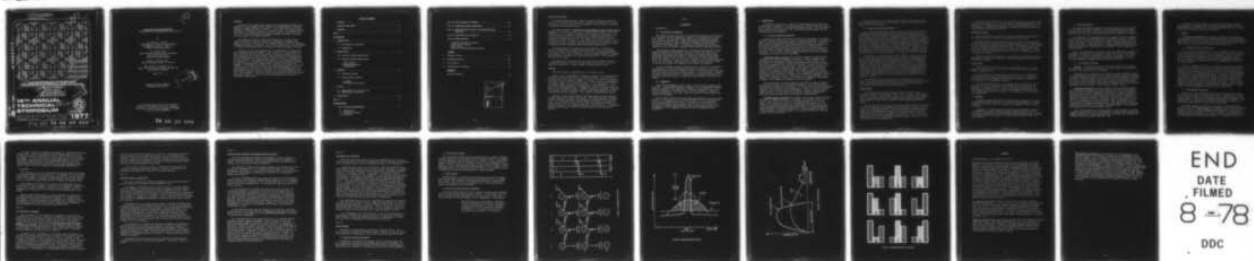
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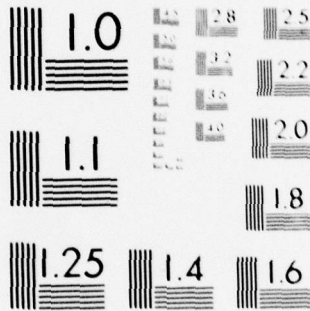
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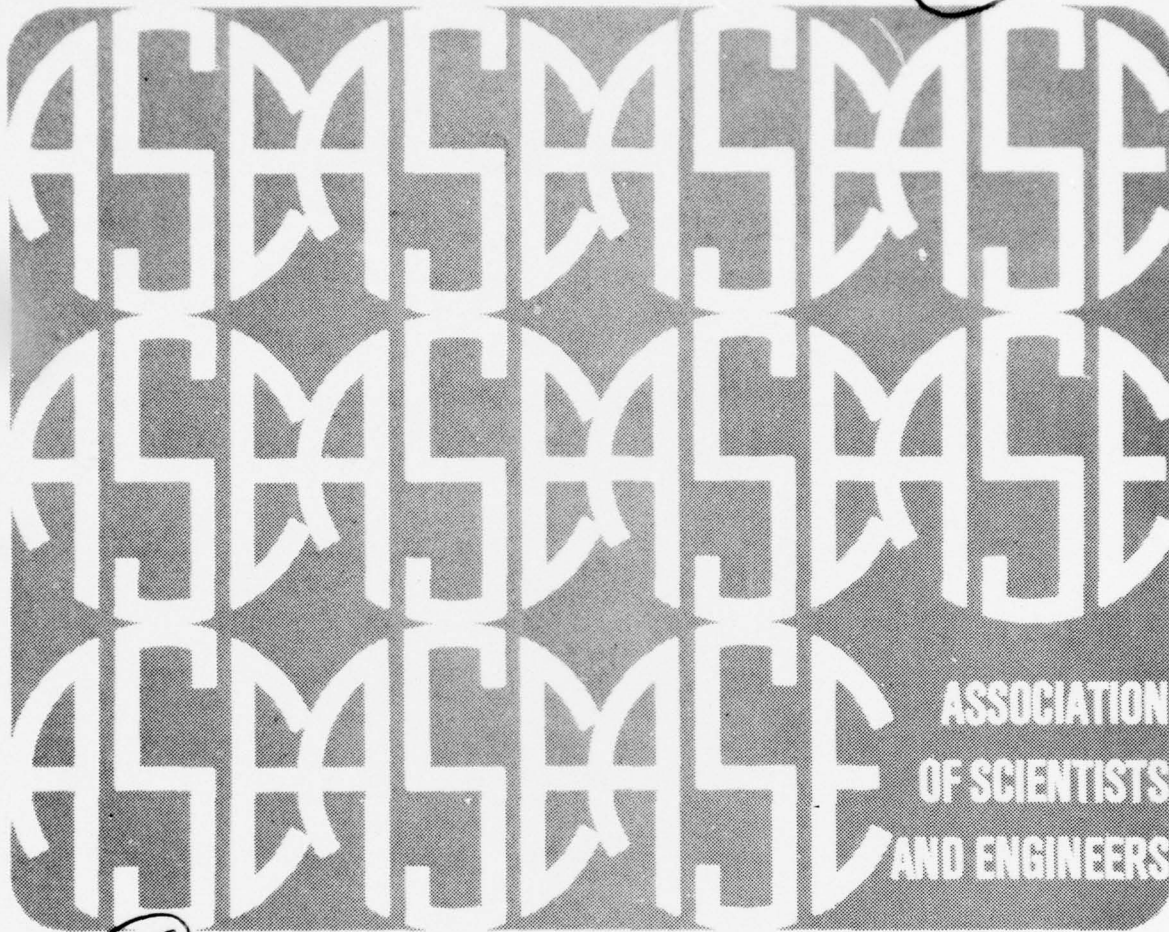


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6 IS ENGINEERING EDUCATION ENOUGH?
(THE PROBLEM OF INTERDISCIPLINARY EDUCATION)

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IS ENGINEERING EDUCATION ENOUGH?
(The problem of interdisciplinary education) ✓

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March 1977 ✓

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ABSTRACT

The paper lists observations related to the requirements imposed upon managers of large programs, where frequently an understanding of technical, legal and economic problems is expected. It has often been observed that problems of communication exist in two distinct areas: (a) between different disciplines, for example, engineers and lawyers and (b) between different levels of the same discipline, for example, between the theoretician and the practitioner of the same discipline.

The causes for these two observed problems are traced back to the single-discipline professional education of engineers, economists and lawyers as well as to the attitude of academia toward the trade-off between broadness and depth in education. This in turn leaves it up to the individual to broaden his knowledge rather by absorption than by systematic learning.

The Navy and the other departments of the Department of Defense have long recognized this shortcoming of public education in these respects and have instituted numerous in-house courses, schools and colleges for continued education as a partial remedy. Some universities are experimenting with interdisciplinary curricula; these efforts, however, are sporadic and not goal oriented. The present paper searches for a coordinated approach and analyzes in a preliminary form the need for interdisciplinary knowledge of legal, engineering and economic aspects, leading to the acronym of LEGENOMY. In response to this need, the rudimentary structures of different interdisciplinary curricula are developed, with prime emphasis either on engineering or on economics or on law, and with secondary emphasis on the two remaining aspects. Plans are outlined as to how such educational concepts can be tailored to the Navy's needs, and incorporated into the existing educational efforts, in order to develop systematically a new elite of Government professionals.

