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CONCEPT FORMULATION AND SHIP DESIGN - THE NEW WAY

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THIRD ANNUAL TECHNICAL SYMPOSIUM

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CONCEPT FORMULATION AND SHIP DESIGN-
THE NEW WAY

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THIRD ANNUAL TECHNICAL SYMPOSIUM

BUSHIPS A. S. E.

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ABBREVIATIONS

P.D.P.	Project Definition Phase
C.F.	Concept Formulation
D.O.D.	Department of Defense
T.S.O.R.	Tentative Specific Operational Requirement
S.O.R.	Specific Operational Requirement
P.T.A.	Proposed Technical Approach
A.D.O.	Advanced Development Objective
A.S.D.P.	Advanced Ship Development Program
S.C.D.D.	Ship Concept Design Department
NAVSEC	Naval Ship Engineering Center
NMSE	Naval Material Support Establishment
OPNAV	Office of the Chief of Naval Operations
R&D	Research and Development
DTMB	David Taylor Model Basin
P S.F	Prior Support Function
SAF	Systems Analysis Function
SDF	Supporting Design Function
RFP	Request for Proposals
SECDEF	Secretary of Defense

ABSTRACT

The application of "Concept Formulation" to the Navy Shipbuilding Program is examined as of a year after its inception. The opportunities and problems thus far identified are discussed. The future of a program, designed to be responsive to the aims of DOD Directive 3200.9 of 1 July 1965, is projected in terms of what needs to be done and how it might be approached. Exposure, such as this paper provide, is intended to solicit application of promising analytic tools and a cooperative atmosphere for potential participants.

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I. INTRODUCTION

Genesis of the DOD Policy on Major System Development

The cost of maintaining a credible defense posture has risen dramatically since World War II. This can be ascribed to the rapid advance of technology in this time and the increase in the number of countries capable of exploiting it for military purposes. The exploitation of technology has resulted in increasingly complex systems for securing our defense capability. From a 1966 vantage point the problems which have plagued the system development projects since World War II are not too surprising. Some systems did not live up to their advertised operational effectiveness; large cost overruns occurred on some projects; many had to be cancelled after substantial investments of time and money because of difficulties they were experiencing; others were beset by disruptive changes because of overdepending on technological breakthrough; some though not having these problems were cancelled or reduced in scope because of the financial demands of higher priority projects which were suffering serious problems.

Clearly the amount of resources that could be allotted to Defense were not being utilized as efficiently as they could be. The problem was the economical selection of strategy to achieve the Defense Departments Objectives. Quoting from an address by the former Assistant Secretary of Defense (Comptroller), Mr. Charles J. Hitch;

"From the point of view of Defense managment, strategy, technology and economy are three interdependent elements of the same problem. Strategies are ways of using budgets or resources to achieve military objectives. Technologies serve to define and limit the possible strategies. The economic problem is to choose that strategy -- including the forces, equipment and everything else necessary to implement it -- which is most efficient or economical, keeping in mind that the strategy which is the most efficient will also be the most economical."

DOD System Development Policy

Not all project developments were negative however. As a result of the lessons learned from the successful and the unsuccessful, the Department of Defense in 1964 directed that major systems development must meet certain prescribed requirements before being initiated.

This new look was promulgated by Department of Defense Directive 3200.9 under the title, "Project Definition Phase" (PDP) and was applicable to that phase of development in which major commitments of Research and Development or Production dollars are made with serious consequence obtaining if subsequent changes or cancellations are made. The policies expounded were designed to assure readiness for Engineering Development by exhibition of "achievable performance specifications, backed by a firm -- proposal for" system development. The ability to arrive at such a state of preparation is itself a costly achievement. This was recognized by the demand for accomplishment of prerequisites (Pre-PDP).

The first year of implementation was one of trial and lesson learning resulting in some minor revisions of the rules of conduct and a change of name. In July 1965, the Directive was reissued under the name of "Contract Definition" requiring a preliminary phase of "Concept Formulation." (C.F.)

Contract Definition Phase

The primary fundamentals expoused for the Contract Definition Phase are: on the premise that the interests of the government are best served by the use of Industry, that the Department of Defense should finance competitive fixed price contracts for producing proposals for Engineering Development; that trade-offs of system cost, schedule and operational effectiveness should produce definitive performance specification; and that as a result Engineering Development can be contracted on a firm prescribed basis instead of on a cost-plus-fee-basis.

The prescribed orderly direction for preparation and documentation during this crucial stage of development should provide the following advantages:

a. Better Management Planning
b. Better understanding between Government and Contractors
c. More Carefully Considered Cost and Schedule Estimates
d. More Definitive Specifications
e. Better Understanding of Degree and Nature of Technical Risk
f. More Accurate Projection of Ultimate Usefulness
g. Decrease in number of Changes During Development
h. Savings in Total Cost
i. Increased Effectiveness in Deployed Systems
j. Fewer Cancellations of Development Projects
k. Reduction of Effects on Other Projects

It is not intended that the primary function of the Contract Definition Phase be determination of whether or not to proceed with development but rather to determine the direction development will take. The decision relative to proceeding to a development should be made after the Concept Formulation Phase.

Concept Formulation

Concept Formulation describes the activities preceding a decision at the DOD level to carry out Contract Definition. It is a formal step in the research-to-production sequence.

Specifically the aims of Concept Formulation are defined as the satisfactory completion and documentation of the following six requisities: (see Figure 1)

a. Primarily engineering rather than experimental effort is required, and the technology needed is sufficiently in hand.
b. The mission and performance envelopes are defined.
c. The best technical approaches have been selected.
d. A thorough trade-off analysis has been made.
e. The cost effectiveness of the proposed item has been determined to be favorable in relationship to the cost effectiveness of competing items on a DOD-wide basis.
f. Cost and schedule estimates are credible and acceptable.

The objective of Concept Formulation is to provide the technical economic and military basis for a conditional decision to enter Engineering Development of a system.

