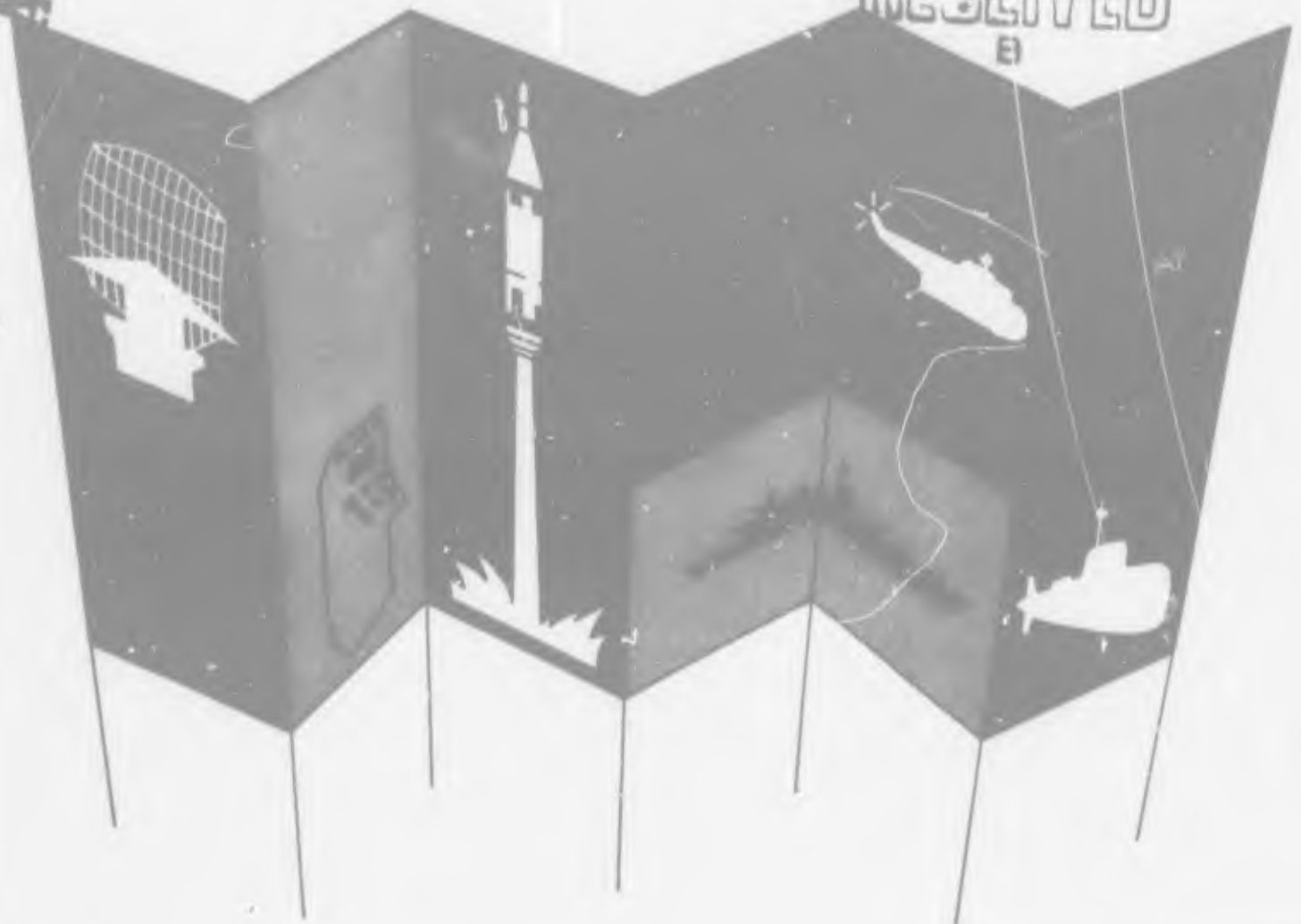


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PROCEEDINGS OF THE NMC FOURTH SYSTEMS PERFORMANCE EFFECTIVENESS CONFERENCE

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Proceedings of the
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SYSTEM
PERFORMANCE
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Navy Material Command.*

T. T. McGillicuddy

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Commanding Officer and Director
U. S. Naval Applied Science Laboratory

CONFERENCE PROGRAM

Session I — Fleet Problems — The Challenge

Moderator —

CAPT P. P. Vail, USN
Director, Technical and
Support Engineering Office
NAVORD

Session II — Meeting the Challenge — Techniques

Moderator —

Mr. E. Jehle
Technical Director
U. S. Naval Applied Science
Laboratory,
Brooklyn, New York

Session III — Meeting the Challenge — Programs

Moderator —

Mr. F. J. Schiavi
Director, Technical and
Systems Engineering
Office, NAVORD

Session IV — SPE Impact on Acquisition

Moderator —

Mr. E. J. Nucci
Staff Assistant,
Engineering Management,
OSDDR & E

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WASHINGTON, D. C.

MAY 8-9, 1968

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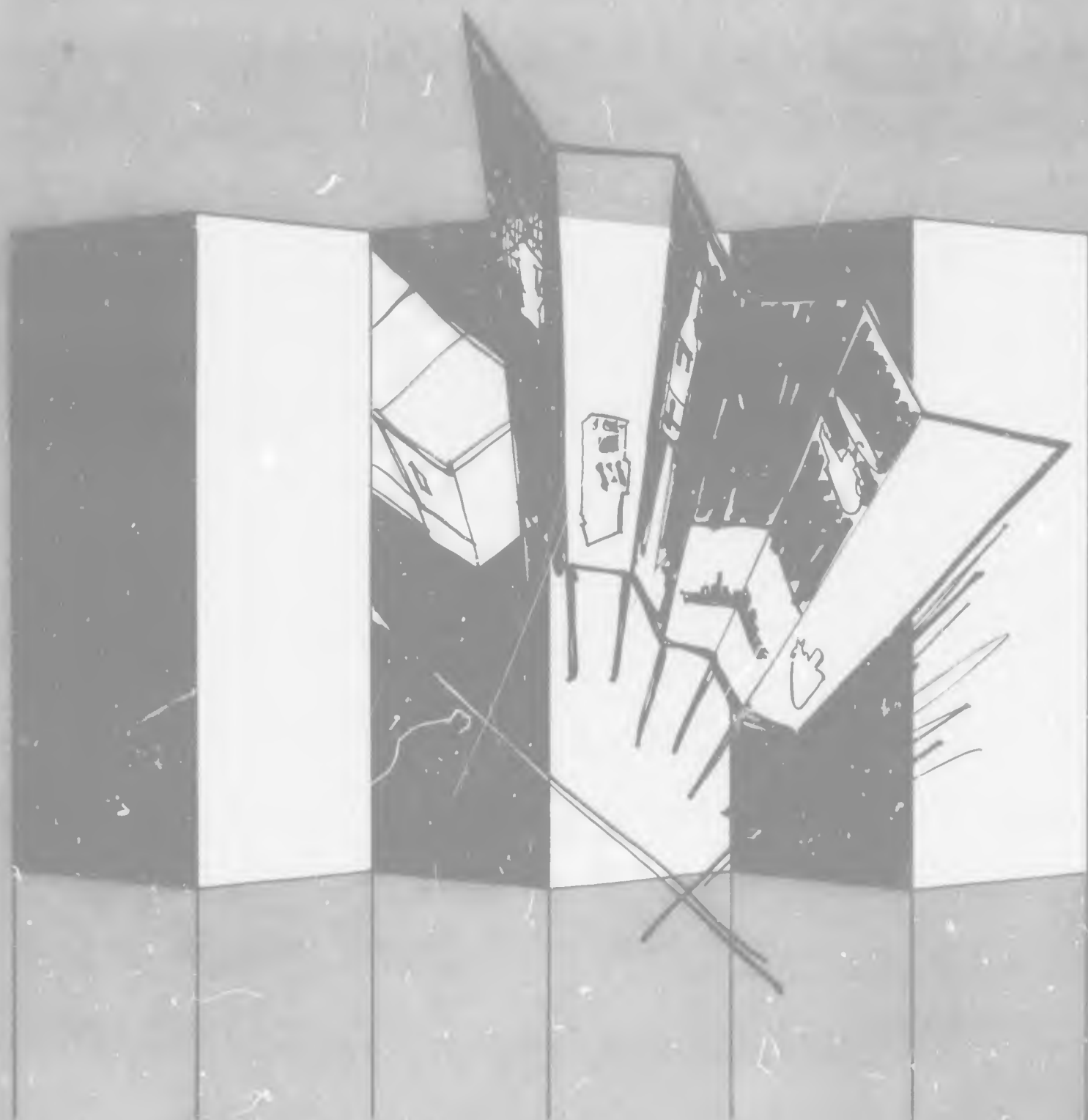
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CONFERENCE OVERVIEW

MR. L. D. WHITELOCK



The SPECON 4 Program Committee was guided in its selection of papers by the conference theme: "Enhancing the Effectiveness of Fleet Systems—A Problem of Teamwork."

The papers presented at this conference are indicative of the wide scope of effort now underway to predict, to measure, and to improve the performance effectiveness of Fleet systems. In these "Conference Overview" remarks, rather than summarize any of the papers presented, I wish to stress the "teamwork," and the data and communications integration aspects, essential to the achievement of systems effectiveness.

First, looking at figure 1, let us review the "teamwork" required against our "check list" of factors involved in systems effectiveness. This figure is also found in NAVMAT P3941. One industrial concern defines systems engineering as a scientific/engineering/management team discipline. In this vein, SPE in the Navy is a scientific/engineering/management/military operations team discipline involving the Chief of Naval Operations, the Fleet, the Chief of Naval Material (and his associated systems commands), the Bureau of Naval Personnel, and all industrial concerns doing business with the Navy.

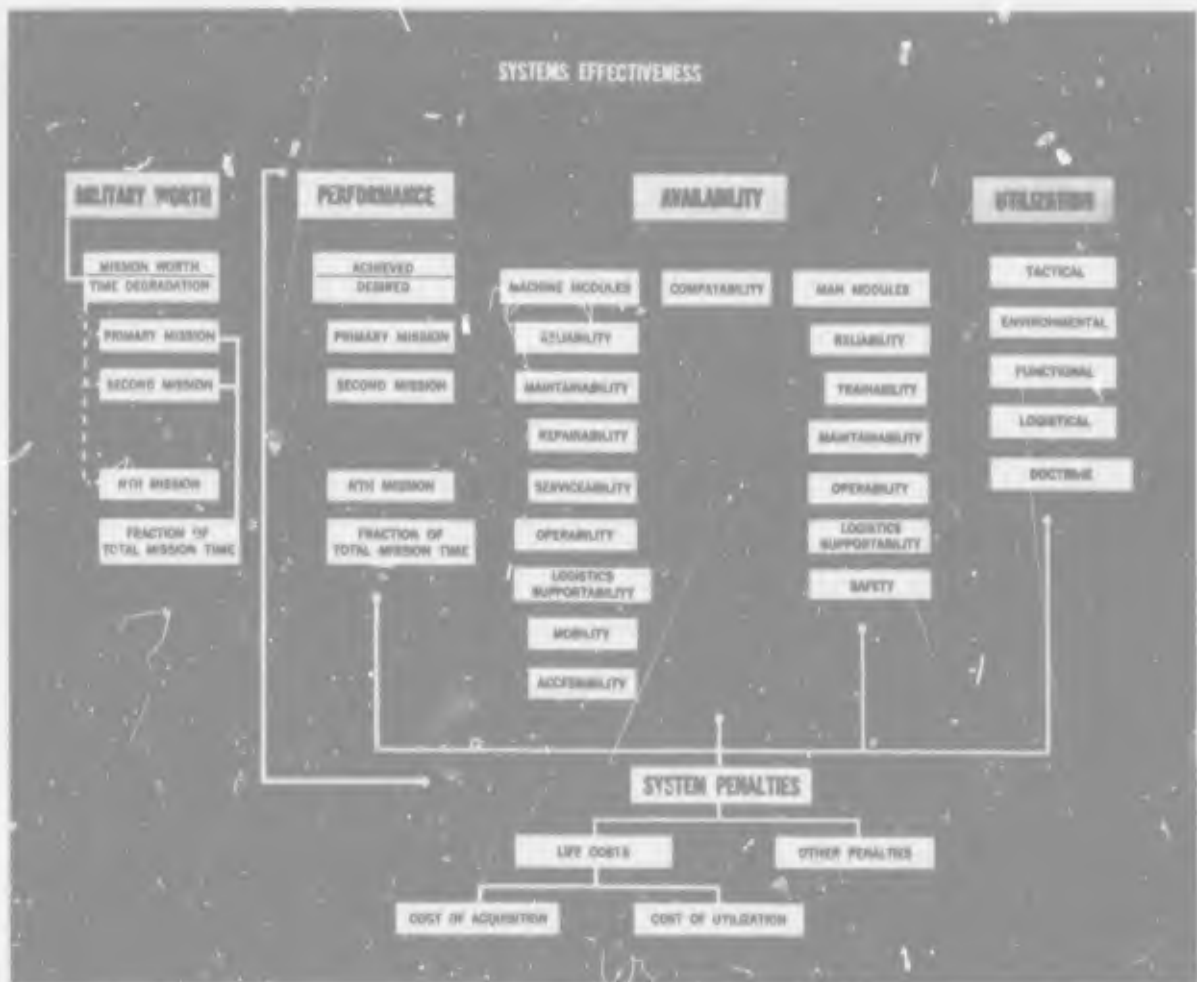


Figure 1

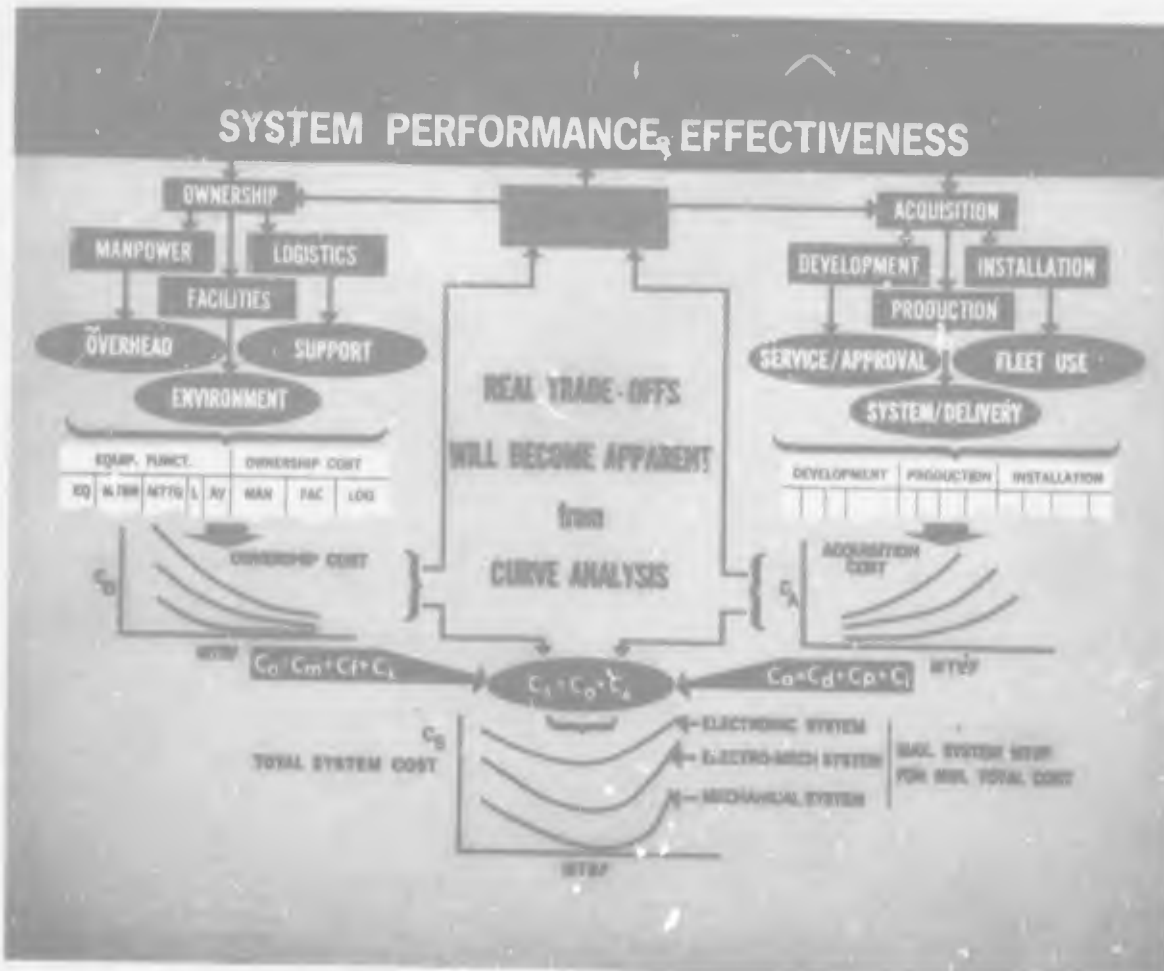


Figure 2

"Team" responsibilities are briefly summarized as follows:

MILITARY WORTH

CNO/Fleet—Mission analysis and system operational requirements.