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OBJECTIVES AND SCOPE

The present paper intends to direct the readers attention toward the subject of interdisciplinary education in general, and within the U.S. Navy in particular, in the hope that it may provide a basis or point of departure for further discussion and actions.

The paper represents a Search for Problem Definition and Possible Problem Solution, but does not intend to offer a single definite answer. The paper intends to be a first step toward an orderly discussion of the subject and as an invitation to comments. Therefore, all suggestions made must be considered and evaluated as contributions within a research-effort and not necessarily as final propositions. Only under these conditions will it be possible to discuss, in public, concepts which may not have reached the state of maturity; and also concepts which may be controversial in academia, among professional groups, and within institutionalized organizations.

The weakest part of the paper may be the data base. For example, different distributions of skills have been observed on an industry-wide basis; but neither a firm definition of skill, nor a measured distribution is available at this time. Therefore, in some instances subjective judgement must substitute for desired but nonexistent objectivity. This determines the scope of the paper.

The authors are fully aware of the scope related problems. However, the importance which the subject may have seems to justify the risk of an imperfect presentation. Simply, somehow a beginning must be made.

APPROACH

The present paper is subdivided into two distinct parts:

Part I, called "AN OVERVIEW", discusses the subject of interdisciplinary education in general terms and in an editorialized form. The Overview may be considered as the executive summary of the subject, wherein no particular attention is given to details; however, the interactions and interdependency of the many facets of the problem are shown. In the introduction to Part I an attempt is made to justify the constraints to the approaches. In the next section some observations are summarized in generic form, providing the basis for the following response. Finally, actions are indicated, considered as necessary in order to proceed toward a better understanding of the outlined observations and responses. Also tentative conclusions are offered.

Part II, called "SELECTED NOTES", addresses specific points mentioned in Part I and explores them in some depth. Each individual note represents a single problem. An attempt has been made to address problems in similar form: (1) to describe and if possible define the problem; (2) suggest how those problems could be solved; (3) anticipate expected positive and also negative critiques to the suggested solutions, and finally (4), if appropriate, outline research steps in order to clarify further the problem and its solution.

PART I

AN OVERVIEW

1. INTRODUCTION

1.1 The problem of education

Few subjects attract more public attention than education and few areas are blessed with such an abundance of experts, true, selfstyled, or otherwise. However, one must also concede that really everybody is an expert on education in his own right: namely based upon his personal experience with his own education. There is general involvement with education, - collectively and individually. The personal involvement and the personal experiences lead to personal conclusions and opinions of unlimited plurality.

Such plurality leads necessarily to conflicting positions and strongly emotionally-dominated propositions about the right or the wrong way of formal education; about the purpose and goal of education; about duties, privileges, desirability and benefits of education and many other aspects. From a more general point of view, it is justified to say that education shapes the society; it is also justified to say that society shapes education. It is a two-way street. This may cause a dilemma in the search for causes and effects and charges the atmosphere still further with emotion.

All these problems, normally associated with a discussion of education, are recognized; so are the philosophical subtleties related to aspects of humanistic-versus scientific-oriented education. Social aspects have validity to be discussed and so also an unlimited gamut of related subjects. However, the authors have abstained from a discussion of all aspects and instead concentrate on practical aspects, - especially those related to the Navy's interest.

1.2 Pragmatism

From a purely pragmatic point of view, one may say that education must be useful. This motherhood-and-sin statement, in its overwhelming banality, holds true whether or not usefulness is defined as the capability to cope with the problems of the personal life or as the capability to achieve a desired earning power. Of course, these are only two of many possible definitions of usefulness.

Every possible definition of usefulness has importance in its own right. However, for the purpose of the present discussion, only one specific definition of usefulness shall be used: how useful, - or how compatible - is the present higher formal education with the needs for very specific positions in industry and Government; namely those positions which can be designated as (1) the interdisciplinary and (2) the intradisciplinary activities.

2. OBSERVATIONS

An attempt has been made to reduce and condense many observations into a simple generic framework. The observations have been made over many years and in various endeavors in Government and private industry. The observations are grouped into two categories: (1) Activity-related observation and (2) Behavior-related observations.

2.1 Activity-related observations

Looking at the entire spectrum of activities in procurement and private industry, one may be inclined to accept the following grouping: (1) activities, which can be well defined and classified in type and scope; (2) activities which cross the borderline of many disciplines and (3) activities which are well within one single discipline but which cannot be narrowly scoped. The first activity, mostly found on the lower levels of the work hierarchy or on the level of highest specialization are of no interest in the present discussion. The two others however, interdisciplinary activities and intra-disciplinary activities, will be discussed.

Interdisciplinary activities are those which demand the understanding of more than one single formalistic discipline. This for example is the requirement for each project manager in the Navy. First, he must fully understand the technological or engineering problems of his project because this is the fundamental tool for all his decisions. Secondly, he must have full appreciation of the economic impact, resulting from his decisions in order to understand the trade-offs open in his options. Thirdly, he must be aware of his delicate legal position with regard to possible disputes between the Government and contractors. Other professionals, who need wide interdisciplinary competence in addition to a fundamental management competence, are primarily contract officers, claim lawyers, all logistic managers, the managers of Government production facilities such as shipyards, the managers of depots, audit managers and planners of future programs.

The practitioners of interdisciplinary activities are heavily rooted in one specific discipline and have gained knowledge of the other disciplines by postgraduate studies or by absorption. To broaden from a single disciplinary education into interdisciplinary capabilities is often the goal of continued education, and of special courses and seminars. However, existing higher formal education in itself does not provide the necessary prerequisite to deal with activities requiring interdisciplinary understandings.

Intradisciplinary activities are defined as those which cover the entire spectrum of a single discipline. For example, the technical director on a project team should not only have a full understanding of all practical aspects of the project but also full comprehension and judgement of the value of all theoretical aspects and research work relevant to the project. In the extreme, the technical director (for example of a shipbuilding program) may combine the practical experience of a shop foreman with those of a chief estimator, a design engineer, and a research professor in the same generic field or discipline.