Determination to Apply Concept Formulation Principles to Ship Development

The successful application to a dozen or so projects during this period led to the recommendation, in February 1965, of meeting the aims of Concept Formulation in the development of Navy ships. It was noted that the aims of Contract Definition were apparently being met satisfactorily, but the pre-Contract Design activities which justify the decision to initiate Contract Design were either inadequate or unidentifiable for formal review. DOD requested that procedures for applying DOD Directive 3200.9 be developed and, initially, selectively applied to several new ship designs. In compliance with the desires of the SECDEF, an ADO (46-27x) has been issued calling for the establishment of procedures and the development of resources for achieving the intent of Concept Formulation in the Ship Development Sequence and the application of these procedures and resources to "specific ship types as assigned by the Chief of Naval Operations."

Present Ship Development

It had long been obvious to those in the Navy ship development business that there was indeed a deficiency in the conceptual phase of the Navy Shipbuilding program. The urgency of todays National Defense and the tending toward austere budgets has always limited the resources available for long range planning. A minimum allocation of people and dollars has normally made the quality of this early phase minimally acceptable even to the Navy sponsor. Also the complexity of such an undertaking can be overwhelming to the point of despair without the proper analytic tools. Thirdly, the high cost of experimental or prototypes models has weighed heavily against treatment that is considered normal for other system development.

Under current procedures there is evolved a set of situations for various time periods which are analyzed with a view toward satisfying the apparent needs (resulting from Department of Defense or Navy strategic studies) with a combination of existing or developing Naval units. The number of these units required, each with its assumed capability, is determined on a fleet-wide basis and the deficiency, when

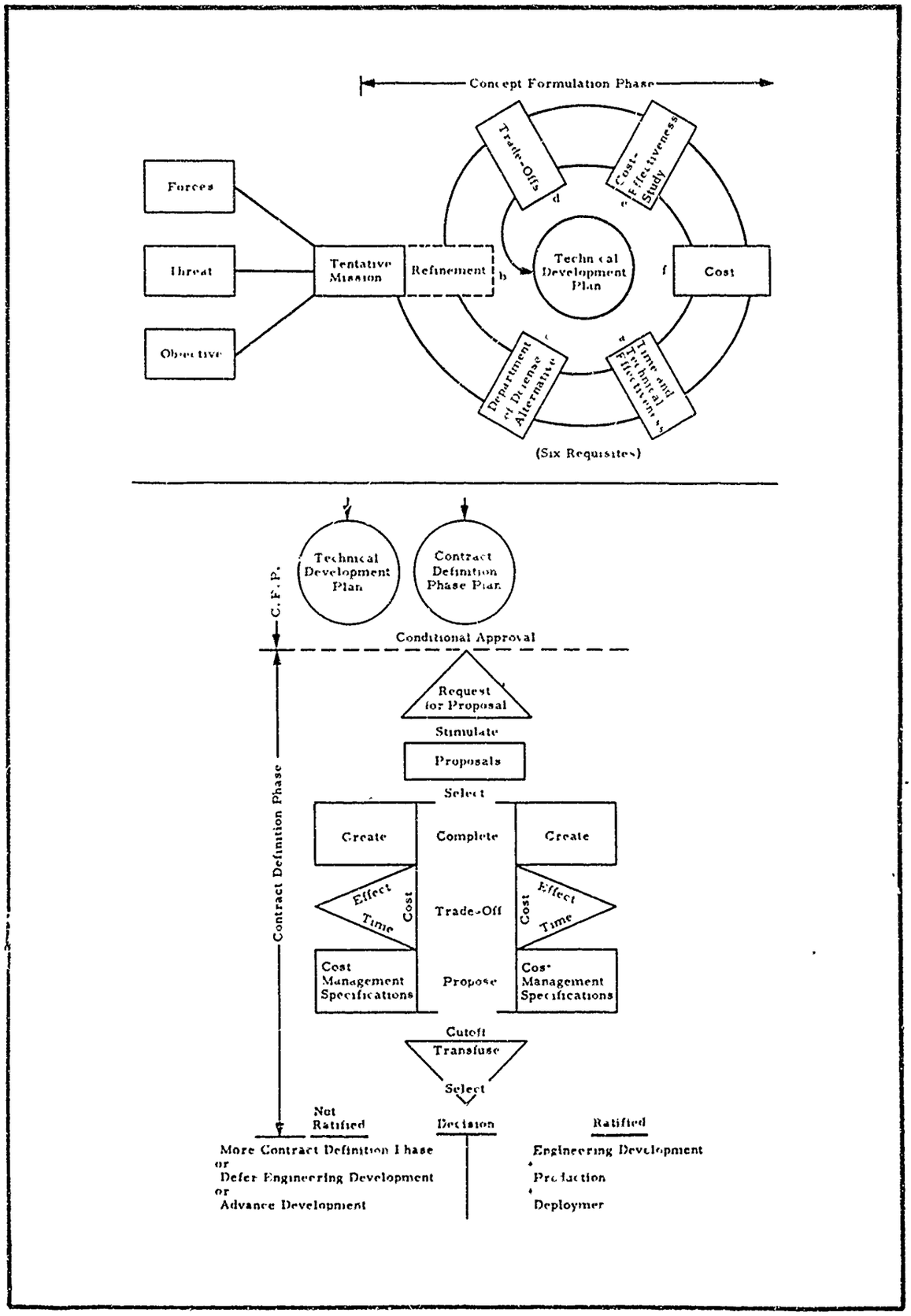


FIGURE 1 - DOD DIRECTIVE 3200.9

compared to the already approved building program, provides the next proposed increment.

Concurrently, the progress made in other system developments, such as weapons, sensors, propulsion, etc., are kept in mind. These improvements are then candidates for inclusion in the next class of appropriate ship type.

Eventually the tentative decision based upon the preceding is documented in the form of "One Sheet Characteristics" for the purpose of making feasibility and cost studies. This information is used to firm up the decision on whether a new class ship is desirable and if so, its performance characteristics. The selected ship is then put through a preliminary design and upon approval, contract design. It is at this stage that a building contract is sought, on a fixed price basis, for one or more ships of a class.

The R&D Sequence and Concept Formulation

The dialogue which has been recognized for systems other than ships, is presented in Figure (2) in order to identify events in the R&D Sequence corresponding to events in the Ship Development Sequence which occur prior to Contract Design.