CNM/Systems Commands/BUPERS—Systems design criteria, facilities, logistics, and personnel.

Industry—Design criteria and design implementation.

PERFORMANCE

CNO/Fleet—In-service determination of "achieved" versus "desired" performance and information feedback to development activities.

CNM/Systems Commands—Performance specifications, including effectiveness criteria. Facility and logistics support.

BUPERS—Personnel selection and training.

Industry—Equipment and system design, manufacture and test per specifications.

AVAILABILITY

CNO/Fleet—Operation and maintenance.

CNM/Systems Commands—System design criteria for reliability, maintainability, operability, logistics supportability, and facilities support.

BUPERS—Personnel selection and training.

Industry — System design, manufacture and testing for adequate reliability, maintainability, operability, and logistics supportability.

All Concerned—Safety and human factors.

UTILIZATION

CNO/Fleet—Tactical and strategic use;

All other "team" members are concerned with how the systems are used—Time, environmental factors, etc., so subsequent designs can be improved.

Appropriate information feedback from the Fleet is important to the overall "team" effort for SPE enhancement.

The second point that I will discuss, is that data and communications integration is essential. Figure 2 depicts the important interface relationships in arriving at an optimum level of System Performance Effectiveness. It is clear that adequate intercommunication of data is required within the SPE "team" to make appropriate tradeoffs between cost and important SPE factors.

As yet, data integration to meet the requirements of such an analysis is inadequate but improving. For instance, Reliability (MTBF) is important to the measurement of effectiveness, yet reliability prediction techniques and reliability validation techniques for actual performance in the Fleet need further development to provide the integrated data required.

In closing, I believe all SPE "team" members will be interested in answers to the question, "What's next in SPE?" Between now and SPECON 5, which is our channel for integrated communications on effectiveness,

and which we expect to schedule for May 1969, the NMC SPE Steering Committee will focus attention on the following:

- Data and communications integration problems
- Effects of combined environmental factors on effectiveness
- Packaging uniformity (update NAVMAT P3940)
- System effectiveness philosophy and techniques (update NAVMAT P3941)
- Human factors (2 symposia have been held, another is being planned)
- Coordinate and publish several system design guideline manuals, and similar documents on such subjects as microelectronics, design disclosure techniques, design review, and expanded GEM
- Provide a focal point for effectiveness communications by scheduling monthly steering committee meetings for appropriate discussions and presentations.

Very broadly speaking, I believe that the wide scope, the type of papers presented in this conference, and the subjects planned for future attention indicate that systems effectiveness is an emerging technology and methodology for multi-discipline integration.

Each of us has a part to play in its continuing development!

WELCOME AND
OPENING REMARKS

ADM A. B. GOODFELLOW
MR. J. W. STONE



SPECON
4



On behalf of Rear Admiral A. S. Goodfellow, Deputy Chief of Naval Material for Development, it is indeed a pleasure to welcome you to the Fourth Systems Performance Effectiveness Conference sponsored by the Naval Material Command. The large number of attendees and the varied organizations represented here is most gratifying and demonstrates the significant role Systems Effectiveness performs in the development of today's systems.

The evolution of Systems Effectiveness in the Navy has followed the pattern outlined by OSD in the DOD Directive 3200.9. The first SPECON, held in the spring of 1965 can be equated to the results of the "Concept Formulation" phase as it displayed the evolving methodologies and techniques of Systems Effectiveness. SPECON-2 of 1966 represented a "definition" of the Navy's Systems Effectiveness efforts by providing methods of predicting, measuring and demonstrating. Last year's SPECON-3 placed us in the "development phase" and followed its theme "Implementation and Application of Systems Effectiveness into Navy Programs."

This year SPECON-4, the fourth of the Navy's annual series, is geared to the theme "Enhancing the Effectiveness of Fleet Systems—A Problem of Teamwork." While still in the "development phase," Systems Effectiveness in the Navy is being tested and validated. As with all tools the usefulness of Systems Effectiveness will improve as the skill of the users improve.

It is our privilege to have Rear Admiral Frank L. Pinney, Jr., Commander, Operational Test and Evaluation Force, present the "Keynote Address." Admiral Pinney is very knowledgeable of the Naval Material Command Systems Effectiveness efforts and will draw parallels with the factors tested for by OPTEVFOR.

KEYNOTE ADDRESS

RADM F. L. PINNEY



The Navy's Operational Test and Evaluation Force has a major stake in the products which this conference is designed to improve. "The effective performance of Navy systems in Fleet use is essential to successful Naval operations." Those words are quoted from the foreword to the Navy systems performance effectiveness manual, a document which was first published one year ago this month. During the past year, the Force which I command has been involved to a greater or lesser degree in determining just how well this objective has been met in the several hundred active projects assigned to us. I have reluctantly concluded that progress in enhancing the effectiveness of Fleet systems has been minimal. To bring home my message, I will first discuss our views on the system effectiveness model and its relationship to the development process and then give some recent examples of our experiences in proving the worth and effectiveness of Navy systems.

It must be understood that OPTEVFOR's participation in the process of getting new weapons systems to the fleet falls into two main categories. The first is the development assist test in which we participate to a greater or lesser degree with the development agency in scheduling services and arranging for the installation, test, and evaluation of developmental equipment in ships and planes of the operating forces. The second category is the true operation evaluation in which the developing agency certifies that the system meets the design specifications, is reliable, maintainable, and in all respects ready for quantity production and approval for service use. A third and most important category, but not directly related to the acquisition process, is the Fleet operational investigation in which we attempt to devise new tactics and procedures for in-service systems to meet new threats, or find out how best to use something we already have. Here I would like to say parenthetically that too many systems

are being presented to us as a *fait accompli*, already in production, that will not do what they are supposed to do. It is our job to find out how to best use them.

The elements which make up the systems effectiveness model are identical with those around which we design our test plans. Such elements as mission performance, reliability, maintainability, safety, logistics support, tactical use, and doctrine are all key points in our OPEVAL plans. To pass our tests then, a system must be satisfactory in all applicable elements of the effectiveness model. And here, I must insert a note of caution: we do not look at the cost of the systems we evaluate since by DOD directive they are required to be cost effective before they are approved for development. I regret to say that some of the systems we evaluate appear to be rather costly in terms of the results they produce, and some others, which were presumably cost and performance effective when they fought their way through the ideological jungle of concept formulation, and the paper forest of contract definition, seem to have had the sharp edges of performance, availability and utilization slightly dulled!

Considering the first of the three SPE factors, performance, OPTEVFOR in our OPEVALS is directly and totally concerned with determining whether or not the system achieves its design criteria and carries out its assigned mission in the established time frame and under Naval environmental conditions. But the fact that a system or component meets specifications does not necessarily mean that it will perform its mission effectively. The following example will serve to illustrate my point. Several years ago a sonar designed to locate mines was evaluated and recommended for service use. It was far better than any existing device and had a probability of detection of .55 for the slant range specified and a probability of correct classification of .83. Subsequently, an explosive device was developed to neutralize mines by

detonating them and found to have a probability of hitting the target of .77 and a material reliability of .87. Putting the two gadgets together and changing their combined mission to that of ininefield clearance, was an obvious next step. Faultless logic and impeccable mathematics led to the conclusion that by using them together and changing the mission the kill probability of the system as a whole would be .56 if detection of the mine were assumed. Alas, in actual tests such was not the case. The sonar detected the mines as predicted, but more than half the time the destructive device blew up the anchor and not the mine. In addition, after each detonation the sonar was masked for such a long time that the maximum clearance rate which could be achieved by a single minesweeper was three one-hundredths of a square mile per hour, and an average of 4.7 destructors instead of two, would be needed to neutralize one mine.

Availability of systems depends upon some of the elements which are most often found deficient in our evaluations: reliability, maintainability, safety, and repairability. The faults we find in these elements are more often due to poor design rather than poor workmanship, probably because equipment destined for OPEVAL generally gets the type of treatment reserved for the chairman of the house committee in the club dining room. This is really an asset because it focuses our attention on design deficiencies, and at the same time gives us a standard of manufacturing quality which can be useful if quality control fails in later productions. Some examples of deficiencies uncovered would be funny if they weren't so costly and time-consuming to correct. A radar antenna designed for a carrier that wouldn't rotate when the wind speed exceeded 40 knots; a radar relay and junction box with exterior wave-guide connections, and inside the box, bare copper wires to carry the X-band energy with resultant cross-coupling; an underway transfer gear that works beautifully on land, but is unusable when mounted on a working ship's structure are just a few samples of the material deficiencies that continue to crop up in our systems. There are still many designers—too many, in fact, who forget that hu-

man beings must maintain and operate the gear. Quite recently, we evaluated a large fire control radar console with a seat built so high and close that the operator couldn't get his knees under the ledge and had to sit side-saddle to operate it. A glide slope error meter in a landing control radar console was oriented so that it deflected left and right of the center position to show error above or below glide patch. This was confusing, to say the least.

Now let me give you some numbers to support my earlier contention that the systems being presented for evaluation do not appear to be improving in effectiveness. During the past 15 months, the OPTEVFOR has completed—or terminated—23 full scale operational evaluations involving thousands of manhours, hundreds of flying hours, and many weeks of surface ship and submarine time. Of these 23 evaluations, four were terminated because the systems were so unready for service use that a meaningful evaluation was not possible. Six were not recommended for service use, three were provisionally recommended, and only ten of the 23 were recommended for service use. Bear in mind that each system had been certified by the developing agency as meeting the specified performance criteria: was capable of accomplishing its mission, was reliable, maintainable, and ready in all respects for Fleet introduction, and quantity production.

Now, what can be done to ensure that the systems reaching the Fleet do perform effectively in a maritime environment? First, I think you gentlemen must devise methods to make the disciplines of SPE effective, enforceable, and mandatory. The simple fact is that if every system met all the valid criteria there would be no need for proving its worth through OPTEVFOR evaluation. Secondly, developing agencies should make maximum use of the development assist test so that the advice and assistance of Fleet personnel in a seagoing environment can influence the course of development as early as possible in the cycle. The 1300 officers and men of OPTEVFOR are not only skilled in the various technical and scientific disciplines but they are also, to a man, operators who have a vested

interest in seeing that our Navy gets the most effective weapons systems this nation can provide.

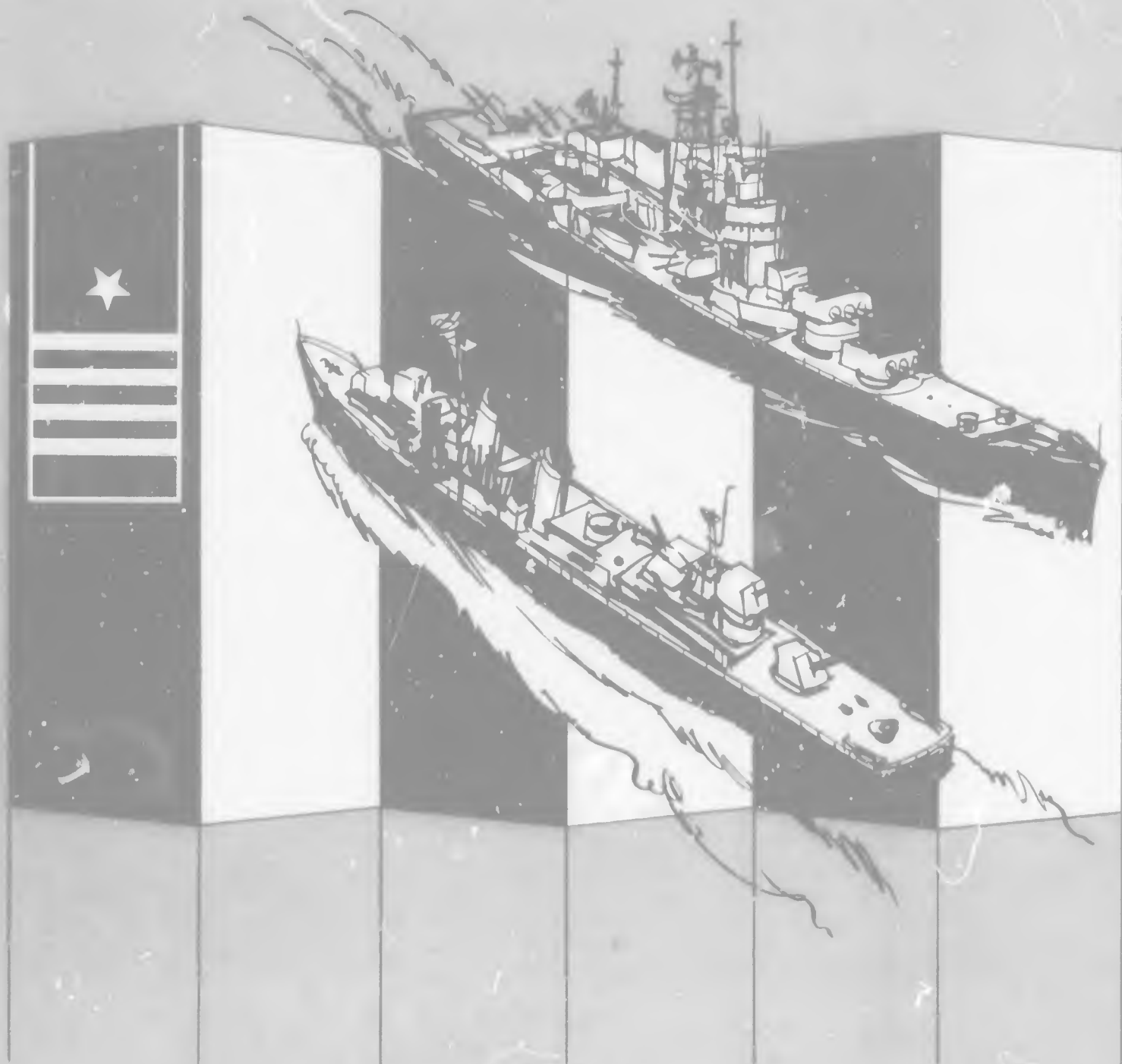
We have many systems which do perform effectively, but much remains to be done to publicize and enforce the disciplines of SPE.

I wish you success in this conference in moving toward our goal of systems which complete their assigned missions within the established time frame, and under the specified environmental conditions.

Thank you.

TODAY'S PROBLEMS IN FLEET EFFECTIVENESS

CAPT P. B. SMITH



Cruiser-Destroyer Force Pacific consists of 174 ships and 55,000 officers and men. Among a group of companies ranking fourth in the nation, CRUDESPAC has a capital investment of 4.8 billion dollars and an annual operating cost of 0.5 billion dollars.

In spite of our size and what we hear these days about DX and DXG, over half, 54 percent of the Force is in excess of 20 years old, 20 percent is between 11 and 20 years old and only 22 percent is less than 10 years of age.

FORCE MAINTENANCE

As the Cruiser-Destroyer Force Commander, RADM Freeman's responsibility is primarily that of supplying ships to the numbered Fleet Commanders, COMFIRSTFLT and COMSEVENTHFLT. As a wholesale supplier, he wants and expects that these ships are to be prepared for fleet operations and deployment in maximum material condition of readiness within available funds and that they remain in this condition during sustained operations with limited upkeep periods. This material condition within the Force is usually accomplished by judicious work request screening policies, and effective ship's force personnel management during regular overhauls and restricted availabilities. RAVs (restricted availabilities) are primarily for unscheduled repairs of an urgent nature that cannot be delayed until the next overhaul. Occasional planned RAVs are scheduled for specific alterations, updating systems, or installing new equipment.