Very few species of this category exist. They are often the few who went through the university as work students and who often finished their degree while fully employed.

2.2 Behavior-related observations

This group of observations attempt to depict in generic form how the individual, especially the member of the engineering profession, reacts (1) to his general job involvement, (2) toward the need of interdisciplinary understanding and (3) toward the communication gap between the practitioner and the theoretician in a particular field. It may be justified to summarize all three aspects under the name of Pattern of Education because whether or not one is fully aware of it, any successful professional life is a permanent process of learning and adaption. It may be simply termed "gaining of experience" or "coping with the need of a particular job". However, no one can remain for long at the level of competence at which he entered the job upon completion of his formal education. This applies especially to engineering graduates, and is independent of the level of the formal education.

The pattern of learning and with it the behavior related observations may be subdivided into (1) the shift-pattern, (2) the broadening-pattern and (3) the void-pattern. The continuous learning may be represented by the shift-pattern, where first an upward mobility and second a departure from the original discipline of education can be observed. The adaption toward a particular job requirement may be represented by the broadening pattern and finally the void-pattern may illustrate the communication problem between practitioner and theoretician. The shift-pattern may apply to both inter and intradisciplinary activities; the broadening pattern to interdisciplinary activities, and the void pattern to intradisciplinary activities. Within each of those three patterns, the engineer has a very specific position.

The three patterns are an abstraction, developed in the search to depict and summarize observations which can not be quantified at the present time. The quantifications offered in this paper are only based upon a consensus of opinions but not upon statistical data.

SHIFT-PATTERN

The principle of the shift pattern is shown in Figure 1. The pattern is based on four different levels A, B, C and D of formal education, entering the field of engineering. Level A may be a high-school graduate with some drafting courses; B, an engineer with a bachelor degree; and C and D, engineers with a master's degree and other advanced professional degrees.

In the first year, in which all four groups (lets call them the Classes of 1950) are entering the job market, the distribution between the levels A, B, C and D may be 15:60:20:5. After 10 years, only 73 percent have remained in the engineering profession; 27 percent have moved out; and 12 percent have moved from A to B, from B to C and from C to D. Again, 10 years later only 52 percent remain in the profession. By 1970, a total of 48 percent have left the engineering profession proper, and a total of 20 percent have moved to higher levels.

The significant point in the shift pattern is the fact that a percentage, increasing from groups A to D, are leaving the engineering profession. This means there is a shifting from design, research and development toward administration of engineering, management of engineering, technical sales and similar engineering related activities.

BROADENING PATTERN

In the description of the shift pattern, the movement of the members of the group took place (1) within the group and (2) of the group.

The determination of the movement within the group is easier than the determination of the movement out of the group because of a missing definition of what constitutes the engineering profession. Nevertheless, we may accept the fact that many engineers, almost 50 percent, are shifting during their career into engineering related fields at some level of management. During this shift, they are broadening into other than their original field, such as indicated in Figure 2.

Figure 2 shows that a large part of the originally implanted engineering knowledge will never be used; however, additional knowledge will have to be absorbed by necessity.

VOID PATTERN

The broadening in turn will lead to a considerable lack - or void - between the practitioner in a particular field and the specialist, mostly found in academic cycles.

It has been quite frequently observed that the lack of communication between the practitioner of engineering and the scientist in engineering is as dominant as the communication gap between different disciplines. The void-pattern is diagrammed in Figure 3.

The three patterns may help to recognize areas for educational needs. The patterns are the recording of observations and therefore facets of symptoms. The patterns are not causes in themselves, although they may point toward probable causes. It also may be assumed that some or all of the symptoms may overlap to some degree. This however is not discussed in the present paper.

3. RESPONSE

The before-listed observations are forcing us to respond with a search for possible causes and also with a search for possible remedies. The combination of both, the search for causes and for remedies, shall be called a response.

Generically, it seems possible to break out two dominating responses: (1) the personal response from the engineers themselves and (2) the institutional response from universities and employing organizations. Although both responses are inter-related, an attempt should be made to deal with them separately.

3.1 Personal response

The engineers personal response may be the cause for the shift pattern as illustrated previously in Figure 1. The young engineer enters the professional life often with over-extended expectations groomed by university curricula which are often remote from professional requirements or reality.

Once employed, the young engineer may be trapped by specific competence: He may do a specific job exceedingly well and therefore he may be retained in the interest of efficiency in his slot longer than advantageous for his further development. This combined with salary limitations and strong competition from the following generation of engineers with even better specialized training than he, leads finally to a break-out from the engineering activity proper.

Some of the ambitious ones put new efforts into additional education in management, administration or economics. Others shift into sales related activities, or leave the engineering profession all together. Only a few have the staying power or encounter a sufficiently rewarding opportunity to remain engineers throughout the entire professional life.

3.2 Institutional response

Academic: One would accept that the personal responses of engineers are well known to universities and that all institutions of higher learning may well tailor their curricula accordingly.

Unfortunately only relatively few universities have recognized the need for interdisciplinary education and the trade-off between depth and broadness in education seems not to fit into the institutionalized thinking of existing curricula. For the university, specialization is the only accepted criteria for academic competence and, in turn, only extreme specialization permits early achievement of academic credentials, and beside, even the most dedicated teaching is of little credit to the educator's academic career.

Government and Industry: Large industries, many procurement agencies, and in particular the Navy, have long recognized the need for continuing education either toward a broadening of competence or toward intensified specialization, and such organizations offer many educational opportunities. These opportunities are tailored principally toward a short range goal of immediate job-related training. Essentially, however, the civilian's education is considered to be his own business and the development of a specific career pattern only a recent innovation. Only the military have an opportunity for training and education with a long-range view by presenting opportunities for growth in an orderly and planned fashion. No equivalent, centralized plan for civilian education exists.

Seen from the other side, no means exist for the Government to require continuity in education for civilian employees, whereas the military has the command capability to require such education. Of course, this cardinal difference is paid for by both sides with a price.

Continuing educational benefits in industry are somewhat desirable because the goal of better-trained personnel and higher productivity are more amenable to quantification. The trade-off between costs for in-house education and possible benefits are measurable.

4. ACTIONS

Recognizing a problem because of specific observations, responding to the problem by searching for the underlying causes, and finally suggesting affirmative action, is a three-step proposition with ever-increasing difficulty and with ever-increasing need to go from generalities to specifics. This section will be restricted to some selected specifics.