The initial expression of an operational requirement (TSOR) has the effect of putting a priority on one avenue of progress over others within temporal considerations. If the material "producer" has had the foresight of preparing for the expressed need, the proposed technical approaches (PTA) to satisfying the need will present timely alternatives so that a firm requirement (SOR) can be tolerated. In fact, the option exists for progressive exploratory developers to propose exploitation of advanced technology without the benefit of the formal (TSOR). This option in practice is the more normal procedure for other than recently recognized tactical deficiencies.

If the proposals, self initiated or responding to a (TSOR), indicate a lack of preparedness then either the requirement must be met with emergency measures or emphasis is put upon responsive system exploration by generation of a notice of such intent (ADO). This advanced development should then result in acceptable proposals.

Concept Formulation is tuned to this development cycle. More emphasis may be put upon documentation of the evidence resulting from efforts aimed at effecting the Research and Development dialog, and this in turn instigates better organized and controlled analyses, estimates and plans, but otherwise Concept Formulation is compatible with the normal workings in Research and Development.

This atmosphere has not prevailed for ship development and so the application of concept formulation demands major reorganization of procedures as well as contributor recognition.

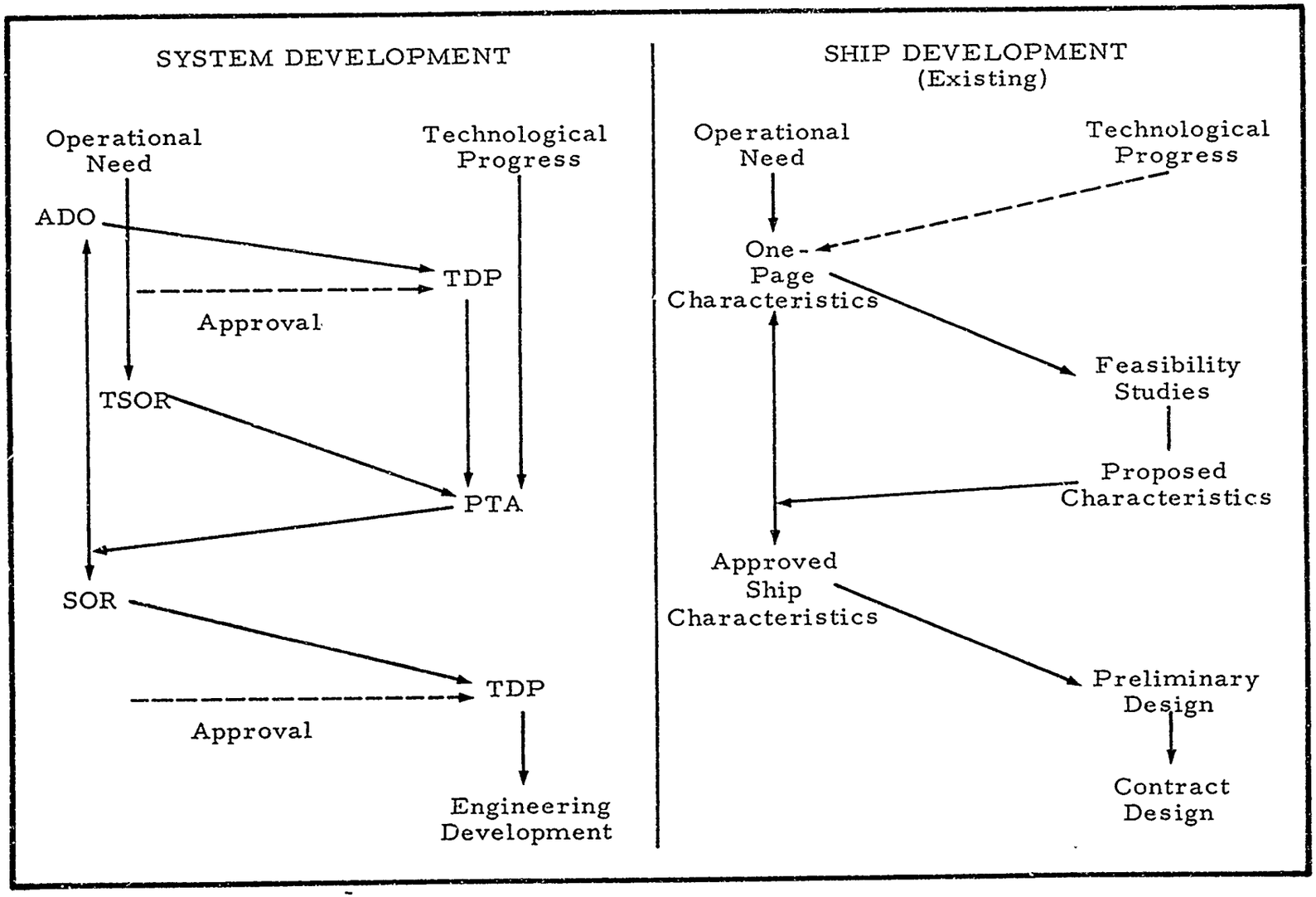


FIGURE 2 - DEVELOPMENT DIALOGUE

II. ESTABLISHING THE CONCEPT FORMULATION CAPABILITY

Advanced Ship Development Program (ASDP)

The problem of how to be responsive to the aims of Concept Formulation as applied to the Navy Shipbuilding Program became a Bureau of Ships project in July 1965 when the Chief of Naval Material designated the Bureau of Ships as Principle Development Activity for Ship Concept Formulation. Resources were made available for Advanced Development efforts and two "operational deficiencies estimated to require naval ships" were designated as pilot subprojects. While the producer side of the Navy was gearing its capabilities to take on this task the user side was concurrently examining its position and cooperative plans were begun.

Figure (3) is a representation of the essential aspects and the overall scope of the program as it evolved during the first six months of examination. It is basic that Concept Formulation connotes exploration as well as decision-making in a systematic manner.

The ASDP includes both the execution of Concept Formulation for ships and the establishment of resources designed to facilitate timely and competent execution. The latter function is represented as Prior Support. The former is divided into Systems Analysis and Supporting Design functions.