Maintenance Management is stressed strongly within the Force and it involves the maximum use of all available resources of money, people, and time. Decision must be made as to the level of maintenance required: ship (organizational), tender (intermediate), or shipyard (depot). Engineering judgment is exercised in the determination of the scope of repairs authorized. The judicious apportioning of a ship's total required overhaul (ROH) and restricted availability (RAV) repair package among an industrial activity,

destroyer tender, and ship's force results in optimum utilization of all available assets. Appropriately assigned repair work performed by ship's force personnel during an ROH/RAV results in greater shipboard competence and confidence in ship repair capability. This asset manifests itself in greater underway reliability and reduced repair costs. The nondependence on industrial activities for all but major repairs is not only desirable economically, but is also a vital asset when operating in a combat zone for extended periods. Effective maintenance management includes not only correction of unsatisfactory material conditions but the optimum use of funds available for this purpose.

The determination of funds required to provide the necessary material support is a function of: Force level, standards of material readiness desired, nature of operations anticipated, knowledge of ship conditions and industrial activities cost information.

The impact of operations in Southeast Asia can best be shown by our experience with unscheduled repairs.

Figure 1 is an illustration of CRUDESPAC funding trends in these restricted and technical availabilities. In FY 1964 we expended approximately \$5.7 million. The amount rose

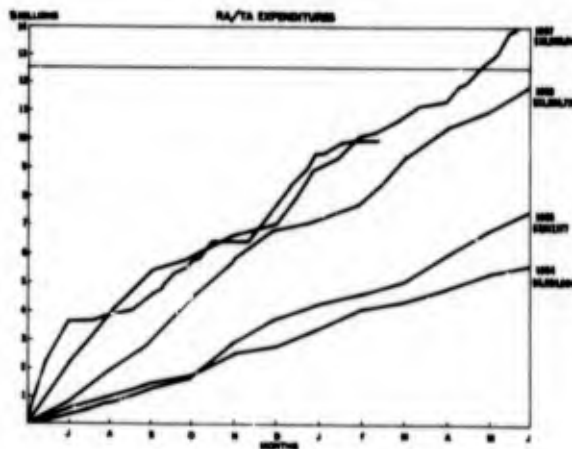


Figure 1

last year until in 1967 it reached nearly \$14 million; 1968 will be about the same. The increase is due to increased tempo of operations, age of ships and labor and material costs.

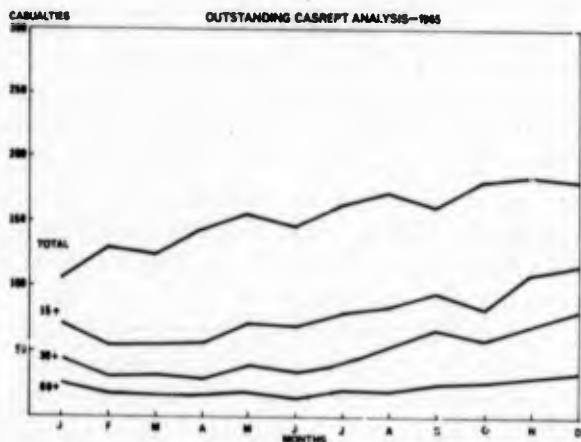


Figure 2

FORCE MATERIAL FAILURE DATA

Figures 2, 3, and 4 illustrate a single factor which is readily identified by Operational Commanders as the most significant ship support problem. As tempo of operations has increased, material casualties have climbed correspondingly. Much has been written on the spare parts problem and the reasons why the industry team is unable to meet the needs of the Navy. The last area over 60 days is of considerable interest to us since it represents

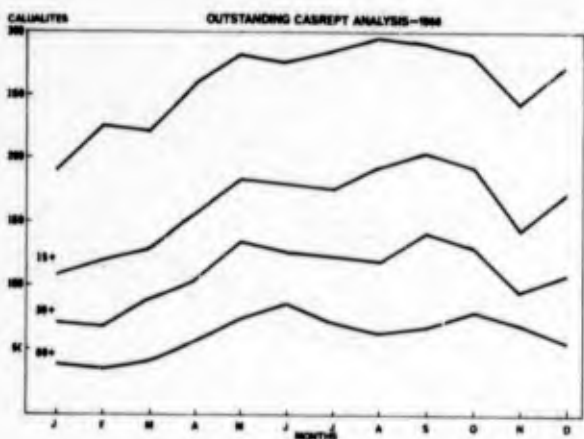


Figure 3

those most irritating if not crippling CASREPs. A breakdown shows 65 percent are due to lack of parts, 15 percent for industrial requirements and technical assistance and 5 percent for miscellaneous reasons. It is sufficient here to point out the problem and to note that though recognized improvement is demonstrated in some areas, the overall condition appears to be degenerating.

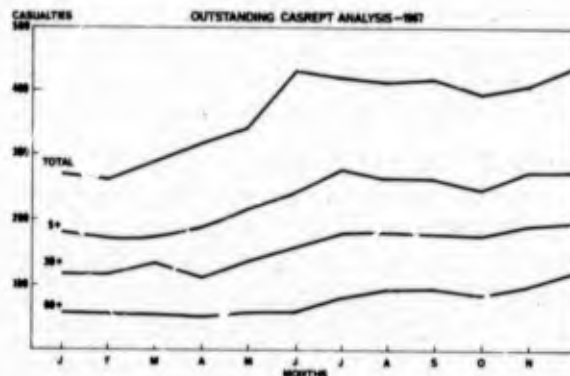


Figure 4

Figures 5 and 6 illustrate a study of ten deployed ships selected at random to illustrate parts support and allowance list conditions in the Force. The most significant point is the low percentage of parts allowed and on board. It might be noted that the ship suffering the longest delay, 163 days, is COMSEVENTHFLT's Flagship, USS PROVIDENCE.

THE TEN BAD BOYS

Computer data on this Force from August 1967 through January 1968 provide us the High Thousand Systems in total corrective manhours and costs. One might expect that in these days of exotic weapons, computers, and communications that these would rank at the top in both categories. However, such is not the case. Ranked in terms of manhours consumed in repair by our Bluejackets are:

1. Boilers*
2. Feed and Condensate Systems*
3. Firefighting Systems
4. Gun Mounts*
5. Ships Service Steam Generators
6. Air Conditioning Systems

PARTS RELATED CASUALTY ANALYSIS

JULY 1967 — SEPTEMBER 1967

BASED ON 10 DEPLOYED SHIPS

Time Delay (Days)	Total CASREPs	Cumulative		Parts Allowed and O/B	Parts Allowed Not O/B	Parts Not Allowed
		% Parts or CASCOR	Total Parts Required			
0-7	16	25.6	34	1	6	27
8-15	14	73.2	27	0	6	21
16-30	7	90.2	11	0	1	10
31-45	3	97.6	8	0	0	8
46-60	1	100	1	0	0	1
61-90	0	100	0	0	0	0
91-120	0	100	0	0	0	0
Over 120	0	100	0	0	0	0
TOTALS	41		81	1	13	67

(100%) (1.3%) (16.0%) (82.7%)

MEAN CASCOR — 10 DAYS

LONGEST DELAY — USS BRIDGET 53 DAYS

Figure 5

PARTS RELATED CASUALTY ANALYSIS

OCTOBER 1967 — DECEMBER 1967

BASED ON 10 DEPLOYED SHIPS

Time Delay (Days)	Total CASREPs	Cumulative		Parts Allowed and O/B	Parts Allowed Not O/B	Parts Not Allowed
		% Parts or CASCOR	Total Parts Required			
0-7	20	33.3	38	1	9	28
8-15	15	58.3	20	0	5	15
16-30	19	90.0	86	10	46	30
31-45	4	96.7	22	2	0	20
46-60	0	—	0	0	0	0
61-90	0	—	0	0	0	0
91-120	0	—	0	0	0	0
Over 120	2	100	51	0	0	51
TOTALS	60		217	13	60	144

(100%) (5.9%) (27.6%) (66.5%)

MEAN CASCOR — 9 DAYS

LONGEST DELAY — 163 DAYS USS PROVIDENCE

Figure 6

7. Distilling Plants
8. Search Sonar*
9. Heating and Ventilating Systems
10. Fuel Oil Service Systems

Ranked in order of cost to repair, that is the cost of the repair parts, used by the Blue-jacket, are some systems we might more likely expect:

1. Fire Control Radar and Director
2. Gun Fire Control Systems
3. Air Search Radar
4. Search Sonar*
5. Communication Transceivers
6. Height Finder Radar
7. Boilers*
8. Gun Mounts*
9. Guided Missiles
10. Feed and Condensate Systems*

You may note that four systems indicated by the asterisk appear on both "Bad Boy" Lists. To give you some figures to gauge the type of CASREPs — total boiler CASREPs run 5 percent of the total. The 1200 psi boiler has very slow part procurement. Safety valves, stop valves, superheater piping are typical examples. Currently boiler costs run 10 percent of total overhaul costs or 90 to 100,000 dollars.

The message from the Type Commander is that we want new ships and new systems to fight the threat of the 1970s, but even more we need more reliable equipment to do the things we have to do right now! We are much more interested in talking about better maintainability and reliability with simplified methods in our present ships, than new and more complex ways to do things in ships to come!

A NEW APPROACH

The greatest single aid to the Type Commander in solving his material problems would be standardization. Not a new concept by any means, but it would be new to the modern fleet. For example, here is a breakdown of installed equipment in three of our newest CRUDESPEC DLGs:

DLG 20 (TURNER)	728 Peculiar
DLG 22 (ENGLAND)	426 Peculiar
DLG 24 (REEVES)	496 Peculiar
DLG 20-22	309 Common

DLG 20-24	300 Common
DLG 22-24	318 Common
DLG 20-22-24	1747 Common
Total Diff Equip	4319

As much as 4,319 different equipments to support in three identical ships of the Force appears to be completely illogical!

HABITABILITY

In spite of the advent of new products and improvements in our daily life ashore, progress within our new ships in the area of habitability has run from slow to non-existent. Overall berthing compartments have been slow to improve in regard to deck coverings, selection of paint colors, bunk lighting and module berthing.

Of significant concern is the location of living spaces, heads, washrooms and mess decks relative to other functions in the ship. Except for a positive military requirement, the use of mess decks and living compartments as passageways should be avoided. The distant location of heads and washrooms from living compartments is functionally impractical in some ships, making general visiting an awkward affair.

Design improvements in heads and washrooms have been exceptionally slow. Unduly high humidity exists in many areas, in spite of our proclaimed progress in the science of ventilation!

New ideas are needed in the design and construction of wiring and pipe free living areas in order to provide the officer, and blue-jacket, pleasing as well as functional living conditions during long periods at sea.

MAINTENANCE AND REPAIR COST REDUCTION

Of interest to the Type Commander are any methods which will provide shorter and less costly overhaul periods. Two plans for weapons alteration and repair have been tried by COMCRUDESPEC with considerable success.

One is the establishment of a weapons system test team, which together with the ships force conducts all subsystem tests. The overhaul or refit yard conducts component and cold check testing only. This system reduces

the costly number of redundant tests and the number of engineers and technicians required in the shore establishment.

Another, for shortening overhauls, has been the farming out of complete guided missile fire control radar subsystems. These are altered and repaired by a major radar contractor at his plant while other systems are being repaired at the shipyard. This is another example of the use of the naval shipyard as the nucleus organization and prime contractor, having special industry teams on call on an as needed basis.

Speaking of teams, the TEAMS, acronym for Test Evaluation and Maintenance System presently under operational evaluation in this Force on COONTZ (DLG 9), is viewed with great hope as a time and cost saving system for our future electronic and fire control technicians. Such a system along with communication monitoring and automated propulsion control systems are long overdue in the Cruiser-Destroyer Force to meet the needs and the training level of maintenance personnel.

A chronic shortage of technically experienced personnel exists in the Navy. Historically, total numbers are available to meet overall needs. This is accomplished by large numbers of first term personnel, essentially untrained, who are trained by the Navy to what might be described as the apprentice level. These personnel use basic knowledge in a technician specialty. These men are or can be skilled in diagnostic repair procedures which are not too profound. Equipments must be built with diagnostic readouts designed for the skill level of a man with no more than basic training of one year!

MAINTENANCE AND MATERIAL MANAGEMENT (3-M)

As a matter of policy no equipment should be designed that requires contractor support for maintenance. The Navy is a mobile force and cannot be tied to production or vacation schedules at a contractor's plant! No company large or small should consider himself qualified to build equipment for the Navy if he does not know the various levels of maintenance and the capabilities of the Navy technician for self-support.

The finest maintenance system yet devised to utilize these skills is available in the Destroyer Force today, the Maintenance and Material Management System (3-M). The Planned Maintenance Subsystem (PMS) and its companion part the MDCS (Maintenance Data Collection Subsystem) provide a complete closed loop maintenance system. The PMS provides each cruiser, destroyer, or tender a complete management tool for nearly every installed system down to component level. The system is flexible to meet both the operating schedules and the unscheduled changes. It is designed for the use of the lowest skill level in the performance of the most simple of maintenance actions, while its companion system the MDCS provides the much needed management data for the Type and Operational Commander or the design engineer or Material Commander.

If you are not a 3-M advocate, I suggest you become one before you consider yourself a member of the Navy-Industry Team.

SUMMARY

There is no question of the ability of the Cruiser-Destroyer Force to operate and to maintain itself at sea under a high tempo of operations in a wartime environment. This has been and is being done daily.

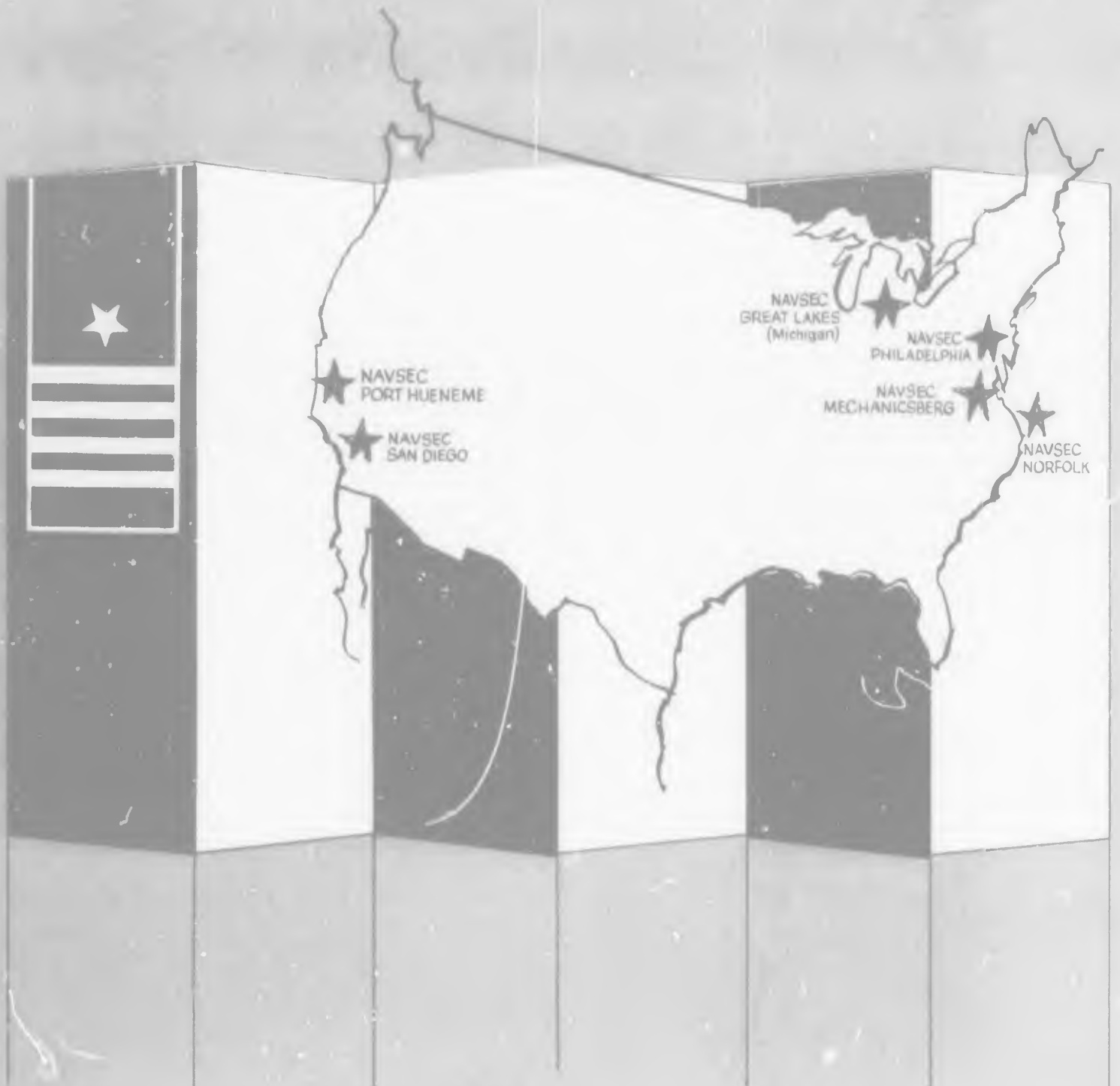
Maintenance management at all levels within the Force and within individual ships is producing a high level of material readiness in both new and old ships alike. There is, however, still much to be done here; both officer and man should have better comprehension of the importance of 3-M to him and to his ship.