4.1 Demonstration of Need and Cost

First, it must be demonstrated that the proclaimed objectives for an interdisciplinary education serves an actual need within the Navy and will help to solve existing problems. Project management, contract activities and the management of litigation may be the first candidates for such scrutiny. This problem shifts into the areas of quantitative analysis of (1) the measurement of objectives and (2) the determination of the costs for such education.

It may be appropriate to select one specific activity as a tool for learning how such quantification can be accomplished and of what the gains could be. The only way to solve this problem may be by an analysis of selected decision processes, wherein the quality of the decision expressed in decision-risk can be measured against the cost for the information base as developed on an interdisciplinary basis. For example, how to utilize the combined information provided by engineers, financial analysis and lawyers toward a single decision may depend upon an understanding of the potential information which each discipline can provide. In turn, the capability of how to utilize the available specialists may depend upon the manager's own understanding of interdisciplinary interactions. To demonstrate the above assumptions would be the first action item.

4.2 Philosophical transition

Regardless of what interdisciplinary education may bring, it incurs definite costs in time and financial resources. Furthermore, only a part of the problem is subject to quantitative analysis and a large part of the problem remains in the domain of judgement and qualitative analysis. These problem types are summarized under the term "philosophical transition," which may be classified with two distinct propositions.

Proposition number one may be the orientation of interdisciplinary education toward the understanding of the methods used in other professions in order to be able to fully communicate with them, and to utilize their potential within well-defined activities or projects. This proposition is thinking oriented, enlisting one profession "to work with" representatives of other professions without being an expert in the other's field. In

this way, true professionalism in the original disciplines can be maintained but the capability of other professionals on a team utilized in the decision process.

Proposition number two may be an expansion of proposition number one up to the point where the education enables its beneficiaries to work actively in more than one discipline. This may lead to the definition of new professionals such as the Technical Lawyer, the Engineering Economist, and similar new terms and classifications.

Proposition number one may be obtainable in practice; proposition number two is a possibly unclear concept. But to find out, where analytical effort should be expended is considered as the second action item.

5. CONCLUSION

The entire paper represents a brief for problem classification and for ways to quantify, qualify and approve the problem solution. Therefore, what one may have expected to be the conclusions have in fact already entered the discussion as axiomatic assumptions. The conclusions offered are more a restatement of previous opinions than de facto conclusions. This vicious cycle shall be considered as a concession to the formalistic mode of presentation:

- It appears, that the present formal engineering education is only sufficient until the engineer is pushed into the public arena, where decisions and judgments are expected beyond the narrow confines of his education. In short, for management decisions beyond the drafting room, present formal engineering education is insufficient and must be expanded into an interdisciplinary one.

- It appears, that the present higher formal engineering education neglects the practical aspects of engineering in terms of theoretical sophistication; the fundamentals of engineering education are eliminated from the curricula until a tremendous superstructure resets upon minute foundations.

- The answer to the first conclusion may be found in an interdisciplinary education; the answer to the second conclusion in the formulation of an education which combines the essential practical aspects with the essential theoretical aspects of engineering knowledge.

- The tasks ahead may be the quantification of the tentative conclusions, the qualification of its desirability, the analysis of costs and benefits, and the delineation of an orderly study of the problem.

PART II

SELECTED NOTES

The notes refer to subjects addressed in the paper either in explicit or implicit focus. Each note is self-sustained and may be considered in itself as an independent topic for research.

Note #1

MUTUAL UNDERSTANDING

1. Observation

Over the last decades, the mutual involvement between the private sectors and Government increased constantly in many areas. In procurement for example, detailed pre-award surveys are made; estimates prepared by both parties are used for negotiations; and the entire contract performance is also closely monitored by both parties. This permanent increase in mutual involvement is a logical consequence of the continuous increase in complexity of new weapon systems.

It has been observed quite frequently that an atmosphere of distrust between the representatives of industry and Government exist, and cliches are used in approaching or discussing the opponent's positions. Anyone who may have worked "on both sides of the fence" will state most affirmatively that this mutual distrust is entirely undeserved. Integrity, competence, enthusiasm and all other good characteristics (as well as the bad ones) are evenly distributed on both sides. Therefore, the mutual uneasiness can have only one single cause: lack of understanding of the opponent's position and his often opposing objectives. The private company and its representative must aim for the highest possible profit, because without profit the company can neither exist nor expand. The Government and its representatives must search for the optimal bid, because only in this way can they fulfill their duty to provide the most for the tax dollar within the limits of the legislated evaluation base.

2. Possible Solutions

The solution to the observed problem lays in education of both parties. First, the Government employees can, by means of courses and seminars, learn why the goals of the private sector must be what they are. The essence of corporate decision techniques, the recognition of uncertainties, the industrial dependency upon the status of the whole economy, the interaction between the various industrial determinators, such as union agreements, inflation, access to markets (and many more) - all these are subjects which can be taught. Similarly, the representatives of the private sector can be taught why the decision process in the Government, as a many-layered organization, must differ from the parallel processes in private industry. The process of scrutiny is much stronger and more visible for the Government employee than for his counterpart in private industry. But again, all these are subjects which can be taught either in seminars or by public relation activities.

Of course, beyond the learning by teaching, the learning by absorption would be open. It may be envisioned that Government employees will be periodically granted a sabbatical in order to work for one or two years in industry. It may also be envisioned that employees of private industry would make a one or two-year tour in a government position in order to familiarize themselves with the problems as seen from the other side. Such exchange would without doubt foster mutual understanding and mutual respect, both of which are fundamental for meaningful communication.

3. Criticism

The proposition, to foster mutual understanding by means of schooling, is definitely within reach of realization. For example, it would be without question possible to establish courses which would teach the "opposite view". The exchange of personnel between government and private industry would of course be the most effective way "to absorb the opposite view."

Little negative criticism can be offered to the suggestion that the mutual points of view be taught, and it may be an overextended imagination to call such teaching activities a method of brain washing. If such arguments are used, each effort to improve mutual understanding is made futile.

However, heavy criticism must be expected regarding the suggestion to exchange personnel between government and industry on a planned basis. The problem of loyalty may not be easily combatted in a non-ideal world. The problems of loyalty, seniority in government and in companies, and loss of pension and other fringe benefits may be administrative nightmares; such peripherals could kill an otherwise acceptable idea.