The Prior Support function is to generate analyses tools, to collect appropriate data, and to determine compatible procedures. This effort is continuous in nature and represents the direct support for ever-increasing capabilities to perform Concept Formulation.

The Systems Analysis function is to perform timely studies oriented toward the specific needs emanating from strategic analyses. Their prescribed operating procedures should be fed the pre-assembled information; or should indicate the lack of specific data thereby inducing synthesis or search of it. The product should be analytic evidence from inter-system trade-offs, suitable for a selection to be made of credible alternatives.

The choices available can vary from new ship designs, through major modifications, to satisfaction with existing types. The responsiveness to the original need should be checked and the decision to foster a particular system made.

This activity, if leading into Ship Design by in-house resources, performs some of the efforts which, if the design were to go into Contract Definition, might be left to the competitors involved. The effort required to prepare an RFP is thus replaced with some manipulation of the same type of information in preparation for "Ship Design."

The foregoing description of a system designed to be responsive to the Concept Formulation requirement will be discussed more fully later.

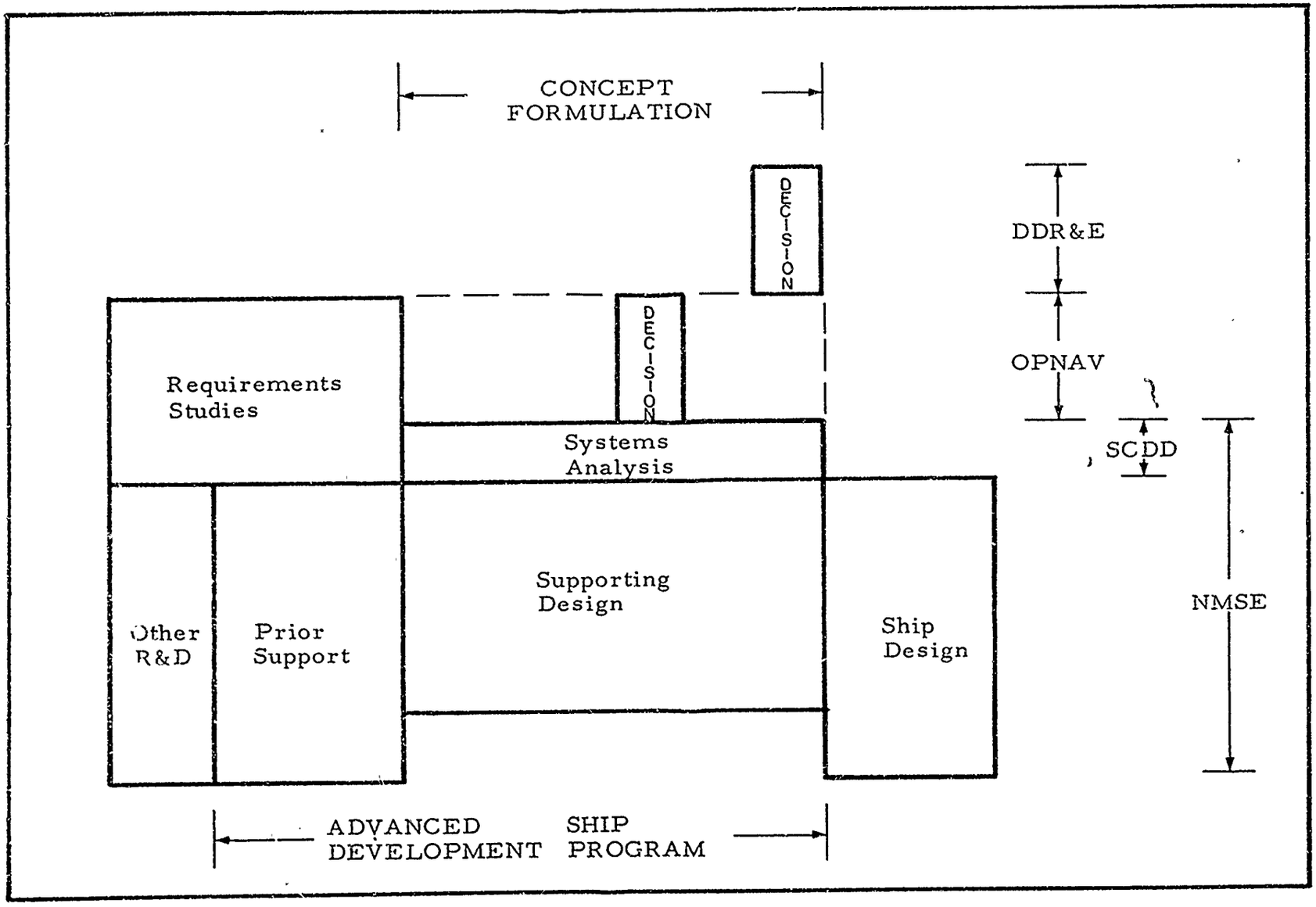


FIGURE 3 - ADVANCED SHIP DEVELOPMENT PROGRAM SCOPE

The responsiveness can be evaluated in terms of the recognized constraints in the current ship development system and in terms of the attributes intended in the current R&D Sequence.

a. By identifying Concept Formulation as an Advanced Development project recognition is given to the importance of the phase and clearly defined resources are assured for its execution.

b. A streamlining of the procedures involved by their delineation and by analysis of their contributory function assures better utilization of available resources.

c. Providing objectives for participants enhances the effectiveness of the overall development system.

d. Emphasis on computer applications for recurrent and iterative efforts permits the developer to give greater attention to necessarily subjective or creative functions.

e. Use of models allows a greater volume of variations to be examined in a timely manner.

f. The identification of a support function reduces the operating group's unproductive effort involving duplication, preliminary learning and fact gathering.

g. The recognition of required capabilities, their organizational location and the guidelines for their compatibility attunes the responsibilities of the participants.

h. The invitation to innovate and apply new techniques encourages participants in progressive thought.

i. Anticipated comparison of proposed or developing subsystems by predetermined criteria firms up the objective guiding their development.