Help is needed at the Department and Industry level to provide improved component, subsystem and system reliability. Standardization of design and a better understanding of the Bluejacket in his working and living environment aboard ship will provide giant steps in Force Material Readiness.

With the above there must be better understanding by the designer, of the level of maintenance to be specified, and the level of training available to the Bluejacket called upon to maintain his equipment.

MORE EFFECTIVE SHIPS SYSTEMS FOR TOMORROW'S FLEET

CAPT R. PEREZ



The Naval Ship Engineering Center (NAVSEC) is the engineering arm of the Ships Systems Command. The Headquarters group in Washington headed by RADM Fulton totals about 1900 and has three major functions:

- (1) Design of totally integrated ships.
- (2) Design and procurement of NAVSHIPS equipment.
- (3) Direction of the Field Divisions.

The six Field Divisions, whose population totals about 1300, are distributed geographically. Their primary functions are:

- Main propulsion, auxiliary systems and components (Philadelphia Division).
- Hull, mechanical and electrical equipment and spare parts support (Mechanicsburg Division).
- Electronics equipment maintainability and reliability (Norfolk Division).
- Electronics equipment and spare parts support (Great Lakes Division).
- Combat ship systems engineering support in shipbuilding (Port Hueneme Division).
- Pacific Fleet maintenance support for NAVSHIPS equipment (San Diego Division).

In this manner, NAVSEC defines today's Fleet problems and feeds back improvements for inclusion, by the Headquarters group, in total ships systems integration. On-site definition problems, single activity responsibility for correction, and field verification of adequacy of the modified product, result in accelerated action and improved responsiveness to the needs of the Fleet.

A typical field division operation is illustrated by the Norfolk Division. By systematically looking at an electronics equipment in terms of (1) design, (2) installation, (3) personnel (manning and training), (4) documentation, (5) test equipment, and (6) logistic support, one gets an objective measure

of performance. Under development are maintenance plans which will enable engineers to anticipate and design out problems in these six areas before hardware procurement. Fleet failure data feedback systems, improved provisioning monitoring, quality assurance efforts, and analysis of computerized data contribute to rapid recognition and correction of failure trends.

Similar approaches enlarge the Philadelphia Division support in main propulsion plants and auxiliary systems for the Fleet. The simple fact of age of these systems dictates massive maintenance by all concerned. The tempo of operations in Vietnam precludes normal preventive maintenance, demanding maximum repair effort by the crew, which rank as one of the highest in terms of manhours.

San Diego Division acts as the eyes and ears of NAVSHIPS and provides immediate Fleet support in the San Diego area, as well. Port Hueneme works closely with Headquarters in the design and construction of new ships going to the Fleet.

The most serious Fleet material problem is that of spare parts. If the necessary parts are not on board the ship when needed, the equipment down-time is increased by a factor of 8 to 10. Decreased repair time is less vital a problem, but still an important one.

NAVSEC Great Lakes Division provides the engineering required for efficient determination of quantity and quality of electronics spare parts procurement. Recommendations for design changes and documentation improvement are by-products of this logistical effort. Quantitative data provides realistic justification for action, while utilization of computerized analysis assures an effectiveness measurement for new components.

Another great need exists in hull, mechanical and electrical equipment and their repair parts. The CNM, VADM Gallantin,

considers this one of the most difficult standardization areas, and has given it his personal support. The Mechanicsburg Division, under CAPT Ithi, has defined the problem areas and is vigorously pushing towards a solution. As an indication of the work ahead, there has been a 50 percent increase in the variety of these parts in the last three and a half years. Another indicator is that 64 percent of the variety of these parts exist in only four ships. As can be expected, due to random failure and small population, support here is marginal.

The main causes for this situation are overemphasis on competitive bidding, and the use of performance specifications in lieu of definitive specifications.

Aggravating this problem is the age of ships in the active Fleet; over 60 percent were built during World War II.

NAVSEC's general approach to this problem is the severe limitation on new type parts, and the purge of marginally-supported parts.

Concomitant to improvement of today's ships is the design of future ships and systems to meet tomorrow's threat. Improved systems engineering, systems analysis, linear programming and other operations analysis techniques are used to optimize the allocation of scarce resources. Trade-off studies are more than simple arithmetic computations. They require the latest techniques for quantification and proper weighting of alternatives that can meet probable enemy capability. An essential ingredient is a broad advance in technology. In this short presentation, it is impossible to discuss these developments at length. Furthermore, security constraints on one of the fastest moving technological areas, electronics, must be observed. There is a definite inter-dependence between Fleet personnel and ship system designers for definition and solution of Fleet technical problems. Therefore, the following items can only give an inkling of the wide variety of effort now in progress.

The **Operational Stations Book MIL-0-24312(SHIPS)** is designed to obtain requisite Fleet reaction. It defines the ship system in operational terms and outlines correct

equipment system usage under all modes of operation. An essential part is the feedback system by which the Fleet user can suggest improvements in new design.

Another example is the **Engineering Operational Management System** which provides approved operating procedures for complex machinery plants. It has been successfully employed in aircraft carrier and destroyer escort programs. It integrates equipment technical manuals into system documents, and has significantly reduced machinery plant downtime.

Since manning is the most expensive life cycle cost, ships are designed for centralized remote control. Accordingly, automated machinery plants are being installed in 23 ships which are starting delivery in 1968, and high-maintenance vertical draft blowers are being replaced by new horizontal forced-draft blowers.

Responding to urgent Vietnam requirements, shallow draft boats have been quickly fitted out with armor and improved shock isolation, saving many lives in riverine warfare.

Hull designers have completed the first large Navy catamarans for submarine rescue ship (ASR21), and an oceanographic research ship (T-AGOR), to fill the need for more stable platforms.

Another promising development is the use of glass-reinforced plastic in wooden minecraft. Sections up to 34 feet in length are under test.

Single-screw submarines have large hull penetrations for hydraulic actuators which drive emergency propulsion units. A new externally-mounted electric motor requires only a small cable opening, permitting much safer operation at great depths.

Another propulsion improvement is the use of contra-rotating propellers driven directly from the turbine, which increases submarine speed by about two knots with no corresponding increase in power.

The need for more effective communications continues. NAVSEC has established an Afloat Communications Management Office to coordinate all shipboard communications. By participating in large Fleet exercises (which resulted in immediate definition

of requirements), the office was able to initiate corrective action in quality monitoring, in work studies for improved functional arrangements, and in the installation of automated message processing and distribution facilities. Satellite communications equipment was installed in ships bound for Vietnam. A comprehensive communications system handbook on systems criteria is due for completion this year.

The necessity for increasing strike rate and short turn-around time of carrier aircraft in Vietnam means that decks are normally loaded with armed and fueled aircraft, thus increasing fire hazards.

As a temporary measure three mobile fire fighting units were assigned to each carrier within five months after the FORRESTAL fire. These units are self-propelled and use

light water and dry powder specially designed for gasoline and oil fires.

As a long-range solution, a Flight Deck Conflagration System is under development. Resembling a grant sprinkler system, it is permanently mounted on deck, is zone-controlled, and also uses light water.

In summary, NAVSEC's support to the Fleet encompasses all phases of the ship's life cycle. The Engineering Center takes all steps necessary to ensure that the Fleet is provided with hardware and documentation second to none. By means of modular design, the combat systems of a 30-year ship can effectively be updated. Proof of this excellence is the purchase of our warships and their systems by friendly nations using their own funds.

SYSTEM ORGANIZATION FOR ASW SYSTEMS EVALUATION

CDR A. E. McMICHAEL



INTRODUCTION

System organization for antisubmarine warfare system evaluation became necessary in order to answer detailed questions about fleet effectiveness today and to demonstrate the need for effective new systems in tomorrow's ASW Fleets. These questions proliferated as analytical models multiplied and the credibility gap widened. Fleet validation of analytical models and results were required by defense planners in framing their decisions. The challenge that faced the Chief of Naval Operations (OP-95) was how to obtain statistically valid operational data to validate (or invalidate) analytical results so that momentous decisions might be made concerning the needs of the fleet. The purpose of this paper is to describe the challenge, the plan organized to meet it, and the evolution of techniques to provide the Chief of Naval Operations with data on operational readiness as well as on requirements for research and development.

Problem. Early in 1966, it was evident that there were more users of fleet data than there were generators of it. The fleet-sponsored FACTS tactical data system and the CNO-sponsored FADAP data bank were contributing some valid data. The problem was to obtain these required performance data, without severely over-loading fleet analysis groups.

The problem was complex requiring:

- Design data,
- Technical evaluation data,
- Operational test and evaluation data,
- Fleet evaluation data,
- Fleet free-play performance or validation data.

The first three categories seemed to be well in hand due to their formalized laboratory origins and controlled methodology. The latter two were unable to respond as rapidly as needed because of the high tempo of operations and a lack of means to handle such a dynamic and complex problem.

The most practical answer was to augment certain portions of the fleet with professional technical and operations analysts to assist in exercise design, methodological development, analysis, and report of fleet derived validation data. It was soon discovered that while it might be desirable to have the Operations Evaluation Group (OEG) or a single contractor implement this increase in fleet resources, it was not practical. This was due to the fact that neither the OEG nor a single contractor could provide the expertise or personnel to handle the problem. Accordingly, an alternative plan was devised that would pull together a number of contractors for a specific, coordinated approach to the development of valid methods. In addition, this organization would have to work within the existing chain of command and be within certain budgetary limits. Such a plan would represent a bold step forward in developing a real-world feedback into the research and development cycle.

METHODOLOGY

The analytic support plan initiated by the Chief of Naval Operations (OP-95) consisted of a series of straight-from-the-shoulder directives, which provided for military billets, contractor augmentation, technical developments, and funding, as required by Fleet commands. About two-thirds of these resources were assigned to the Atlantic while the remainder went to the Pacific ASW System. Such a division of resources was dictated by the realities of command structure and forces available for an intensive developmental program responsive to the needs of the Chief of Naval Operations.

Another aspect of the support plan was its comprehensive nature as it included support for:

- Tactical analysis,
- Technical analysis,
- Behavioral analysis.

The tactical analytic support consisted of military billets, in some cases, for additional

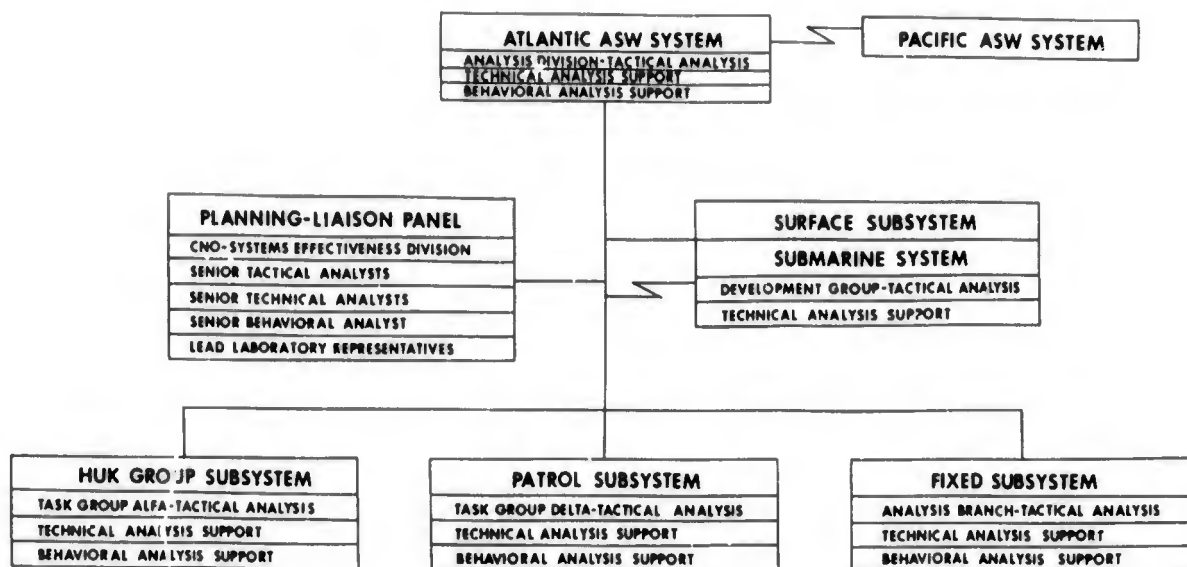


FIGURE 1. SCHEMATIC DIAGRAM OF ATLANTIC ASW SYSTEM AUGMENTATION FOR SYSTEM EVALUATION

Figure 1

operations analysts while in the majority of cases it consisted of civilian contracted operations analysts provided by a fully qualified company. Technical analytic support was to be obtained from Navy laboratories, civilian contractual sources, and, in some cases, other governmental agencies. Behavioral analytic support was to be derived largely from funding of a joint Atlantic-Pacific human factors research and development program. By establishing a schedule of priorities, the Chief of Naval Operations provided merger of tactical, technical and behavioral specialists in support of existing fleet analytical resources. A productive team thus came into being, to provide the comprehensive service, and depth of scientific-technical knowledge required to attack the applied or tactical problems of the "real-world."

The coordinator of these resources in the Atlantic Fleet is the Commander Antisubmarine Warfare Force, who controls the:

- Hunter Killer Group subsystem,
- Patrol aviation subsystem,
- Surface subsystem,
- Submarine subsystem,
- Fixed subsystem.

The distribution and implementation of the augmenting analytical resources within this force has been symmetrically balanced by assignment of tactical, technical and behavioral support to specific commands.

The Atlantic ASW System consists of a series of interacting subsystems, which may be tasked in different "mixes" of ASW platforms to face different levels of submarine threats in widely separated areas and under diverse environmental conditions. For the purposes of this discussion, however, and to simplify understanding of the analytical functions and interactions, command titles have been omitted in figure 1.

The Commander Antisubmarine Warfare Force, U. S. Atlantic Fleet heads the Atlantic ASW System. The Analysis Division is one segment of his staff, and is the only command in the Atlantic Fleet that possesses an interdisciplinary division of operations, technical, and behavioral analysts. The twelve officers in the Analysis Division are also representative of air, surface, and submarine ASW platforms. A series of civilian contractors provide technical as well as additional operations analysis support in surface

ASW subsystem, and in command and control, and ASW data management. Additional civilian augmentation has been received from the Oceanographic Office and Operations Evaluation Group for specific technical projects. The behavioral analysts in uniform are Aviation Experimental Psychologists. Civilian behavioral analysts have been provided by the Personnel Research Laboratory and Commander, Naval Aviation Safety Center. From time to time, additional qualified Naval Reserve Officers and students from the Human Engineering curricula, U. S. Naval Postgraduate School have assisted with specific human performance analyses. These augmentors and the permanent staff represent a unique organization devoted to developing valid human performance measures within the system.