Note #2

THE STRUCTURE OF LEARNING

This note deals with the argument that organized, school-centered learning must be restricted in time and in substance, for practical reason, because the need for productive earning does not permit the stretch-out of the formal education process beyond a certain limit. The counter-argument to this is the proposition that with better planning and better management of learning, the presently taught knowledge could be brought to the student in a much shorter time, or in reverse, during the presently accepted duration of formal education, a much larger body of knowledge could be taught for the benefit of the students.

In support of this proposition, a flow chart could be outlined for a structure of learning. This structure of learning could identify overlaps and repetition of subject matter, as may be seen by a scrutiny of many university catalogues. At the present time, the only hint toward a structure of learning is contained in the statement of pre-requisite course; but not a single university, to the knowledge of the authors, informs the student about the interactions between many courses. For example, students may be exposed to a repetitive discourse of the same mathematical principles in hydrodynamics, in aerodynamics, in thermodynamics and in structural analysis;

all these subjects could be taught in a fraction of the presently assigned time if students would be given once and for all a solid mathematical foundation, and if the teachers of mathematics would have greater concern and understanding of its applications in the various fields of dynamics and analysis. (More simply expressed, a teacher in advanced literature should not be concerned with grammar and spelling).

The discussion supports the authors' opinion that interdisciplinary education is possible with neither the loss of depth of education nor an unacceptable prolongation of the period of formal schooling.

Note #3

INTERDISCIPLINARY COMBINATIONS

This note addresses the different combination of engineering education and the education in economics and in knowledge of law.

The suggested combinations evolve from a search for a balance between depth and broadness in education and counter the argument that interdisciplinary education produces "Jacks of all trades and masters of none". More specifically, nine different combinations of the key-disciplines of engineering (E), economy (Y) and law (L) are outlined. Each of the nine combinations has one discipline, - engineering, economics, or law, as the core of its educational goal, and the two remaining disciplines as support-activities grouped around the core area.

The selected core area would proceed toward a professional degree either in engineering, or in an economics-related field, or in law, and academically be bounded approximately by a master's degree. The two supporting disciplines would be academically bounded by approximately a bachelor's degree. For illustrative purposes only, the equation is suggested, that one master's degree (with professional license) plus two bachelor's degrees equates approximately to a doctorate degree. Of course, literary license taken, this equation will be in conflict with the presently accepted opinion of the purpose and value of the Ph.D degree, which is based upon research competence in depth and not on broadness.

The possibility of acquiring two professional degrees, for example, in engineering and in law, is kept open; however, it may be postponed to the area of continuous education during professional employment. However, it is postulated that any interdisciplinary graduate has satisfied all undergraduate requirements, in order to proceed in any of the two other sidelines immediately with graduate studies of his choice. Various combinations are outlined in Figure 4.

The search for the pros and cons of the different interdisciplinary combinations is open for discussion and analysis. It would be a study in itself.

Note #4

QUANTIFICATION OF NEED FOR INTERDISCIPLINARY EDUCATION

This note addresses the problem of determining, how many interdisciplinary-educated engineers, lawyers and economists will be needed in the future. Of special interest are the requirements within the Department of Defense, and in particular the Navy Department.

If experiences of high-level research companies such as RAND or CNA can be taken as representative, it is estimated that the need for true interdisciplinary generalist, or in terms of the present paper, multi-disciplinary specialists, would amount to approximately 15 percent of all engineers, lawyers and economists.

In order to determine the actual quantitative need for interdisciplinary education and the most desirable composition and combination, it is suggested that a questionnaire be developed for (1) in-house Navy use, (2) for in-house DOD use and (3) for industrial use. To develop such a data base would be a study in itself.

If the experiences of the RAND corporation and of CNA are valid for comparative purposes, it appears as if the need for true generalists or for interdisciplinary professionals would be at the 15-percent proportion of all professionals (and also of the group of engineers). Or expressed the other way round, the presently existent single-disciplinary education may fully suffice for approximately 85 percent of all present and future engineers, and therefore the key considerations underscored in this paper may apply only to a relative small group. However, even this small group consisting of 15 percent of all engineers would amount to approximately 20 graduates per year.

It also should be noted that the "numerical need" may not constitute a prime interest to the institutionalized business of learning; this however cannot detract from the urgent need for multidisciplinary-educated personnel in industry and in government.

It is accepted that at the present time many of the interdisciplinary problems are under competent management control, because selected and especially gifted engineers were able, during long years of experience, to absorb interdisciplinary qualities beyond the limits of the engineering discipline. However, a drastic scarcity of such talents may become apparent with the continuous increase in complexity of project management and contracting procedures. There may no longer be time, as there has been in the past, to permit the "growing into the job" for the necessary numbers of personnel at the top and in the median management levels. In short, the balance between demand and supply of interdisciplinary talents may in the future not be attainable by "on the job learning" and the need may well arise, to devote specific attention toward the education of an interdisciplinary-oriented professional group.

Note #5

PHILOSOPHY AND DISCIPLINE

This note directs the interest toward an understanding for the interaction of philosophy with specific disciplines, and for the power or influence which philosophy exerts on the professional thinking of each discipline.

To make the point clear, it is necessary to make some simplifications. Also, greater clarity may be gained by starting with the subject of economics. In that field various different catch words are used to describe principal directions of economic thinking: "Capitalistic" economy and "Marxist" economy are two examples of such designators. This indicates that economics, and especially the teaching of economics, is based upon the acceptance of a set of axioms. This makes economics essentially a political/philosophical science. The next discipline in closeness to philosophy is the science of law. Its closeness to philosophy is more remote for the observer than in economy, because law is already the pragmatic condensation of the philosophy of the majority. For the practitioner of law, the understanding of the manipulative aspects of law are more important than the philosophic-formative aspects leading toward the law structure and interpretation. Finally, the discipline of engineering is the discipline most remote from philosophy as long as one is concerned with its application only. Within limits, the product of engineering can be based upon formal calculation, even if the calculation is nothing more than standardization of empiricism.

The relationship may be even more highlighted by stating that economics is based essentially on belief, law on dogma, and engineering on how-to-do standards and prescriptions. In short, different intellectual "leitmotifs" dominate the three different disciplines. This in turn may be one of the major difficulties, if not the key reason, for the struggle to combine the studies of those three disciplines into a single personality pattern.