The Ship Concept Design Department of NAVSEC

The Ship Concept Design Department (SCDD) of NAVSEC is the Navy group which has been assigned the position of "primary technical agent for the execution of C.F. for ships." This group has the responsibility of performing the Systems Analysis function. In this sense, theSCDD is also the prime critic of the product of the Prior Support effort and thus influences its direction.

The capability of this group to perform its functions is thus the prime resource to be established as the SCDD will be responsible for generating or collecting all the necessary information, and assembling it into a package, to meet the requisites of C.F. This responsibility

is made more difficult by the fact that heretofore Concept Formulation was defined only by its end product. There exists considerable literature on the nature of the product but almost none on the procedures involved in its generation.

The development of the Concept Formulation Capability by the SCDD will go through three phases.

In the first phase the emphasis will be on the development of procedures. This is being attacked from two directions; theory and practice. One group is trying to define what must be done. A second is trying to produce a package which meets the requisites. Both will probably fail in the sense that a child fails when it attempts its first step. This will be a most critical period because many will feel that Concept Formulation has failed because its first step was something less than a total success. Other services have had similar experiences but have persevered and are now reaping the benefits.

When we have learned enough from these initial efforts we will move into the second phase. In this phase SCDD will know whatmust be done and will have established links with all the resources necessary. It will be capable of a successful Concept Formulation. It will be an effective but not an efficient organization. The inefficiency will derive from the physical and organizational separation of the component resources. Therefore, it will be developing in-house resources it lacks and cannot acquire. As these capabilities are developed it will move into the third and final phase.

In the final phase, the SCDD will have sufficient in-house capability to efficiently perform Concept Formulation. This does not mean total self-sufficiency in any sense. The problem is one of avoiding unproductive bureaucratic delay. In its mature form, SCDD will provide analysis of ships to OPNAV throug h CNM much as the Office of systems analysis works for DOD.

Support for SCDD

The Concept Formulation effort will require the assistance of many people. Like an iceberg, only a small fraction of the people will be visible. Without their cooperation however, the objective of concept formulation cannot be achieved. The task is to harness the corporate capabilities and experience of the Naval Material Support Establishment and other Navy activities so that they can be effectively and efficiently applied to achieve the purpose of concept formulation.

Figure (4) is intended to convey the breath of support, which the SCDD of NAVSEC will require in the preparation for and the execution of Concept Formulations. When the request for a concept formulation effort begins, it is too late to start gathering information and data or developing and debugging computer programs. While something new may be required during a particular effort, the foundation of the concept

exploration capability must exist prior to a formulation effort. Otherwise, the primary purpose of the concept exploration will be blurred and the full force of our capability blunted by the distraction of not starting from a firm base.

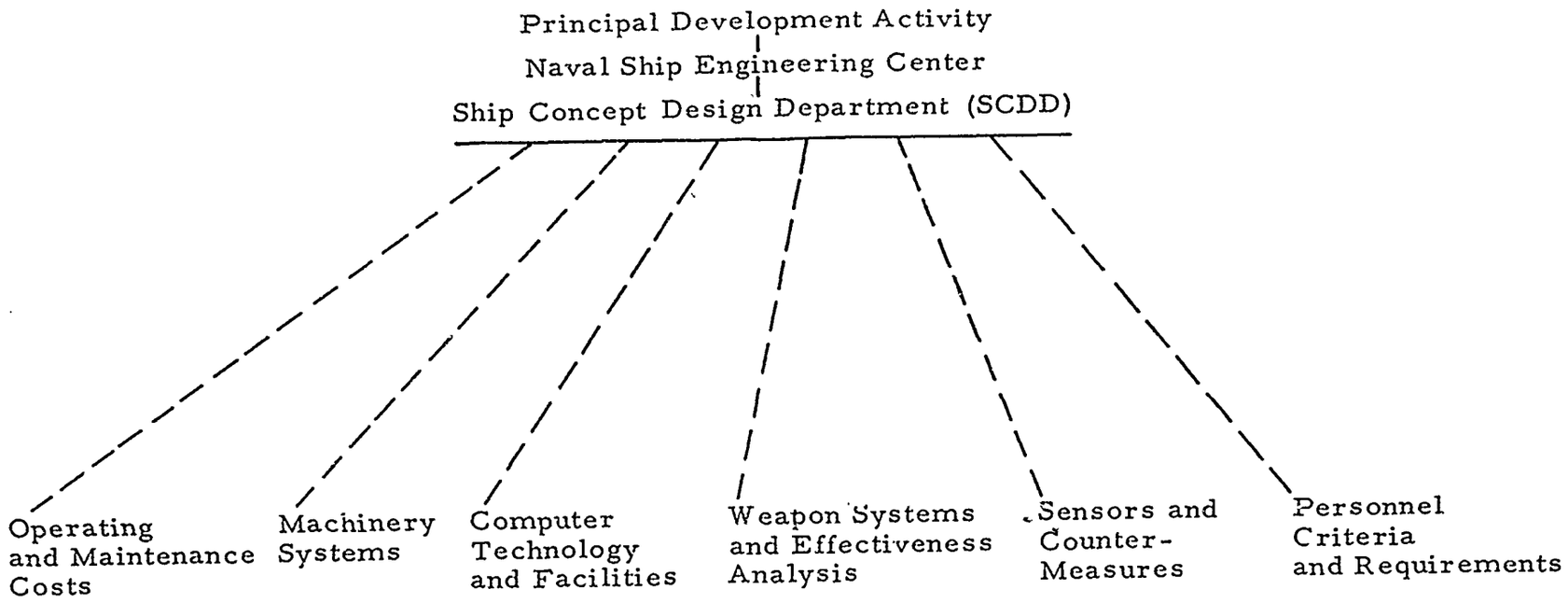
This foundation is the inventory of information and data, ship and cost models, etc. which is developed by the NMSE resources best qualified by their experiences. Its application is made by the SCDD in consultation with these same NMSE resources. This does not mean that Concept Formulation requires the same degree of detail as later stages in the Ship Design. However it is essential that the information used during this phase though expressed in general terms, reflect the general criteria, policy and state of the art that can be expected to be applied at successive stages of the ship's design. In many areas this will require capabilities that do not exist today and information in a form not heretofore required.