Each of the other participating subsystems have three or four permanent tactical analysis officers. This initial cadre is augmented by four or five civilian operations and technical analysts. In addition, one or more professional behavioral analysts are assigned to three of these subsystems who are involved in collecting and analyzing system performance data. All of these participating subsystems are represented in a functional Planning-Liaison Panel, which is concerned with problems of experimental design, utilization of existing and planned resources, and monitoring the progress of this unique development program.

The Planning-Liaison Panel while not initially, is now an indispensable part of the Atlantic ASW System. This Panel consists of (1) representatives from the Chief of Naval Operations (Op-95), (2) the senior military tactical analyst and civilian technical analyst from each participating command, (3) the senior behavioral analyst, (4) representatives from the lead laboratory, and (5) invited participants from other government agencies. These last participants are invited upon the request of the CNO and the Planning-Liaison Panel, which is headed by the Assistant Chief of Staff for Analysis, COMASWFORLANT. The overall objective is to provide a forum for the airing of CNO requirements and the smoothing out

of planning and operational problems that may arise. From this, a technique has evolved for carrying out both the letter and intent of the Chief of Naval Operations.

RESULTS

The Planning-Liaison Panel came into being as the result of attempts by subordinate commands, tactical analysts, and civilian analysts to determine precisely what was to be done, in what sequence, and how each of these groups related to one another. There also were many opinions on how each military-civilian team related to the Chief of Naval Operations. Initial hurdles were overcome by developing a forum where key military and civilian members of each participating command could air problems, concepts, and methodology, so that each exercise would be executed in the same way each time. This forum was organized along the lines of the Joint Atlantic/Pacific ASW meetings, which have successfully brought problems and agreements into sharp focus for presentation to higher authority in the form of joint letters, Navy-wide positions in ASW, and joint requests for action.

At the initial meeting of what was to become the Planning-Liaison Panel, representatives both the Atlantic and Pacific ASW Systems met with representatives of the Chief of Naval Operations to identify the subsystem, the participants and operations required to meet the needs of this novel program. Joint concurrence was required and covered the following activities:

- Assessing fleet resources,
- Establishing fleet priorities,
- Identifying operational constraints and relevant variables,
- Developing qualitative and quantitative performance measures,
- Identifying type of analytic model with pertinent parameters,
- Developing a core of controlled and free-play exercises in ASW detection and localization, and
- Writing a common operations order to execute planning.

Progress accomplished in all of these areas, has been refined during successive meetings.

With publication of the operations order it became apparent that the Hunter Killer Group and Patrol Aviation subsystems would be scheduled on a once-a-quarter basis with the same submarine target and over essentially the same geographic area. The Surface subsystem would be scheduled with the same target, if possible, or a similar target for their quarterly exercise. This schedule has been adhered to (in spite of submarine target cancellations) to enable data collection at an orderly, though slow, pace.

The command assigned to conduct these exercises has been instructed to complete a series of tasks to produce valid operational data. These are:

- Conduct the specified exercises,
- Collect the planned data,
- Verify the sensor data,
- Rectify the navigational data,
- Reconstruct the exercises,
- Develop valid inputs to tactical data bank, and
- Report results.

In the case of tactical or technical exercises, the design has consistently been cross-sectional while the behavioral studies have been longitudinal in character. The reason for such a difference becomes apparent when one considers that individual differences can be more easily ignored in tactical studies than in aircrews. In the latter case, small samples do not sufficiently guard the analyst from bias, so that larger populations are required. These large samples need to be statistically representative of reality while tactical operations can afford the luxury of presumed independence.

Since those initial meetings, the Planning-Liaison Panel has continued to monitor progress, refine parameters and variables, and assert stronger scientific rigor to each succeeding exercise. A total of fourteen exercises, each averaging eleven working days

on an around-the-clock operational schedule, and involving ASW units of one or more subsystems, have been planned. Only two of these exercises have been cancelled and both of these were due to non-availability of a suitable target submarine. The Hunter Killer Group and Patrol Aviation subsystems each have been responsible for six exercise periods in the same geographic area. Four of these exercises were devoted largely to highly controlled experiments on the amount of noise emitted by the submarine. This was accomplished by measuring the loss due to the attenuation of sound in water, determining the signal to noise ratio at the point of detection, and the signal strength at the sensor operator's receiver relative to the noise and vibration of the operator's environment. Each of these measures served as inputs to the lead laboratory in model validation. The other two exercises were devoted to developing statistically sound probabilities of detection and localization under controlled and free-play conditions.

Similar exercises, on a somewhat reduced schedule, have been conducted by the Pacific ASW System. As the data accumulates, preliminary, significant findings are forwarded to the Atlantic ASW System for merging with similar information prior to a formal report. The Planning-Liaison Panel reviews these results periodically. The preliminary reports may cover tactical, technical, or behavioral analysis results. Sometimes these reports cover all three aspects. Whenever a study that is of special interest to operational commands and higher authority contains recommendations for progress in ASW, it is forwarded to the Chief of Naval Operations and is usually accompanied by senior tactical and technical analysts to answer questions. Normally, however, a formal report is written and forwarded simply containing the findings to date.

Periodically, the Commander Antisubmarine Warfare Force, U. S. Atlantic Fleet, is briefed on progress, on reports that have contributed to this progress, and on events planned for future research operations. In addition, readiness standards and force requirements can be stated in quantified terms,

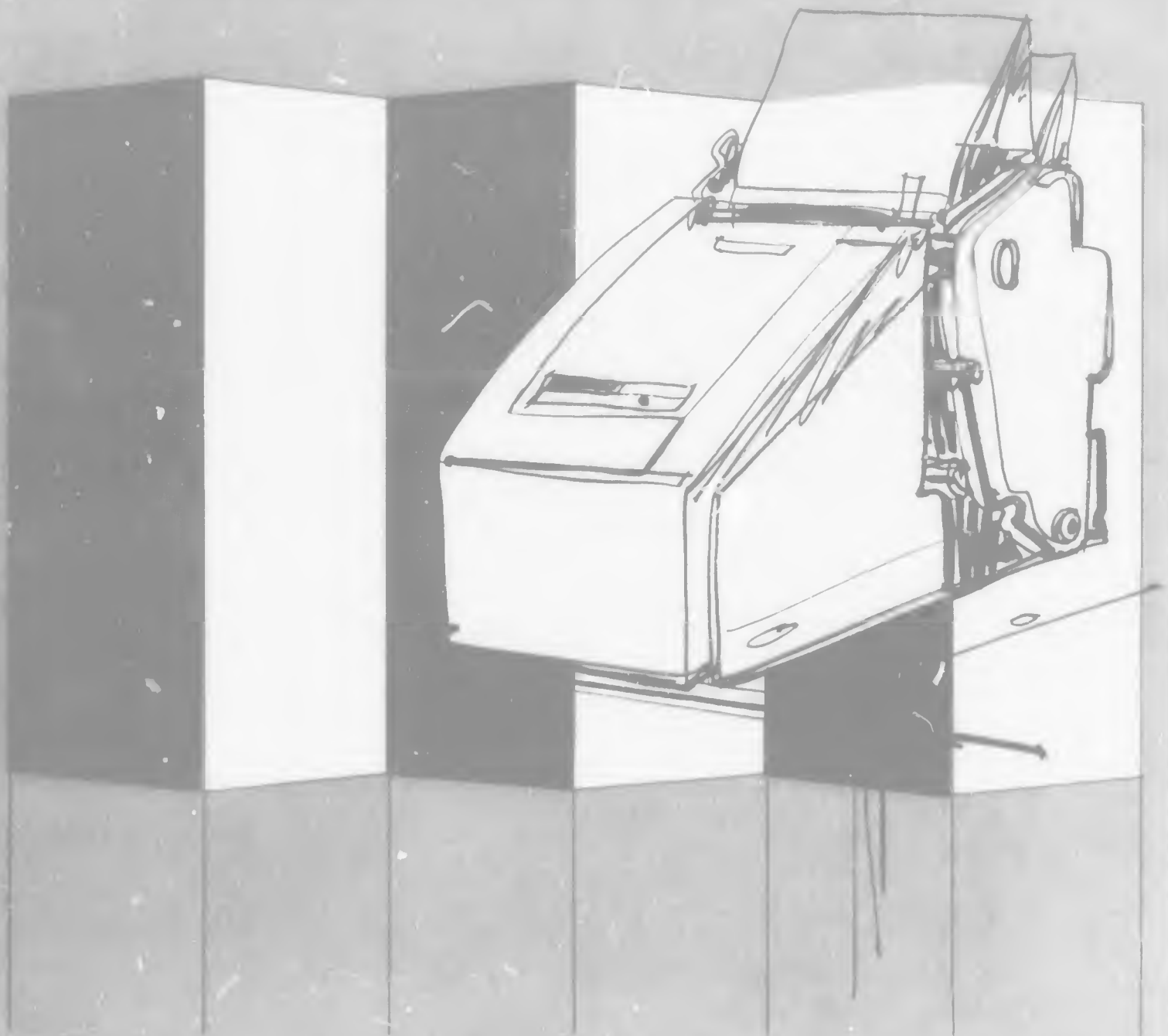
they are forwarded to higher authority, such as, to the Fleet Commander, Chief of Naval Operations, and the Secretary of the Navy. These standards will be promulgated throughout the Atlantic ASW System so that today's research-derived, validated standards may become tomorrow's mode of operation.

It is anticipated that the cycle of events described above will recur with the advent of new equipment, tactical developments, and change in the quantity and quality of the personnel manning the Atlantic ASW Sys-

tem. When the analytical models more nearly represent "real-world" conditions, as validated by operational fleet units, many of the repetitive, costly, and time-consuming tasks of varying parameters in order to maintain effectiveness can be delegated to computers. Until that point is reached it will be necessary for the Fleet to determine its readiness and to report it in quantified terms that demonstrate its worth or to levy a requirement upon the research and development community.

AN ANALYSIS OF THE 3-M APPROACH TO PROBLEM RECOGNITION

MR. M. L. HENDRICKSON



ABSTRACT

The availability of Aviation 3M Management products has evolved to a point where a systematic approach to data analysis is necessary in order to provide the needed communication links among the members of the operational-material-industrial team. The inherent abundance of measurable data and the unique needs of the various levels of management preclude the production of a simple single page summary report. A comprehensive report listing every permutation of all input data elements is likewise impracticable because of the sheer numbers of, and the complex inter-relationships between, the input parameters. In an attempt to resolve the apparent dichotomy of "management exception reporting" containing "detailed analyses," a systematic series of structured reports has gradually evolved. This paper summarizes existing Naval Aviation 3M data products to show how the data can be used to disclose perturbations in fleet readiness in order that optimum systems performance effectiveness can be maintained within given resource allocations.

INTRODUCTION

Providing the fleet with the most effective, reliable and maintainable weapons systems and the best logistics support available is the major endeavor of our operational-material-industrial weapons systems management teams. However, even the most dedicated efforts of the Department of Defense and industry will not unilaterally bestow "Systems Performance Effectiveness" upon the operational units. The logistician can, through the judicious allocation of men, money, and material, furnish a viable atmosphere for the attainment of the desired goals of systems performance effectiveness; however, the melding of the raw materials into a functional combat-ready entity must take place at the operational command. The measure of whether the goals have been achieved cannot be determined solely in terms of the state-of-the-art design innovations, the compliance

with production schedules, or the sophistication of the material distribution process. The true measure lies in the effectiveness of the total weapons system package in the operational environment.

As a consequence, reliable communication channels must be established to enable the fleet to voice its assessment of the effectivity of the overall integrated logistics support cycle. The main-line communications system of Naval Aviation, the Naval Maintenance and Material Management System (3M) is the theme of this paper. A major emphasis will be placed on the analysis techniques inherent in the system to provide Logistics Engineers with the maximum amount of relevant data at the least expenditure of management resources for the extraction of pertinent trends and their aberrations. Exhibit I is included in order that certain specific terms may be defined in relation to the particular context in which they are used throughout this paper.

It is evident that a data collection system, such as Aviation 3M, must provide for systematic analysis procedures if timely and accurate communication is to be attained. The technique currently employed is based on the concept that a particular aircraft can be best managed by the sequential analysis of certain key parameters such as operational readiness and the in-service indicators of reliability and maintainability. This procedure enables the weapons systems managers to select only that

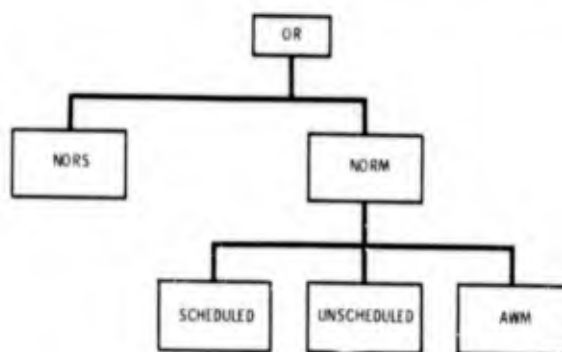


Figure 1

data pertinent to their unique level of interest and which falls within their immediate span of control.

As shown in figure 1, the analysis is initiated by the consideration of Operational Readiness (OR). Readiness data is collected on each operational aircraft. The preliminary evaluation point for 3M analysis is the standard established by the Chief of Naval Operations. This standard is based on operational requirements and is the baseline for comparison. In comparing the basic data with the assigned standard, the weapons systems manager will also take into consideration the design goals of the weapon and historical trends.

Concurrent with the review of the Operational Readiness status a determination should be made as to whether the problems are attributable to supply (NORS) or maintenance (NORM). For the purpose of clarity this paper will analyze Not Operationally Ready (NOR) problems as though they occurred as isolated events and were primarily either supply or maintenance oriented. In actual practice the problems will arise from both sources. The main point is that whether the analytical train leads down one path at a time or through a combination of interrelated paths, a systematic development of the problem definition phase must be followed.

NORM events can be further categorized as scheduled and unscheduled maintenance actions. In considering maintenance downtime it is necessary to recognize the fact that personnel and scheduling limitations preclude continuous maintenance of all aircraft. The period during which an aircraft is in an Awaiting Maintenance (AWM) status is

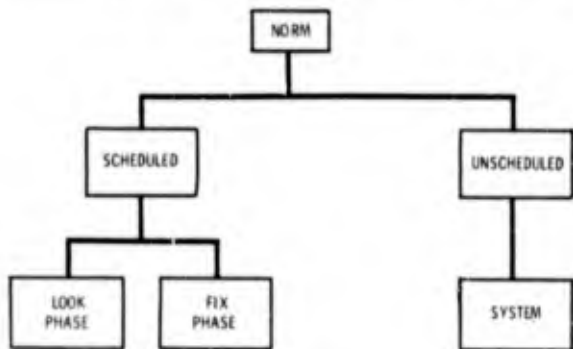


Figure 2

logged and indicates that portion of the reported NOR time during which no active maintenance was being performed. This time can be disregarded in conventional maintainability studies but may be the first indication that the required maintenance resources are not being made available to the fleet when needed.

A more detailed analysis of NORM events, figure 2, shows that they are primarily related to organizational turn around times. NORM measures the number of hours required to return an aircraft from a Not Operationally Ready status to an "OR" status when the required parts are readily available. The first step in a NORM analysis is to determine whether the condition is caused by scheduled or unscheduled maintenance. Scheduled NORM is for the most part predetermined based upon preventive maintenance requirements and is a relatively fixed constant determined by local inspection intervals. Deviations in scheduled maintenance downtime are largely under control at the local manager level and will not be considered in depth here.