It is recommended that the relationship of the various disciplines to philosophy be explored and a search be made for the particular resolution level, wherein a common philosophical basis can be established as a take-off line toward the teaching of interdisciplinary curricula.

Note #6

OTHER PROBLEMS

The subject of interdisciplinary education has many facets. Only a few of them are addressed in the present paper. However, in order to convey some impression of completeness a few of the related problems are listed:

- Corporate learning and memory

Frequently, a wide range of knowledge rests in a person rather than in an institution, and may be lost through such causes as retirement. One may consider the retention of prospective retirees, for a pre-determined period of time, as teachers or instructors in the field of their competence.

- Institutional Aspects

The view toward interdisciplinary education may be entirely different from the perspective of a university than from the perspective of a company, and more especially from the perspective of the Navy. First, education for a private university must be "business" and this in turn depends upon the market. Second, a curricula must comply to some accepted academic standards, regardless of how irrelevant these standards may be to the customer. The Government support for interdisciplinary activities at universities and the accreditation of in-house education may be a mutual problem.

- Legal Aspects

Within the Navy, the problem of civilian education toward a certain level of knowledge or toward a career-goal may more easily be recognized than handled. The problem of shifting personnel between localities and jobs in the interest of career development may run into legal barriers. Related investigation may be necessary.

- Goals of interdisciplinary education

Interdisciplinary education and the balance in depth versus broadness may have to be tailored toward specific careers. At the moment, more intuitive perception than knowledge exists in this respect. Goals must be clearly defined in order to produce a viable combination of disciplines.

With this final note, the subject of interdisciplinary education may be sketched sufficiently to enter the discussion of a topic, deserving in-depth study by all of us both in Government and industry. It is hoped this may serve to encourage further research of this subject.