Problems

One problem which became immediately apparent was the collision course of the R&D and the Ship Design procedures and organization. Each had to tread upon a domain which had been slighted in the past. Although identifiable ship development efforts were already underway, their position in the spectrum of activity did not demand special recognition or exhibition of comprehensive plans.

Another problem is the orientation of existing progress in developing analytic techniques and in data collection. The people who know how to accomplish this already have a full job aimed at previously existing objectives. Enlisting their support will require, first, making them aware of the ASDP and its potential, second, establishing a priority for this application above others and third, leadership in coordinating and evaluating timely products.

The next problem is far-reaching in its implications. When treating the more familiar systems it is often best to use parametric analysis. As a result of past practices and organization however the necessary quantitative relationships are not readily available. It is tempting to make the mistake of many analysts, to take the available information and derive your own relationships. Often these "off the cuff" relationships are not very good and as a result are spurned by the experts. Nothing will destroy the usefulness of an analysis more thoroughly then this. It is important that the parametric analysis be based on relationships approved by and, if possible, derived by the appropriate experts. To facilitate this, we must make clear the use of these relationships. The common fear of being quoted must be laid to rest. To do this the SCDD must assume full responsibility for any errors or inaccuracies in the analysis. It is a common bureaucratic trick to consult others only as a means of diluting the responsibility and thus sharing any "blame." This must be avoided at all cost because full communication with supporting agencies is essential.



Naval Material Support Establishments and Other Supporting Activities

FIGURE 4 - SUPPORTING CAPABILITIES

III. DESCRIPTION OF THE EFFORT

Prior Support Function (PSF)

Returning to Figure (3), the orientation of this function is preparedness. Recognition of the need for mass production of Concept Formulations is the guiding objective. The PSF will not exist as an entity either physically or organizationally. A common plan and good communication feeding back progress or changes in the plan can focus the contributory efforts of sub-groups in Bureaus, Labs and other supporting activities.

Techniques for analysis, reports of study findings, technological opportunities, etc. may be critically examined by Navy participants for applicability to the goals of Concept Formulation. Making them suitable for exploitation by SCDD is an inherent responsibility of each contributor. The established method of carrying out Concept Formulation is itself subject to improvement as advanced development allows. In turn, the foreseeable demand for increased performance, as it is identified by practicing Concept Formulation, should incite direction or emphasis for R&D efforts outside the ASDP.

The natural course of events in many R&D programs leads to various studies as deficiencies in appropriate information are recognized. Unknowingly these instigators are building a base for other than their own interest and it is a waste of resources if advantage is not taken of this contribution.

The utility of the foregoing to a large degree depends upon the clarity of communication permitted by established format. Compatibility of the products of the PSF is essential for achievement of the objective; preparedness for Concept Formulation as carried out by the SCDD. The eventual demand for documentation is a strong factor in guiding the orderly development of information. The basis for decision emanates from the quality and appropriateness of the evidence gathered and presented. The SCDD does not have the time or capacity to determine the optimal character or arrangement of evidence.

The continuing nature of the SCDD provides an opportunity to capitalize on experience. On one hand the complexity of identification and commencement of each Concept Formulation subject is not an independent process. The concentration of effort is influenced by the preceding courses of events and the repetitious utilization of information and analyses. The data base, and thus the quality on the Concept Formulation process, continues to grow with each succeeding trial.

On the other hand, the feedback from the Concept Formulation process for use in reinforcing the quality and quantity of information and analytic techniques available to itself is just as important to its growth. The support functions depend upon the evaluation process to measure their progress.

Deficiencies found to exist in the system options considered and the light in which the weaknesses appear provide strong support for the aspirations of the entrepreneur of that particular technological advancement. This resource of guidance should not be wasted. It is difficult enough under ordinary circumstances to choose significant directions for progress to warrant special attention when assistance appears.

Although no hardware development would be sponsored under this program, the knowledge of its existence and the orientation of its potential is required and must be solicited.

Systems Analysis Function (SAF)

This will be the major function of the SCDD. Where a possible need for a ship system is identified, an analysis is initiated with a view toward examining the requisites of Concept Formulation. An analysis, as intended here, can be discussed in terms of four major components:

a. The objective
b. The alternative ways of achieving the objective
c. The models used to describe the alternative
d. The criterion used to select from the alternatives

The objective is the immediate, specific interpretation of the overall objectives of the Department of Defense. Usually there are several systems which can be used to achieve the objective, a system being equipment and how men use it. The spectrum of available alternative systems is determined by current technology. Defining these alternative systems in the first task of the SCDD as will be discussed later.

The heart of the analysis is constructing models of these alternative systems so that we can study their trends and effects. The entire cost effectiveness model is constructed from several parts which can be used separately. The model can be as simple or as complicated as necessary. It can be many volumes of detailed characteristics or it can exist in the mind of a single man.

As an example of a simple but very useful model it is possible to predict, roughly, cost of a ship based only on its displacement, year built, where built, and whether or not it has guided missiles. The entire Design Division of the Bureau of Ships can be considered a very complicated model. A more typical and practical model is a computer program which receives the required payload and performance as inputs and relates this to ship characteristics and costs. This can be used with a program which takes this same payload and performance, operates on a target and estimates effectiveness.

All of these models are abstract representations of reality and their usefulness depends on how well they approximate reality, or at least, that part of reality with which we are concerned. Since the

entire analysis rests on the validity of these models we must use the best ones available.

The last part of the analysis and, the whole point of the analysis, is choosing one of the alternatives. To make a choice there must be criteria. We must decide how to use what the model tells us about the system to decide if it is the way to achieve the objective. Models are tools by which we abstract reality not to obtain "the" answer in an uncertain world, but for analyzing more clearly and more completely the necessarily complex problems of that uncertain world.

The most valuable use of such models usually lies in shedding light on how much difference an alteration in the assumptions and/or variables used would make in the answer yielded by the models. The process of model formulation virtually forces on us both a better understanding of complex problems and a rational critique.