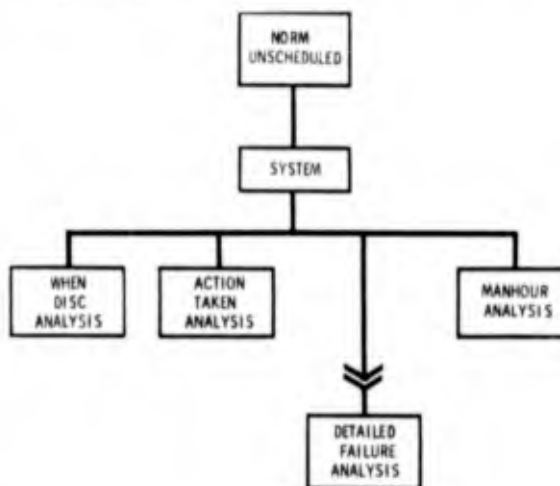


Figure 3

Unscheduled maintenance, figure 3, is the area in which the major trends in maintenance activity will develop. An aberration in unscheduled maintenance downtime, whether related to the inherent reliability, maintainability or logistic support will usually be reflected in the aircraft's operational readiness posture. The main considerations for further analysis are, the determination of how many

maintenance actions occurred and, how many maintenance manhours were required to return the aircraft to an OR status. In a NORM analysis, a "maintenance action" is considered on an equal level with an "equipment failure." When the processing of a maintenance action discloses an actual equipment malfunction, an analysis of the type, complexity, and frequency of failure of components is essential in order to disclose the engineering implications of the problem. However, the pacing ingredient of a NORM event is not the failure rate per se, but the calendar time expended to return the aircraft to an OR status. It is important to note that it is possible to expend many NORM significant manhours troubleshooting reported discrepancies for which no verified "failure" as such can be found. A "when discovered" analysis can be of major impact in understanding the true nature of the problem. It's quite apparent that a malfunction discovered by a worker during preventive maintenance under optimized conditions, will be repaired much faster than one discovered during an operational period requiring respotting the aircraft to a maintenance area at the termination of the mission and scheduling the maintenance resources to effect the repair. An "action taken" analysis will give an indication of the depth and type of repair required. It will answer questions such as, "Are reported discrepancies being turned around as ground checked—OK, No Malfunction?" "Are components being repaired at the organizational level or are they being turned back into supply?"

All the data considered up to this point is made readily available to the manager in the monthly recurring reports. In those cases where a manager needs a more detailed report on a specific system, the data bank can be interrogated for a detailed failure analysis. This break is now shown in the logic train.

An optimized example of the use of the NORM logic train would be the isolation of a normally insignificant component that suddenly causes abnormal problems because of type or frequency of maintenance. It is relatively easy to review the data and isolate

real or potential problem areas. The true determination of a problem and the course of action to be taken is up to the weapons system manager. Should he tighten up his inspection requirements? Redesign the equipment? Provide the operator with improved tools or technical data? The weapons system management team must collate the diverse input data, sort the wheat from the chaff, and exercise management prerogative. Once the decision is made, 3M enables the Fleet results to be readily observed and a judgment to be made as to whether the action taken has corrected the unsatisfactory condition.

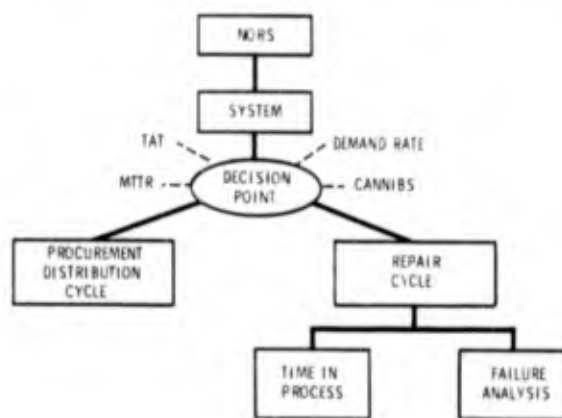


Figure 4

The first step in analyzing the NORS train, figure 4, is to isolate those specific systems contributing to the excessive NORS condition. The word NORS normally connotes problems in the procurement and distribution cycle. In fact, however, NORS events are much more comprehensive in nature. Discretion must be used in this analysis since a high turn around time (TAT) in the supporting maintenance activities, or an excessive high failure rate causing an increased demand on the supply system will produce problems hard to distinguish from the procurement and distribution difficulties. For example, when a weapons system is considered for delivery to the Fleet an analysis is made of its projected reliability, maintainability, and supportability to determine how often replenishment demands will be placed on the supply system. This analysis must include an evaluation of how long it will take to return those items coded repairable to a Ready for Issue (RFI)

condition. This criteria is then used to procure the spares needed to assure adequate response to Fleet demands. Assuming this has been done the following technique can be used to isolate the true cause of supply downtime.

If the TAT and the demand rate have not exceeded the original estimates used to determine the procurement criteria a discrepancy will probably be found either in the procurement or distribution cycle. If, however, either of these parameters differs from the estimates, it is possible that the problem exists in the reliability or maintainability of the equipment. This may be caused by the failure to take into account the operating environment in the design criteria. If the TAT only has gone "out of control," efforts should be channeled to an analysis of the repair cycle. The TAT will indicate whether the repair line is moving as scheduled or whether administrative or logistic support problems are causing bottlenecks in the supporting activity. On the other hand, an increasing demand rate and/or an excessive Mean Time To Repair (MTTR) will indicate that a deeper look into the reliability and maintainability characteristics of the system is unwarranted. It is quite possible at this point that a detailed maintenance history, as described in the NORM train, will be required to properly define the problem.

Cannibalization is practiced when replacement parts are not readily available. It can consume up to 10 percent of direct maintenance manhour resources for a given weapons system. Cannibalization is hard to fit into a NORS logic diagram. It does not necessarily have a direct cause and effect relationship but provides one more indication of whether the parts are readily available.

The preceding discussion provides a survey of the analysis techniques available in Aviation 3M. The remainder of this paper will study actual examples of existing reports, utilizing representative fleet data, to determine and analyze specific problem areas.

READINESS AND UTILIZATION SUMMARY

The basic report of Aviation 3M is the Readiness, Utilization, and Manpower (RUM) report. It is shown in figure 5. This report is

produced in 10 day and monthly increments and provides management with summary information of all Fleet operational aircraft. It is broken down into Navywide, major command and individual squadron activity figures. Its principal value lies in the broad base of data utilized, which includes inventory, readiness, utilization and manhour data, measured against historical and programmed standards. A report of this nature provides a broad survey of the entire readiness, utilization, and manhour posture and enables a rapid response to the question, "How are we doing?" This report best communicates the Fleet's assessment of a weapons system's ability to meet its assigned mission in a given operational environment. It is acknowledged that this data is difficult to define in consistent terms on a worldwide basis, with reporting activities flying varying missions with identical aircraft; however, experience has shown that there is consistency of reporting and that the data is valuable as a trend indicator.

The specific example shown is an excerpt from an existing monthly recurring 3M RUM summary. Although a fictitious aircraft code is given, the data used are representative statistics for an actual operational USN aircraft. The individual activity and major command statistics are omitted to spotlight clearly the Navywide (ALNAV) statistics. The data depicts the operational posture of the aircraft for the current (C) reporting month, the Previous (P) month, and the average values for the preceding six months (6). The primary

TYPICAL RUM REPORT
(RPT 1)

T. E. A-98

ACTIVITY		CNO OR INV	ACT % OR	ACT % NORS	ACT % NORM	CNO UTILZ STD	ACT UTILZ	CNO DMMH/FH STD	ACT DMMH/FH
LANT NAVY	~	~	~	~	~	~	~	~	~
VA	~	~	~	~	~	~	~	~	~
PAC NAVY	~	~	~	~	~	~	~	~	~
VA	~	~	~	~	~	~	~	~	~
OTHER	~	~	~	~	~	~	~	~	~
ALNAV	C	55	33	23	44	38	41	24	44
	P	55	34	28	30	38	33	24	48
	6	55	33	26	41	38	32	24	44

Figure 5

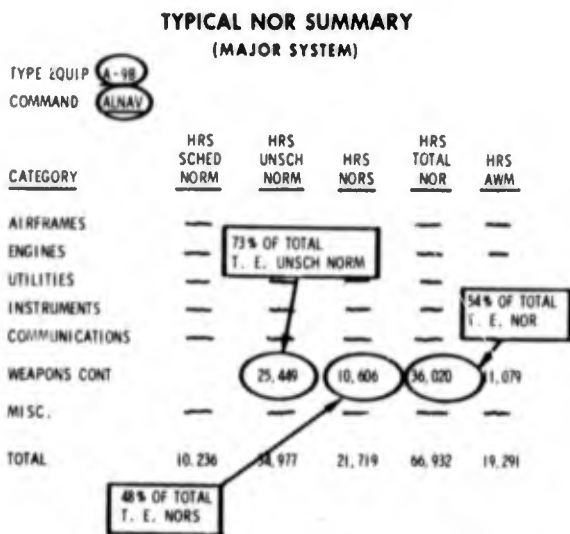


Figure 6

cause for concern in the example report is the chronic low readiness (ACT % OR) in relation to the Chief of Naval Operations programmed standard for Operational Readiness (CNO OR STD). The utilization rate (ACT UTILIZ) is above standard indicating that the aircraft is performing the assigned "mission of the day," but with aircraft that are less than completely operationally ready. (See exhibit I for specific definitions.) The high direct maintenance manhour expenditures (ACT DMMH/FH) indicates that excessive manhours are required to attain the utilization rate realized.

AVIATION NOT OPERATIONAL READINESS (NOR) SUMMARY

When deficiencies are indicated in the Fleet readiness posture, additional information as to the contributing factors, on a Fleetwide or major command basis, are available in the Aviation NOR Summary. This report differs from conventional reliability studies in that the components isolated are measured only as they affect aircraft readiness. High failure rates may not necessarily give correspondingly high NOR rates if the required logistics resources are made available to the maintenance personnel. Conversely, a minimal failure rate with associated long repair times or awaiting parts times can cause high NOR rates. It must be emphasized that these reports should not be used as a measure of

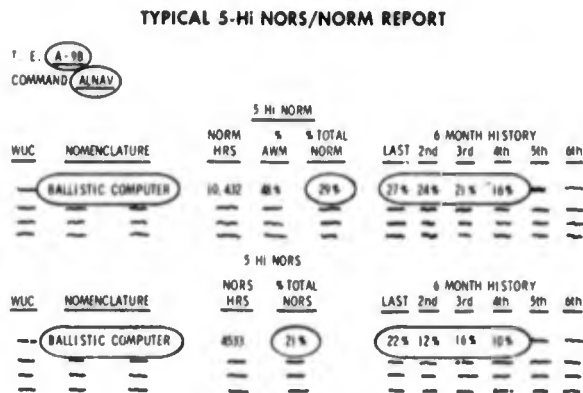


Figure 7

individual maintenance capability. Low readiness of a given component or unit may be the results of a deliberate design trade-off to achieve a given performance level, and may represent the limit of the state-of-the-art.

Figures 6 and 7 are examples of the two-part Aviation NOR summary. These reports pertain to the identical aircraft and reporting period as the sample selected for the RUM report shown in figure 5. Again, only the most significant statistics have been printed. Figure 6 shows that of the total NOR problems, approximately 54 percent of the downtime, was attributable to the "Weapons Control" area, and that both maintenance and supply problems contributed significantly. Figure 7, the "5-HI NORS/NORM" section of the Aviation NOR Summary indicates that in the weapons control area the subsystem described here as the ballistic computer was the major offender both in the NORS and NORM categories and that the problem was of a generally deteriorating nature.

RELIABILITY AND MAINTAINABILITY SUMMARY

This report can be used independently to evaluate the reliability and maintainability of a weapon system or as an adjunct to the NOR reporting system to further analyze those systems contributing to excessive aircraft downtime. Although the normally recognized parameters of reliability and maintainability are Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR), measured on an equipment clock-time basis, this report is based on failures and manhour expenditures on an aircraft flight hour basis.

The "T" (clock-time) of MTBF and MTTR is not measurable in an operational environment. Design or contractual MTBFs and MTTRs are not based on in-service expectations. Rather they attempt to define the inherent characteristics of a system. These measurements are normally written into specifications or contracts based on finite measurements performed on selected equipments under carefully controlled laboratory conditions. While it is anticipated that these conditions can be related to eventual Fleet experience, it is obvious that intangibles such as maintenance skill levels, operating environments, or combat situations will alter the conditions to such an extent that correlation between controlled and field conditions is difficult at best. 3M, therefore, has not attempted to divine the inherent design or contractual MTBF or MTTR. True equipment operating (clock) times are difficult to obtain due to lack of uniform metering devices, bench operating times, and serialized configuration control. What the Aviation 3M system has attempted to do is to select a standard index of aircraft performance that is capable of accurate measurement, and to use this as a baseline for comparative studies. The index chosen was airframe flight hours.

TYPICAL R & M SUMMARY
(TAB 17)

T. E. A9B
SUBSYSTEM BALLISTIC COMPUTER

WUC	NOMEN	COMMAND	FLIGHT HOURS	MAINT ACTIONS	MFBMA	FAILURES	MH/FB	MWH/FH
--	CONTROL CONVERTER	--	--	--	--	--	--	--
--	POWER SUPPLY	--	--	--	--	--	--	--
	<u>CRUISE - NAV CONTROL INDICATOR</u>	CHAL CNAP	234 1.07	36.0 46.3	170 50	59.5 86.3	29 18	
TOTAL	TOTAL	CHAL CNAP	2176 1435	3.9 3.0	180 397	9.8 11.0	1.8 2.1	

Figure 8

Figure 8 can be used to probe deeper into the underlying causes of the A9B ballistic computer problems. In this report it is evident that the single subsystem within the ballistic computer causing the highest rate of maintenance activity (MAINT ACTIONS), failures (FAILURES), and manhour expenditures (MH/FH) was the Cruise/Nav Control Indicator.

TYPICAL NATSF ANALYSIS

T. E. A9B
SYSTEM BALLISTIC COMPUTER
SUBSYSTEM CRUISE - NAV CONTROL INDICATOR
CONTRACTOR XYZ ASSOCIATES

FAILURES 273
FAILURES 100

MAJOR DISCREPANCIES

REPARABLE COMPONENT	FAILED PART	FAILED PART NUMBER	HOW MAL	FAILURES
FRONT SERVO ASSY P/N 846087	VARIABLE RESISTOR ANALOG CONVERTER	980217-137 980234-8	CORRODED CORRODED	23 8
REAR SERVO ASSY P/N 846033	VARIABLE RESISTOR ANALOG CONVERTER	980217-141 980234-9-14	CORRODED CORRODED	20 13

Figure 9

ANALYTICAL SERVICES

Figure 9 is an example of an in-depth analysis triggered by the above problem identification technique to isolate those components within the Cruise/Nav Control Indicator contributing to the high malfunction rate. All the reports described thus far have been limited to gross summaries at a functional equipment level. Manufacturers' designations reference numbers, serial numbers and drawing numbers while readily available in the data bank have not been given. The present series of centrally produced 3M data products were not designed to pinpoint each and every problem to the nth degree. We have neither the machine time, the analytical resources, nor the requirement for this level of data in the central summaries. Only that data which is determined manageable at a specific level of command is produced for that command. The summary tabulations are produced to provide the weapons systems manager and his analysis staff with that data he needs to identify major problem areas and to indicate whether additional research is necessary. Further detail becomes exceedingly ambiguous unless analyzed in its proper perspective by personnel familiar with the intricacies both of the weapons system and the reporting system involved.

Figure 9 was produced by the Naval Aviation Technical Services Facility. It provides the in-depth detail to complement the weapon-system problem areas spotlighted by the NOR, reliability and maintainability studies. This type of report is normally prepared on an as-requested basis when asked for by the weapons system manager and his logistics support team and can be as general or as specific as the requiring agency desires.

OUT OF CONTROL ITEMS TABULATION

This is the latest member of the centrally produced reports. It is designed primarily for use at the headquarters complex. It is an attempt to provide management with an "exception" report. The program for the report considers the past years failure history and then establishes an upper control limit for failures, computed on a basis of two and one-half times the square root of the past years average. Only those equipment with current failure rates in excess of the control limit will be displayed in this tabulation. At the time of this writing, the first edition of this report has just been distributed and no qualitative evaluations have been received, however, preliminary indications are that this report may well become one of the mainline reports of the future. Figure 10.