IN	OUT	REM.	OVER
100	27		12
73	21	61	8
52		44	
	48 OUT	N.A.	20 OVER

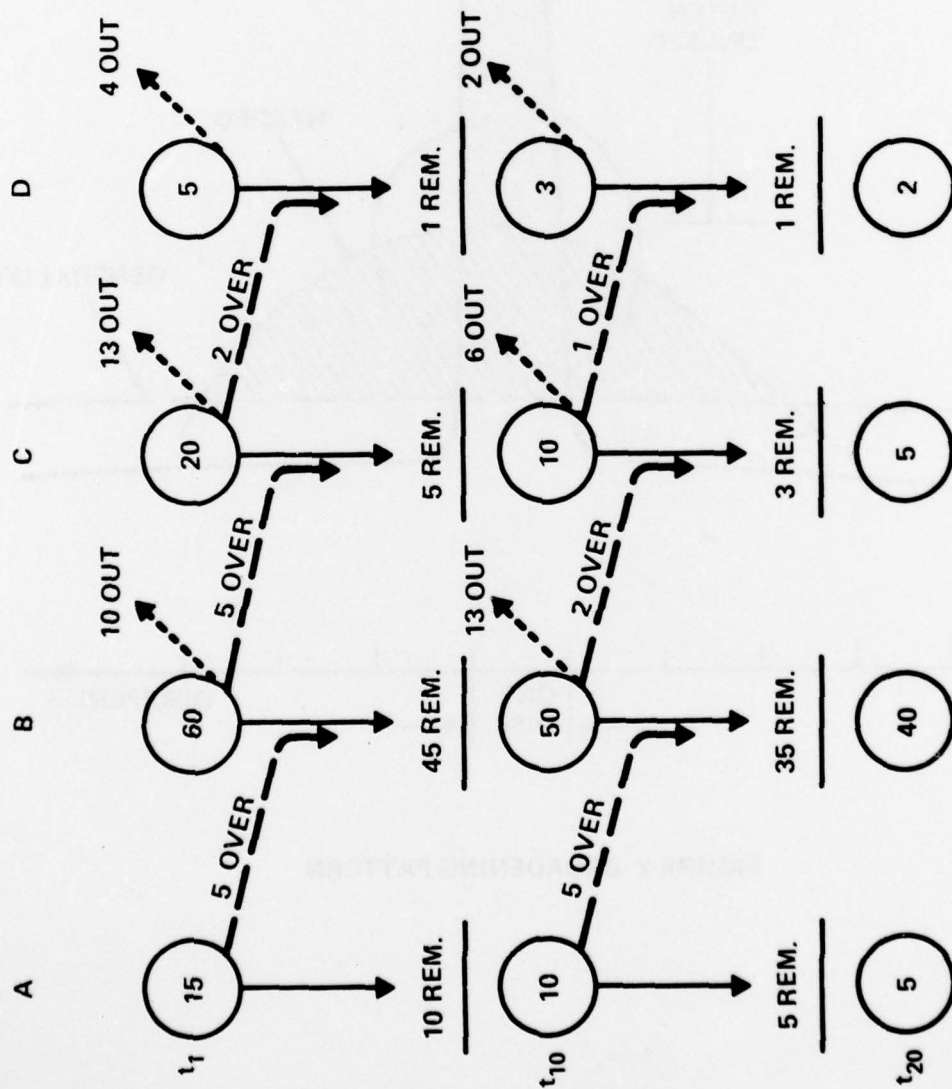


FIGURE 1 MOVEMENT PATTERN

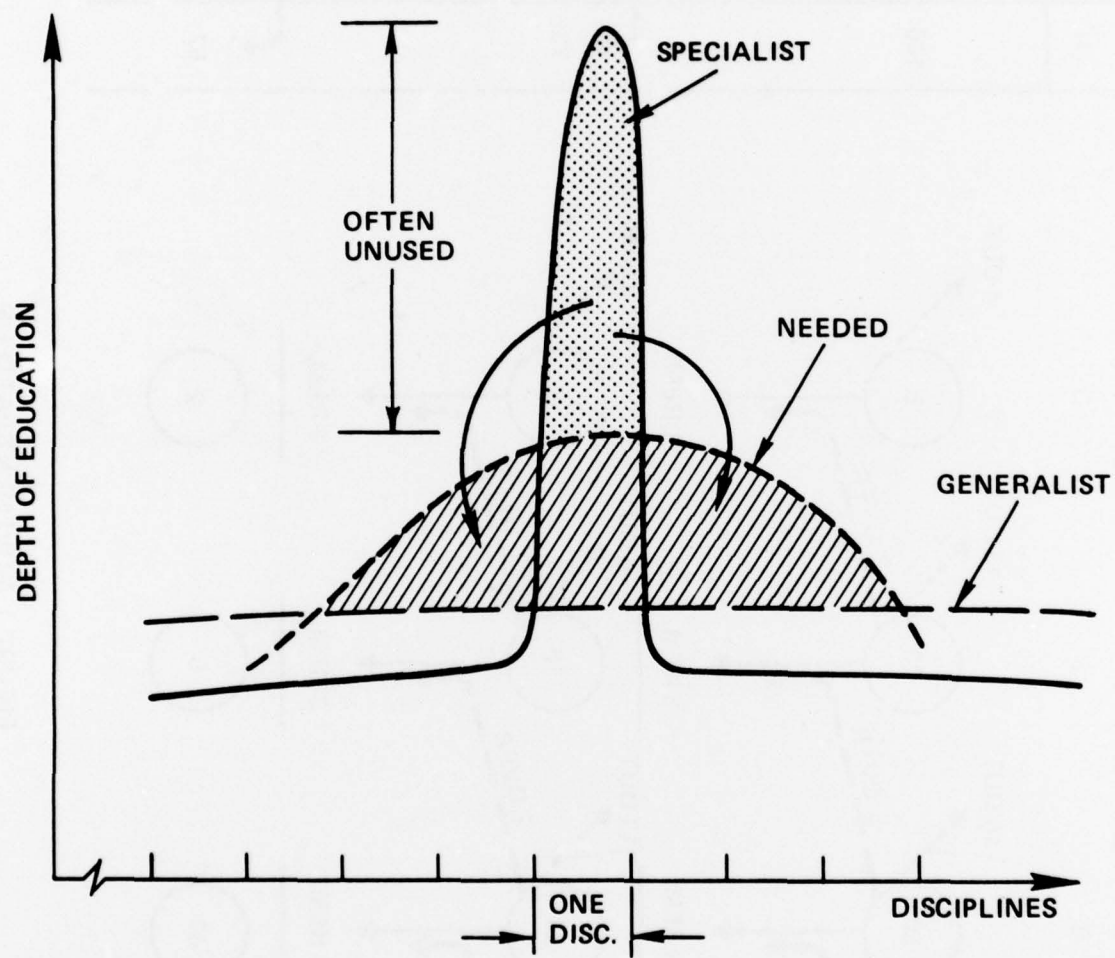


FIGURE 2 BROADENING PATTERN

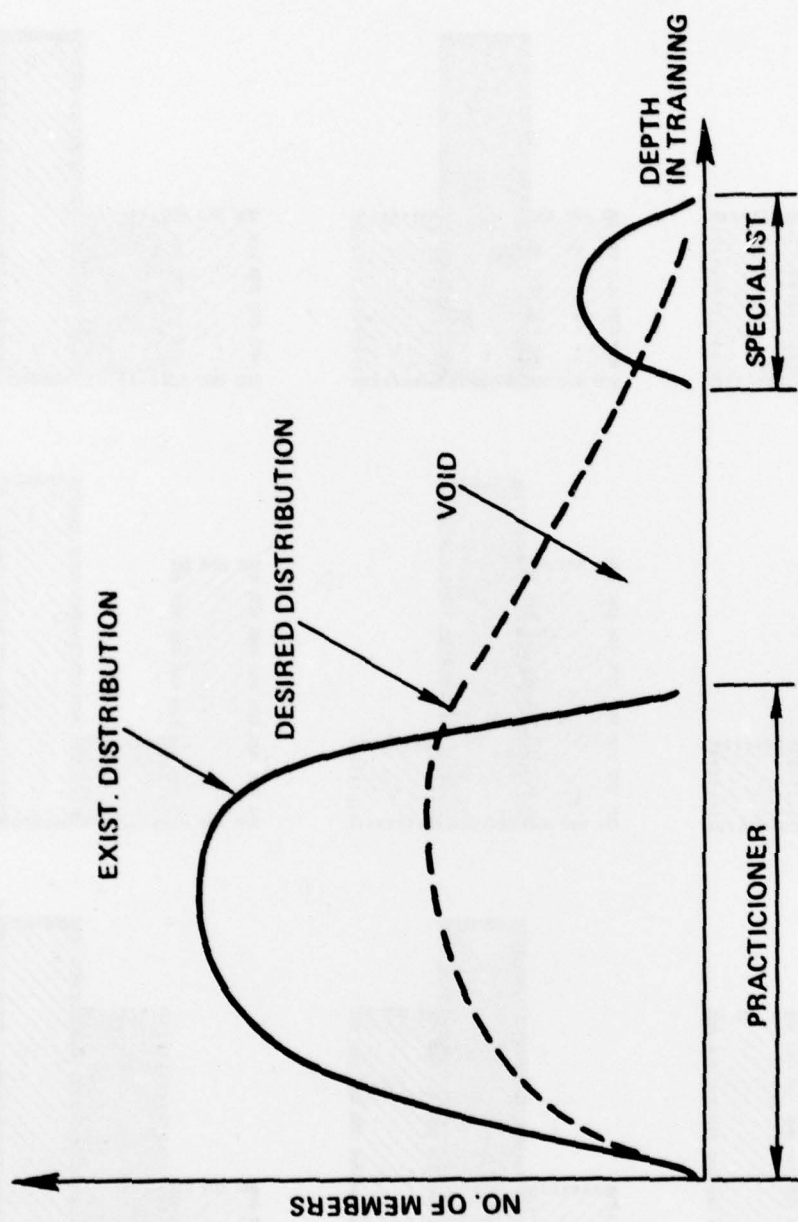


FIGURE 3 VOID PATTERN

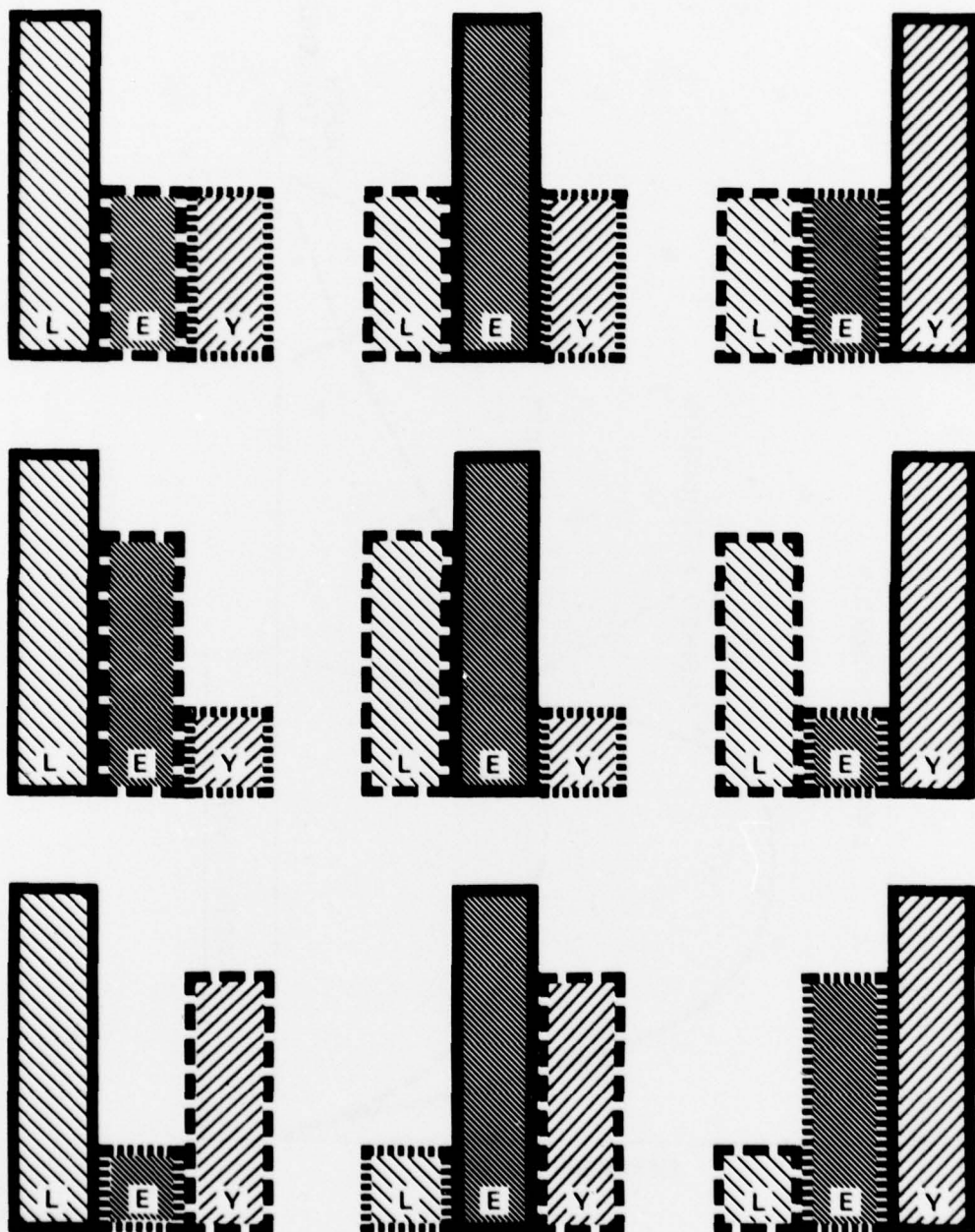


FIGURE 4 COMBINATION OF TRAINING

APPENDIX

About the Authors: (In alphabetical order)

Dr. Franz A. P. Frisch graduated from the technical University of Vienna, Austria. He has close to 30 years experience in shipbuilding and related subjects. He worked as a Naval Architect, Guarantee-Engineer, Chief Estimator, Production Manager, and Director for Shipyard-Planning and Maintenance in Austria, Denmark, Sweden, and Germany. In 1956 he was first invited to the U.S.A. to testify on foreign cost and production in subsidy cases before the Maritime Administration. From 1957 through 1962 he was associated with several U.S. Naval Architect firms. He was owners representative in Europe and Japan; he conducted studies on transport economy for Venezuela, ICC, and shipowners; he was consultant for shipyard planning in Brazil and Europe. In 1963 he joined the staff of CNA (Center for Naval Analysis) and became head of the logistic section and study director; there he originated the FDL ship and ship concept, and was assigned as advisor to the project manager. From 1968 through 1974 Dr. Frisch was faculty member and visiting lecturer at the M.I.T. (Massachusetts Institute of Technology); he lectured on shipyard management, ocean transportation, systems theory in transportation, and in interdisciplinary seminars. In 1972 and 1973 he was consultant to the Dubai Drydock LTD for layout of a new shipyard in the Arabian Gulf. Since November 1973 Dr. Frisch has been with the NAVSEA's ship production office, mostly involved in special projects.