Supporting Design Function (SDF)

A discussion of the typical support required (In the area of machinery systems) may provide additional insight into concept formulation for those on the producer side of the Naval establishment. The Power, Propulsion and Auxiliary Systems Department of NAVSEC has prime responsibility for the support and assistance required by the SCDD in respect to machinery systems. In the following discussion, the term machinery systems includes the main propulsion and auxiliary machinery and systems. The same principles can be applied to other technological areas such as: weapons, sensors, personnel and protection.

These systems make a significant contribution to the displacement, proportions and the "cradle to grave" cost of the ship. They are necessarily an essential consideration in determining even a first order approximation of ship proportions and cost. These systems will therefore be taken into account in conducting any analysis of initial ship cost and ship operating cost.

Figure (5) illustrates the way which these systems are related to the mission requirements and to the proportions and displacement of the ship. The contributions these systems make to construction costs varies with the type of ship, e.g. a modern combatant has very expensive weapon and electronic systems. The range is approximately 15 to 30 percent of ship construction cost. The machinery systems require fuel, lube oil, fresh water to operate, replacement parts, periodic maintenance, repair and overhaul and these contribute to the cost of the ship ownership.

Those concerned with these systems are directly involved at every step of the ship design evolution today. Concept Formulation will not lessen but will enhance their role, as well as the role of all members of the producer side of the Navy, in the decision processes which shape the shipbuilding program.

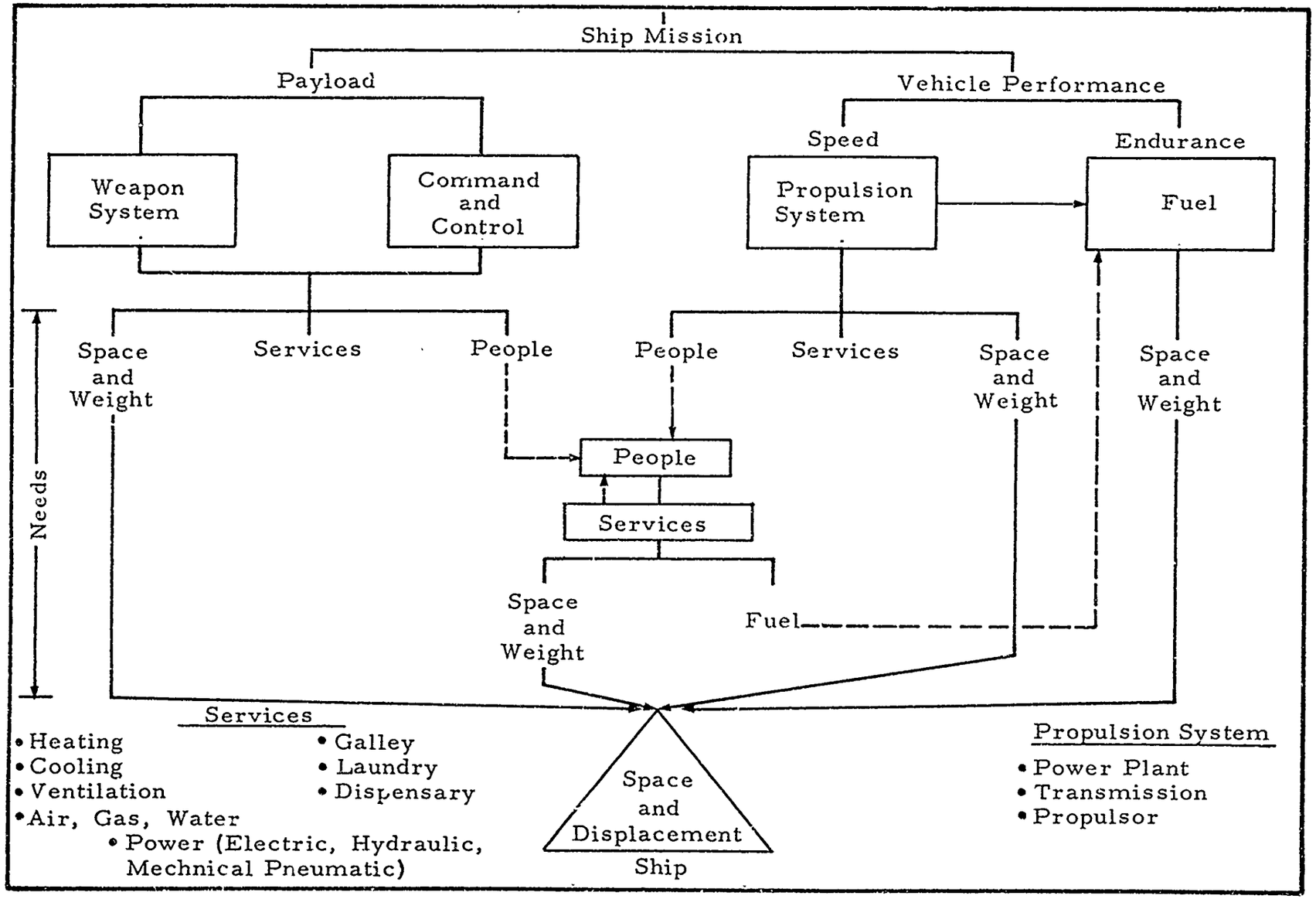


FIGURE 5 - SHIP CHARACTERISTICS/MISSION RELATIONSHIPS

At present, the naval architect does not proceed very far before he turns to the machinery systems engineer for assistance. The information and advice provided by the naval engineer results from a comparison of the requirements and constraints with his experience and his knowledge of machinery characteristics. From this he will arrive at his conclusions about the weight and space needed for the machinery systems. However, this dialogue becomes impractical during Concept Formulation. Concept Formulation will involve the comparative (economic) analysis of a large number of alternative ship system configurations not differing by large degrees. These ship configurations may not be like anything the Navy has built before. The integrity of this analysis requires that these alternatives be evaluated consistently and objectively and therefore the same data, criteria and analytic procedures be employed. This will require explicit and quantified expressions describing the characteristics of the subsystems comprising the ship system. While the complexity of the system, the large number of alternative configurations and the existence of these explicit expressions will lead to the use of digital computers, it should be emphasized that their employment does not generate the need for explicit expression although it will influence their form.