TYPICAL "OUT OF CONTROL" TABULATION

NOMENCLATURE	TYPE EQUIPMENT F-9B FLIGHT HOUR BASE		6902		
	FAILURE BASE *	UPPER CONT LIMIT *	FAILURES CURRENT MONTH *	FAILURES 1st MO. PREV	FAILURES 2nd MO PREV
AIRFRAME	1.13	1.46	1.93	-	-
ENGINE ACCESS DOOR	.07	.16	.17	-	-
WHEEL & TIRE ASSY	5.40	6.11	7.45	-	-
AILERON ASSY	.28	.45	.48	-	-
RADAR SET	4.97	5.65	6.16	-	-
HOOK POINT	.32	.49	1.30	-	-

* Based on per 100 FH

Figure 10

SUMMARY

It is evident that an accurate and responsive communication link must exist between the operational activities, the headquarters complex, and industry. The operating commands need local feedback data to control their assigned resources effectively, and to substantiate their requirements when outside assistance is required. The weapons systems management team needs to know whether it is allocating its logistic resources in a cost-effective manner and whether the material procured is performing as required. The design agencies in the headquarters

and industrial complex need the data to update today's weapons to reflect the ever-changing world conditions and to provide the optimum weapons system for the future. In Naval Aviation, 3M is the main-line data reporting system which enables the diverse members of our defense team to communicate the fleets operational posture and logistic requirements in one standard language available to all interested users with a minimum of delay.

EXHIBIT I

AWAITING MAINTENANCE TIME

(AWM): AWM is that time during which an aircraft is NORM and no maintenance work is being performed on either the aircraft or its related equipment. AWM time does not apply when the aircraft is NORS.

(OPNAV 5442.2B)

○ANNIBALIZE: Removal of serviceable parts from one aircraft or equipment for installation on another aircraft or equipment. (OPNAV 5442.2B)

DOWNTIME: That portion of time during which the item is not in condition to perform its intended function. (MIL-STD-721B)

FAILURE: The inability of an item to perform within previously specified limits. (MIL-STD-721B)

INHERENT: Achievable under ideal conditions, generally derived by analysis, and potentially present in the design. (MIL-STD-721B)

LOGISTICS: "those aspects of military operations which deal with: (1) design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of material." "(3) acquisition or construction, maintenance, operation and disposition of facilities; and (4) acquisition or furnishing of services."
(OPNAV 5442.2B)

MAINTAINABILITY: A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in

accordance with prescribed procedures and resources. (MIL-STD-721B)

MAINTENANCE: All actions necessary for retaining an item in or restoring it to a specified condition.

MAINTENANCE, CORRECTIVE: The actions performed, as a result of failure, to restore an item to a specified condition. (MIL-STD-721B)

MAINTENANCE, PREVENTIVE: The actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure. (MIL-STD-721B)

MAJOR COMMAND: The following commands have been identified as "major commands" for purposes of 3M reporting as determined by the organization code breakout in Appendix C of the Aviation 3M Manual.

LANT NAVY
LANT MARINES
PAC NAVY
PAC MARINES
MARINE NON-FLEET
CNATRA
CNARESTRA
NAVAIRSYSCOM

MEAN-TIME-BETWEEN-FAILURE

(MTBF): For a particular interval, the total functioning life of a population during the measurement interval. The definition holds for time, cycles, miles, events, or other measures of life units. (MIL-STD-721B)

MEAN-TIME-TO-REPAIR: The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time. (MIL-STD-721B)

MISSION: The objective or task, together with the purpose, which clearly indicates the action to be taken. (MIL-STD-721B)

NOT OPERATIONALLY READY MAINTENANCE (NORM): An aircraft is considered NORM when it is not operationally ready due to scheduled maintenance, or

unscheduled maintenance. In-flight malfunctions will cause the not operationally ready maintenance (NORM) time to begin upon termination of that flight. When maintenance work is completed and a check flight is required, the aircraft will be reported operationally ready at the time the aircraft is ready for the check flight. The categories of NORM are defined as follows: (OPNAVINST 5442.2B)

(1) Scheduled maintenance (standard upkeep). An aircraft is not operationally ready-scheduled maintenance during all periods of time when it is unavailable for flight due to routine scheduled maintenance accomplished by other than depot personnel while in the physical possession of the operating unit. When an aircraft is NOR for the sole purpose of technical directive compliance (TDC) it will be considered NORM scheduled maintenance. However, if TCD's are accomplished in conjunction with scheduled maintenance; the aircraft will be considered NOR-Scheduled Maintenance. (OPNAVINST 5442.2B)

(2) Unscheduled maintenance (Special upkeep). An aircraft is not operationally ready-unscheduled maintenance during all periods of time in which corrective maintenance is required or being performed on the aircraft or its systems by other than depot personnel to return the aircraft to an operationally ready condition while in the physical possession of the operating unit. (NOTE: Unscheduled maintenance does not include the fix phase of scheduled inspections). The special difference between unscheduled and scheduled maintenance is that unscheduled maintenance usually represents the correction of a malfunction other than the performance of preplanned preventive maintenance. Damaged aircraft, if in the reporting custody of the operating unit, and not accounted for under status code change, will be reported as not operationally ready — unscheduled maintenance. If TDCs are

accomplished in conjunction with unscheduled maintenance, the aircraft will be considered NOR-unscheduled maintenance. (OPNAVINST 5442.2B)

NOT OPERATIONALLY READY (NOR):

An aircraft is not operationally ready when it becomes known that a maintenance requirement exists which would prevent the aircraft from performing its primary mission safely and completely within the definition of operationally ready.

NOTE: A NOR condition may exist on an aircraft whether it is flyable or non-flyable. (OPNAVINST 5442.2B)

NOT OPERATIONALLY READY SUPPLY

(NORS): An aircraft shall be considered not operationally ready-supply when a supply demand has been made and the material component or part(s) which have been requisitioned are not available, prohibiting further maintenance work. (Maintenance control will determine NORS start and stop times using the following information; (1) the time the requirement for material is placed on the supply activity by material control, (2) the time the material is delivered to the designated delivery point, and (3) whether other maintenance is being performed on the aircraft). If more than one hour is required to deliver a part to maintenance, the aircraft will be reported NORS from the time the demand was placed on the supply activity by material control. The act of cannibalization will be considered a supply action. An aircraft will be NORS during the time a replacement part is being removed from another aircraft. A NORS condition does not infer that normal upkeep cannot be performed on the aircraft, i.e., washing, corrosion control, preservation, painting, markings and compliance with grounding TDCs which have passed the due date. (OPNAVINST 5442.2B)

OPERATIONALLY READY (OR): Operationally ready is the status of an aircraft or system in which it is capable of

safe use and has on board and ready all equipment necessary for the performance of its primary mission, as listed in the applicable mission essential equipment list (MEEL). If an aircraft returns from flight and does not require maintenance, it is considered ready. Time spent refueling, loading munitions, awaiting starting units, or awaiting test flights on "UP" aircraft is considered to be ready time.

(OPNAVINST 5442.2B)

PROBLEM: This paper stresses one specific connotation of the word "problem." When 3M reports that a system is causing aircraft readiness "problems," what it means specifically is that a situation exists which is unfavorable in terms of resource management. This may or may not be a "problem" in terms of its design reliability and maintainability characteristics. For example, a complex radar system may be a "problem" in terms of resource expenditures and yet be technically as reliable, maintainable and supportable as the state-of-the-art allows. The weapons system manager must have the information available to determine whether to attack the "problem" directly; to compensate for the "problem" in terms of increased logistics support; or to develop a complementary trade-off solution.

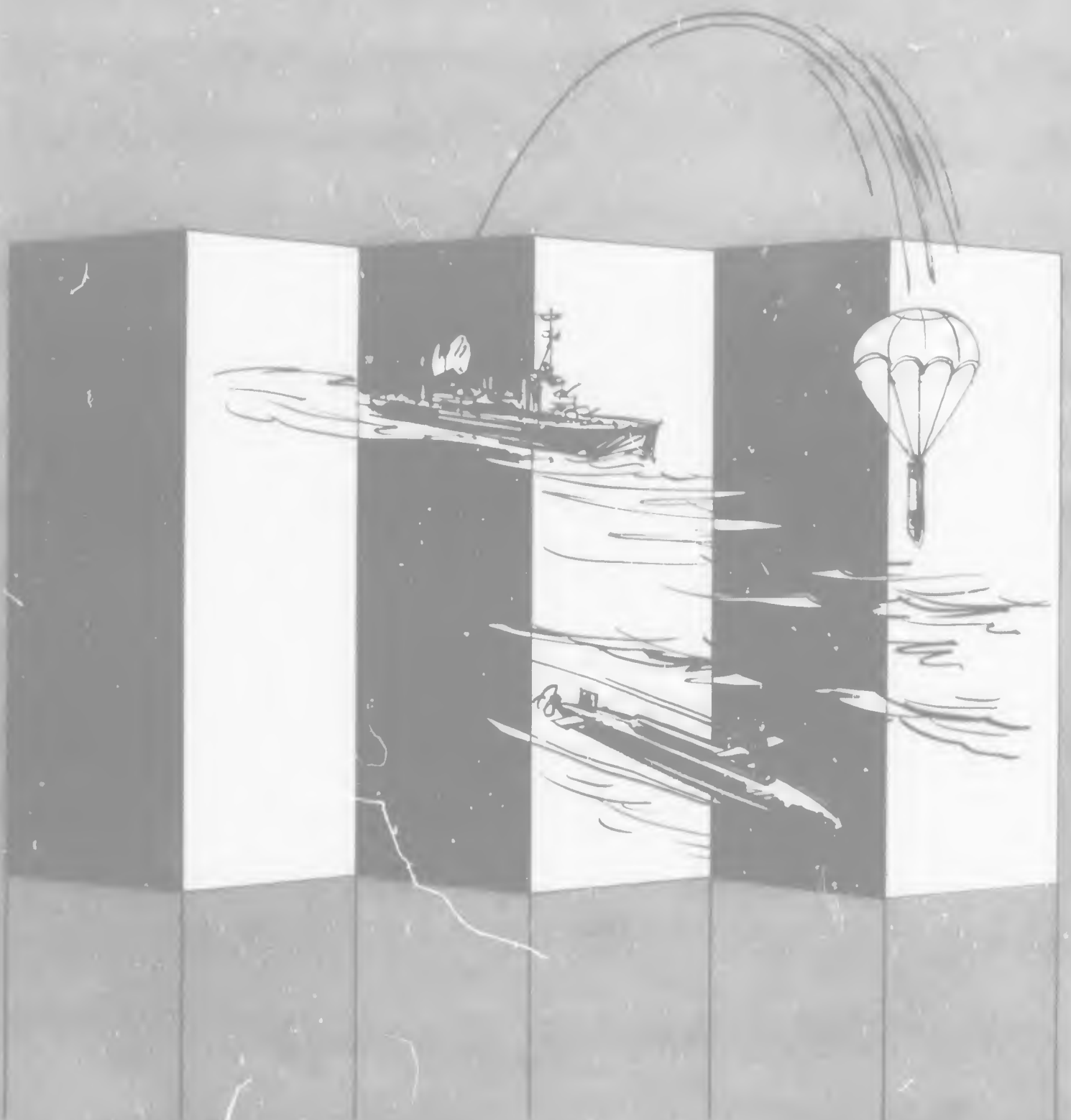
RELIABILITY: The probability that an item will perform its intended function for a specified interval under stated condition. (MIL-STD-721B)

TURN-AROUND TIME: That element of Maintenance Time needed to service or check out an item for recommitment. (MIL-STD-721B)

UTILIZATION: The average number of hours per unit period of time an aircraft is actually in flight. Normally utilization for a particular model aircraft is specified by the average number of hours flown per operating aircraft per calendar month. (OPNAVINST 5442.2B)

ASW ENCOUNTER & MISSION EFFECTIVENESS COMPUTER SIMULATION MODELS

MR. R. L. KULP



This paper describes the modeling effort at the U.S. Naval Weapons Laboratory in the simulation of anti-submarine warfare. A three-phase program has been in effect since 1963 to develop and employ advanced computer models for simulation and evaluation of effectiveness of current and future ASW systems.

The first phase was directed to surface ASW systems (i.e., destroyers versus submarines) with the objective: an ASW Surface Ship Mission Effectiveness Program. This program was a dynamic simulation of engagements between destroyers and submarines. The model is programmed in FORTRAN IV language for the IBM 7030 Computer and is documented in reference 1.

The second phase was directed to subsurface ASW systems (i.e., submarines versus submarines) and resulted in the development of the NWL ASW Encounter Simulation Program. This program, a dynamic simulation of engagements between United States ASW submarines (blue) and enemy (red) submarines, is also programmed in FORTRAN IV language for the IBM 7030 Computer and is documented in reference 2.

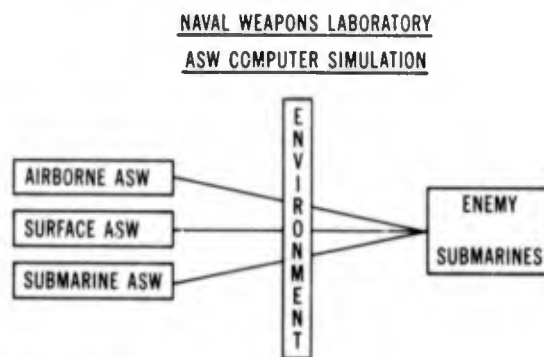
The third phase of the ASW program at NWL is under development and is directed to air ASW systems. This program will result in a dynamic simulation of engagements between multiple aircraft and multiple submarines and will also be programmed in FORTRAN IV language for the IBM 7030 Computer. A preliminary report on this model is contained in reference 3.

It is intended that these research type simulation models will be useful in studying such problems as the effectiveness of a given ASW mission, the interaction between vehicles and weapons, and the optimum use of sensors. Also, and more significantly, these models are "free play" in nature and are a means of evaluating the status of an engagement and making tactical decisions accordingly. Since these models are sophisticated

in the simulation of sound propagation, weapon and vehicle kinematics and environmental influences on ASW systems can be used to validate other models which have been aggregated for simplicity.

GENERAL CHARACTERISTICS OF THE ASW PROGRAMS

The ASW computer models developed at NWL are designed to provide a rapid and economical means of studying the relative effectiveness of proposed or existing hardware and tactics within a defined environmental setting. Figure 1 lists some of the salient features of these models.



SALIENT FEATURES

- SIMULATES CONFRONTATION DETAILS
- GRAPHICAL OUTPUT
- MULTI-VEHICLE CAPABILITY
- DECISION/COMMAND LOGIC
- MODULAR CONSTRUCTION
- VARIABLE SCENARIO INPUT
- QUANTITATIVE STATISTICAL OUTPUT WITH CONFIDENCE LIMITS
- UTILIZES MONTE CARLO TECHNIQUE

Figure 1

The models are so designed that confrontation details are simulated. That is, a space time history is provided as output for each vehicle in the game. Consequently, at any point in the simulation, information is available with respect to a vehicle's position in

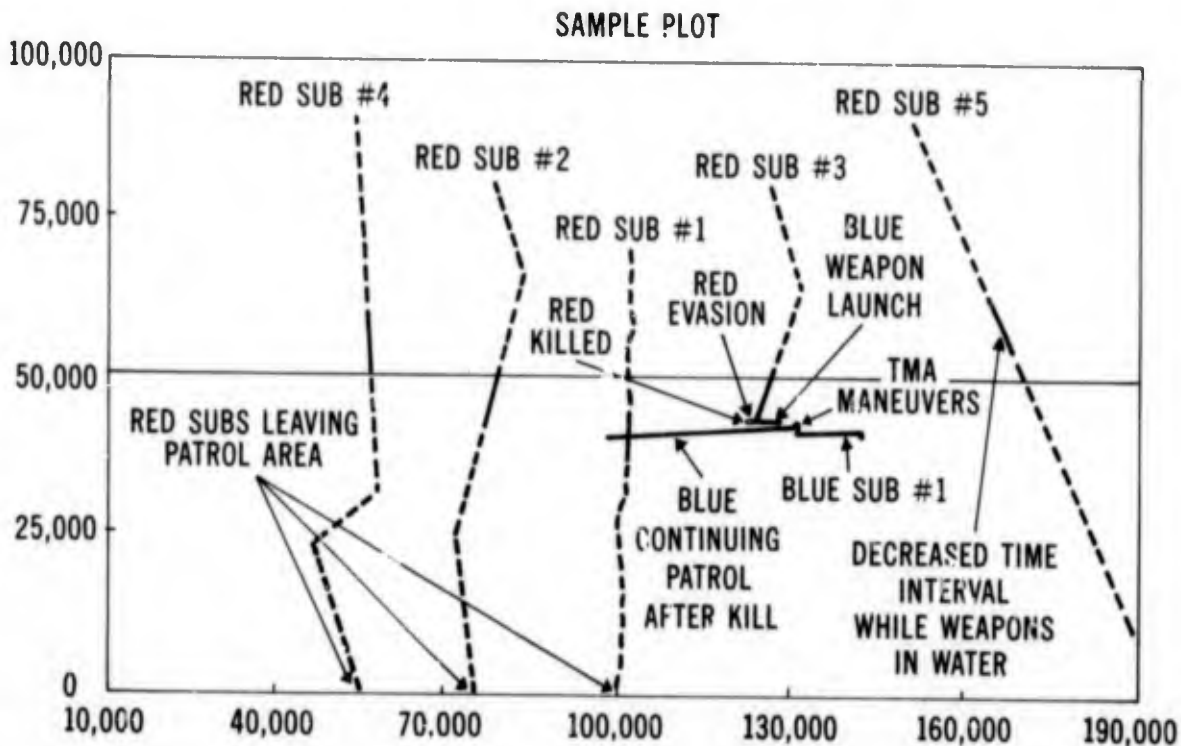


Figure 2

three dimensions: course, speed, and if appropriate, the status of the sonar and fire control systems, both past and present. Output from the model may be a printed sheet or plots from the computer showing a space time history of the vehicles. A sample plot is shown in figure 2.