Dr. John H. Huth graduated from the University of California (Berkeley) and Stanford University. He has close to 30 years experience in engineering science. He worked as a senior research engineer at the Rand Corporation from 1950 to 1964. During this time he published approximately 30 papers, held part-time faculty appointments at UCLA and Cal. Tech., and served on several high level advisory panels. In 1964, Dr. Huth joined the Bureau of Ships as Chief Scientist for R&D. Since then he has been active in a variety of areas, including computer aided ship design, ship survivability, pollution abatement, etc.

Eugene B. Paulisch, Esq., Senior Trial Attorney, Office of the General Counsel, Department of Navy. LLB George Washington University, 1951, member of the District of Columbia and Virginia bar. Engaged in general civil practice until joining the Office of Counsel, Naval Supply Systems Command in 1970. Since 1973 Trial Attorney with Contract Appeals Division, Office of the General Counsel, acting as counsel of record in major contract appeals to the Armed Services Board of Contract Appeals.

CDR. Charles H. Piersall, Jr. is the Head of Project Management Policy and Deputy Director for Systems Acquisition at the Headquarters, Naval Material Command. He is a graduate of the New York State Maritime College and has advanced degrees in Mechanical engineering and Business from the Naval Postgraduate School and University of Rochester, respectively. CDR. Piersall is an Engineering Duty Officer who had numerous tours in shipbuilding and ship maintenance in industrial activities. He was a Shipbuilding Consultant for the CNO while stationed at the Center for Naval Analyses (CNA). Prior to his current assignment he was Director of Production, T&E and Integrated Logistic Support, LHA Project in the Naval Sea Systems Command. He holds the Meritorious Service Medal from that assignment. CDR. Piersall is a full member of the Society of Sigma Xi, having been promoted based on contributions to Shipbuilding/Ship Maintenance Research while on CNA. He is the Assistant Secretary-Treasurer of the American Society of Naval Engineers.