The prior support function role of those concerned with machinery systems is to provide such information before the Concept Formulation begins sothat the SCDD can develop reasonably realistic appraisals of the influence of different machinery systems on the total cost and characteristics of ships with the assurance that the,

a. Appraisals are objective and consistent from one ship to another.

b. Appraisals reflect the policies, technical practices and criteria which would be applied if this information was provided manually.

c. Appraisals reflect the same policies, technical practices and criteria that will be applied throughout successive stages of the ship's design and construction.

Filling the support function has by no means obviated the need for advice and assistance during the execution of this new approach. If anything, the Prior Support Function creates a need for concurrent support. As we will discuss more fully later, the irony of the explicit expressions is that while generalizations, they represent specific system configurations. Astute judgement, not just experienced judgement is required in the selection of which explicit expressions are appropriate to use at any time and in the evaluation of the results they produce.

The development of these expressions will require the cooperative efforts of the system analyst and the component specialist. The systems analyst determining the functional relationships of elements in the systems and providing the component specialist with guidance on the nature of the information he must provide. In turn, the component

specialist contributes to the identification of what elements are of relevance and significance by supplying the system analyst with the means of assessment. This partnership is important for another reason, and it is worth repeating to emphasize this point. The general criteria, policy, and state of the art which these expressions reflect must be what will be expected to be applied at successive stages of the ship design. It is imperative that those who will bring the design to fruition are involved in its formative stages.

This close involvement of the sub-system designer (viewing the ship as the system) will be the case whenever the significance of the system warrants. The task for those responsible for management of the concept formulation and those responsible for the over-all analysis is to achieve this close involvement of the sub-system designers and experts as the situation may warrant, in an efficient manner which is not prejudical to the timely execution of the effort. The relation between ship systems analyst and the sub-system designer, applies to the sub-system analyst (designer) and the component specialist also.

Problems

It is worthwhile to discuss some of the problems which will be encountered. It sounds deceptively simple, but before any analysis begins one must decide what to analyze. Ideally the problem would be subjected to several brainstorming sessions and all the resulting ideas would be thoroughly analyzed to determine whichwas best. We exist in a real world however and manpower and money are limited. We must decide which of the ideas show some promise of value and which, however interesting, are clearly not going to be cost-effective. An essential part of the problem is deciding who will draw the line. A good rule of thumb is to assume that all responsible personnel, military and civilian, are reasonably intelligent people and include in the analysis, all ideas seriously supported by any of the same. Limitations of time and manpower may restrict the size of the list but there is every indication that DOD discourages this practice. That is, they feel that an extra investment in the time and money spent on Concept Formulation is a valid investment in the future.

Another problem encountered early is the general approach to be used in the analysis. For example are we going to assume constant effectiveness or constant cost. In general it is desirable to use one or the other or both but in many cases the analyst falls into the trap of varying both simultaneously. In this case it is difficult to make valid comparisons. One must pick an approach appropriate to the type of information available and to the type of information desired. Some basic assumptions are often part of this selected approach and it is necessary to evaluate the effect of these assumptions. This choice of approach and basic assumptions is particularly important while we are in the first phase and coordination of the variousagencies is crucial.

Another common problem encountered in C.F. is the analysis of developmenting systems. Any list of the systems which might suit the

problem at hand will include some new systems. Of course all systems must meet the first requisite by the time C.F. is completed but this still leaves room for imminent systems. In this case, it is hard to obtain the meaningful quantitative relationships so essential to parametric analysis. To handle these systems, analysts must work with experts in the new system to study expectations and effects. Considerable judgement is required and it must be applied with discretion.

Lastly, it is necessary that we understand the limitations of the parametric expressions representing subsystems as these explicit expressions are generalizations and hence pertain to the whole and are not precise or definite. Being explicit, and yet general, requires that their formulation proceed to the general from the particulars.

Systems are composed of a number of interrelated components. Different combinations of components exhibit different characteristics. Each system design is developed to satisfy the requirements of the ship in which it is installed. Over the years, design criteria and policies have undergone changes as a result of the evolution of technology and our experience in its application. As we well realize, the Navy does not build standard lines of ship types evently covering the size spectrum. For these reasons, empirical expressions derived solely by statistical inference from existing systems are limited to their application. They will usually be inadequate for more than first order approximations when they themselves represent a system. In some case such expression will be acceptable.

It is beyond the scope of this paper to describe, in detail, the formulation of these expressions. In general, there are three approaches, each one successively more involved. When the item for which an explicit parametric expression is desired is of minor importance but must be considered, an empiricism derived from past designs will probably be sufficient. When large data scatter exists and/or the data does not all represent current policies, practices or state of the art, it will be necessary to filter out the inappropriate data and then derive the generalization. If insufficient quality and/or amount of data reflect current policies, etc., or even though supposedly representing current policies, etc., a large data scatter exists then the resort must be to synthesizing the generalizations. Experience to date indicates that this last method will be required in formulating the major system expressions.

IV. SUMMARY

The stage seems to be set for a major advance in the pre-design activities of Naval ship development. By honest recognition of the deficiencies, identified by those involved as well as by higher authority; backed by the willingness to make more resources available to improve the situation, the U.S. Fleet will become an even more formidable instrument of peace in the future.

By organizing both personnel arrangement and intellectual process, especially for the new look of Concept Formulation, directed participation

throughout the Navy will contribute to a viable program.

The ASDP must take into account all the foregoing problems and requirements and ensure an effective responsive force for attaining the objectives of C.F. The achievement of this goal depends upon the initiative, creativity, and resoluteness of each of us whose field of endeavor is affected and who are personally accountable for the success of this venture.

Prudently applied and astutely directed the benefits of the concept formulation approach should be well worth the effort. Comprehensive and objective analysis will not only result in an exemplification of the essence of engineering -- the economical use of resources in the service of man -- but will reduce the waste of resources of our present methods for spotlighting the proper direction.