All the models contain a multi-ship capability. This is true of both our own and enemy systems. The number of vehicles in a given problem is computer limited. In both the surface and subsurface models, about 60,000 words of core storage are required for a six vehicle confrontation. The air ASW program presently under development will require even greater storage.

A unique feature of the models is a built-in command/decision routine, that simulates the processes that a skipper would go through in making a tactical decision. The models are operated on a free-play basis that allows tactical decisions to be made on events occurring during the play of a scenario.

The models are modular in nature. This allows considerable flexibility because routines, developed for one particular model, can readily be added to other models. This also

permits removal of individual modules like sonar, fire control and weapons, and the exercising of these routines independently of the master program.

Another feature is the capability of controlling the scenario through input. The models were not designed for, or constrained to, a specific problem. A tactical library has been developed which contains maneuvers or tactics for most missions or scenarios, and for input flexibility that allows appropriate maneuvers to be specified according to the problem. This tactical package is also modular in nature and allows the addition of new tactical routines, if desired.

The models utilize Monte Carlo techniques so that scenarios may be replicated at will. This allows statistical tests to be performed and provides quantitative estimates of mean, standard deviation, and confidence limits on the output data.

DESCRIPTION OF THE NWL ASW SUBMARINE ENCOUNTER SIMULATION MODEL

Having covered the salient features of the models, the submarine-versus-submarine simulation model is presented in some detail to

further illustrate the capabilities of the model. Figures 3 and 4 represent the elements of the submarine-versus-submarine model.

ASW SUBMARINE ENCOUNTER SIMULATION MODEL

OWN SUBMARINES

MAJOR ASW MISSIONS

FORWARD AREA SEARCH AND ATTACK (WITH AND WITHOUT OUTSIDE INTELLIGENCE)

TRAILING

ESCORT

SHIP TYPES

NUCLEAR

CONVENTIONAL

ORDNANCES

MK 48

MK 45

MK 37 MOD 0, 1 & 2

MK 16

SUBROC

SUBSYSTEMS

SONAR

BQR - 2B

BQQ - 2

FIRE CONTROL

MK - 113

PLOT PARTY

COMMUNICATIONS

Figure 3

The first item in figure 3 is major ASW mission assigned to own submarines. It is here that the tactical library is built up. There are, at present, about 50 different maneuvers to choose from. These include: course, speed, and depth changes; various search and loss-of-contact maneuvers, evasive maneuvers, weapon launch maneuvers and passive approach maneuvers. Routines may be used individually or in sets to form a given tactic, e.g., turn, launch weapon, dive, increase speed to maximum, and run straight. In general, the process that takes place within such a routine permits one to evaluate the present status of the game with respect to the assigned mission, and to recommend a course of action that will facilitate execution of the mission.

Both nuclear and conventional boats are simulated in this model. General kinematic equations have been developed for the vehicle motion. These equations, which allow the

submarine to move freely in three dimensions, are controlled by input characteristics of the submarine being simulated. They take into account performance characteristics such as acceleration, deceleration, turning radius as a function of rudder angle, vehicle slow-down in a turn, and the rate of change of depth as a function of plane angle. If the submarine is conventional, there are detailed routines that increment and decrement the battery level as the game progresses. There is also a routine to determine the cavitation status of a given submarine as a function of speed and depth.

Routines have been developed, to a level of sophistication compatible with the overall model, to represent torpedoes Mk 48, Mk 45, Mk 37 Mods 0, 1, and 2, Mk 16 and SUBROC. Equations of motion representing the pre-programmed run-out, search, attack, and re-attack modes of the torpedoes have also been developed. When the acoustic homing torpedoes begin their acoustic search, the kinematic equations are supplemented with sonar calculations. Sonar calculations are made at each ping or sample time initially programmed into the torpedo, to determine

ASW SUBMARINE ENCOUNTER SIMULATION MODEL (CONT'D)

ENEMY SUBMARINES

MISSIONS

TRANSITER

INTRUDER

SHIP TYPES

NUCLEAR

DIESEL

ORDNANCES

STRAIGHT RUNNING TORPEDOES

HOMING TORPEDOES

WIRE GUIDED TORPEDOES

SUBSYSTEMS

SONAR

BQR - 2B

FIRE CONTROL

PLOT PARTY

COMMUNICATIONS

Figure 4

if the torpedo detects its target. Once a target is detected, the torpedo enters a homing mode and attempts to close the target. If the torpedo misses the target, reattack will take place with other torpedoes having this capability. A hit occurs in the simulation whenever the path of the torpedo, over a time interval, passes through an ellipsoid of an input major and minor axis that represents the target submarine. Simulation of the SUBROC missile is handled somewhat differently than the torpedoes. The reason for this is that ballistic equations for the flight of the missile are not developed. Data are reduced, however, from actual SUBROC firings and time of flight equations, and ballistic errors are derived and programmed into the model. Once the splash point is determined and water entry occurs, the SUBROC payload is brought into the simulation.

Routines have been developed for sonar, fire control and communications. Sonar simulation includes the BQR-2B passive system, BQS-4 active system, and the active-passive portions of the BQQ-2 sonar system. These routines explore sound propagation in considerable detail and are designed primarily for use in a free-play exercise.

These routines simulate operator functions as well as physical and equipment characteristics. For example, provisions are included for automatic or manual search while operating in a general search mode. Once a contact is established, the sonar routine shifts to a tracking mode of operation. Provisions have also been made for time sharing between the three sonar propagation modes, i.e., near surface, bottom bounce, and convergence zone. The passive sonar includes such factors as target radiated noise, ambient noise, biological noise and own ship noise as heard through the sonar transducer. Also, long and short term fluctuations in the observed signal are inserted and if two or more targets are being evaluated at the same time, the fluctuations are correlated with respect to their angular separation.

The same level of detail is found in the active sonar simulation. The physical characteristics of sound transmission are the same as in the passive situation except that

both outgoing and incoming sound travel has to be considered and factors such as reverberation levels (surface, bottom, and bounce) enter into the calculations.

In fire control, three types of target solutions are simulated — active, passive, and plot-party. The active fire control simulation operates on data provided by the sonar routine in the form of a time glimpse, position history of the target. Two types of analysis are available — end point, or least squares analysis. The fire control then determines an assumed target position and develops all the data necessary to preset and launch the weapons. Passive fire control is similar with respect to the end product (developing information to launch and/or guide a weapon to its target), but target motion analysis is performed by means of a churn solution. At present, the actual churn routine is found in the Mk 113 fire control computer as an integral part of the program. Both the Beta-2 and Gamma-0 smoothing routines are options in this simulation. For plot-party simulation, data are reduced from at-sea exercises, where the fire control solution is recorded at weapon launch time, and, through reconstructing the exercise, target position obtained. This information is used to develop an error structure table where mean values of target range, course, and speed are obtained as a function of tracking time and range. The resultant TMA from the plot-party simulation may be used independently or in conjunction with the Mk 113 fire control solution.

In communications, only the inter-ship situation is modeled, and only with respect to time delays in the transfer of information from one part of the submarine to another, i.e., weapon launch delays. No attempt has been made, at this juncture in the submarine program, to consider inter-vehicle communications.

The enemy submarine is simulated at the same level of detail as for own submarine described above. There are portions of the enemy submarine however, that are considerably different from own ship. It is necessary to take into account the different orientation of the enemy with respect to this mission and our knowledge of the

enemy. The tactical packages programmed for the enemy submarine are primarily designed for submarines in a transit or intruder type mission, although the model is not restricted to these two situations. The ship types are identical to those programmed for own submarines. The ordnances are more general than those contained in the blue submarine and allow the user to configure the torpedoes with respect to the projected threat. The level of detail in the simulation of the torpedoes on the enemy submarine is the same as for own submarine. BQR-2B sonar system capability was initially assumed for the enemy submarine. The only fire control solution capability assumed for the enemy, at present, is the plot-party simulation. Communications on the enemy submarine are assumed to be identical to own submarine.

SUMMARY

Space has allowed only a brief description of the simulation modeling at the Naval Weapons Laboratory. This is a continuing task and the models are by no means static. At present, for example, we are working on a simulation of the BQR-7 (passive planar array system) and PUFFS (passive echo ranging) for incorporation into the submarine model. Groundwork is being laid for combining the three programs into a detailed simulation that will integrate all

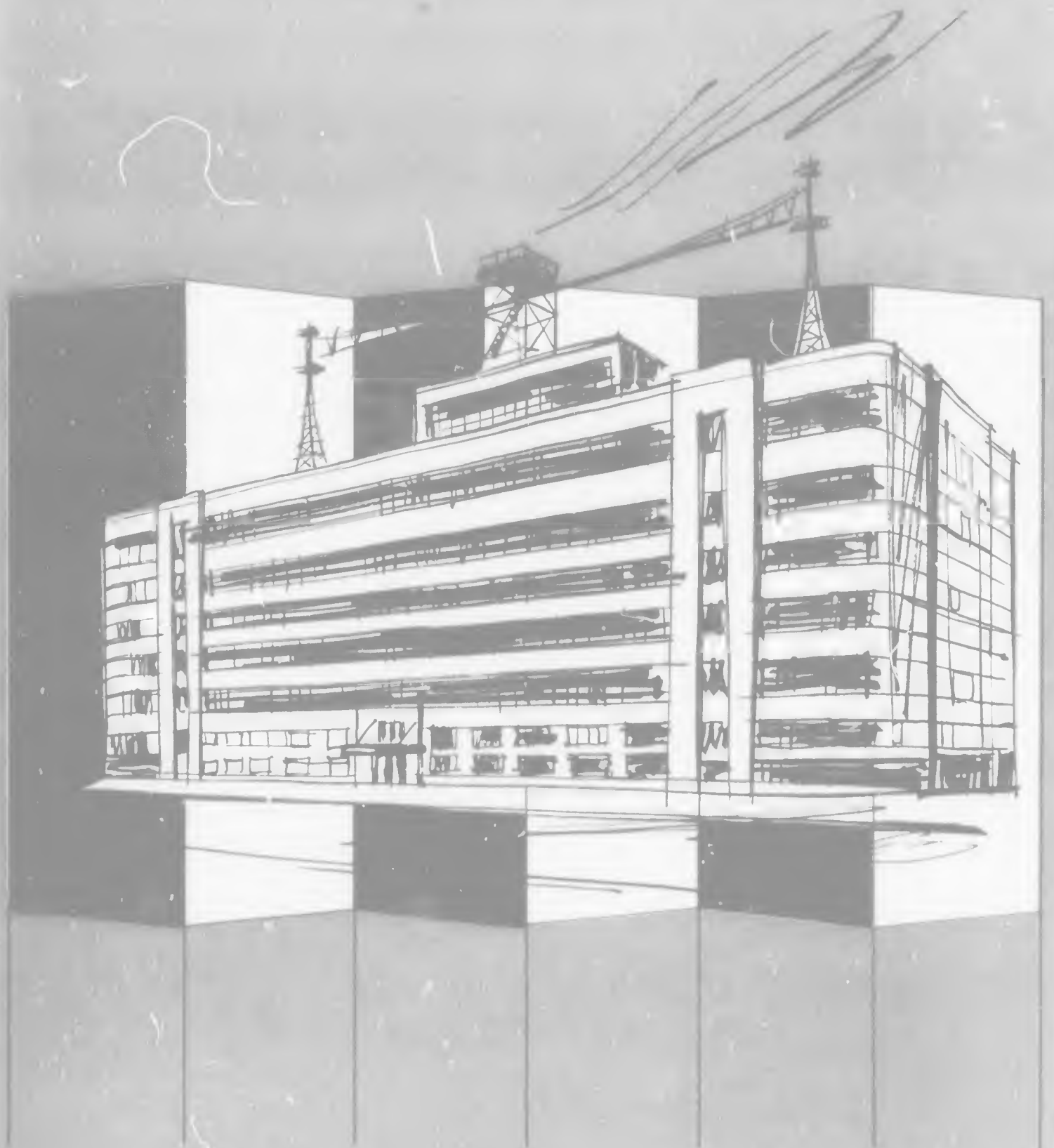
three phases of ASW. In such an advanced, integrated model, coordinated tactics will play a large role in the operation. This will represent a major effort, but the groundwork we are now laying will ease the problems later on. This effort will also require a computer with a large core storage capability, about 100,000 words, a facility which does not now exist at the Naval Weapons Laboratory. For this reason only the initial framework of the model can be accomplished. When a new and larger computer, scheduled for the Laboratory in the near future, is installed, it will expedite completion of the overall ASW effectiveness program.

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SYSTEMS EFFECTIVENESS TECHNIQUES

MR. J. V. SANDERSON



SUMMARY

DOD Directive 3200.9 of 1 July 1965 established policies governing concept formulation and contract definition in the initiation of engineering development of major projects. In so doing it challenges the Navy/Industry complex to develop techniques in effectiveness for realistically applying its doctrines. This is a progress report on some techniques, for meeting this challenge, developed within the Naval Material Command (NMC), sponsored under PACED* by Ship Systems Command, and coordinated by NMC's System Performance Effectiveness (SPE) committee.

DOD 3200.9 POLICY HIGHLIGHTS

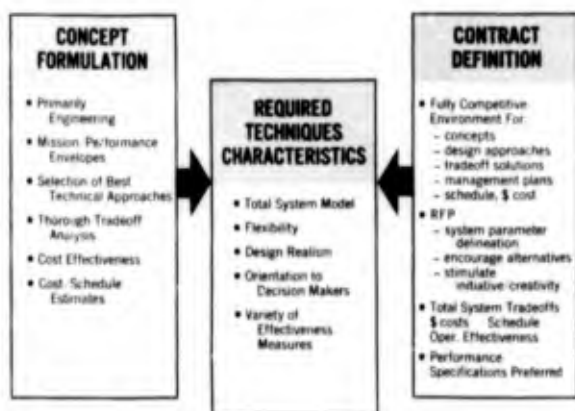


Figure 1

BACKGROUND

DOD Directive 3200.9 (1 July 1965) Challenge for Techniques

The DOD policy highlights, shown in figure 1, point out the requirements that both the Navy and/or Industry must meet by way of techniques and tools for selecting "best" technical approaches, performing tradeoffs, delineating system requirements, selecting engineering development contractor(s), etc. In addition, specific examination of each

highlight provides a boundary definition of the characteristics needed for incorporation in the set of techniques and tools. The synthesis process specifically encompasses the following:

- Mission/Performance envelope. Cost effective determination, system parameter delineation and total system tradeoffs. To accomplish this, a **system model** must be used for prediction and evaluation within defined mission requirements (i.e., operational effectiveness) as a function of life cycle costs and schedule.
- The selection of best technical approaches within the context of primarily engineering effort,* the policy for a fully competitive environment, the development of performance specifications, the encouragement of alternatives, and the stimulation of initiative and creativity. These objectives show the need for maximum **flexibility** in the choice of techniques and tools that will work effectively in an array of proposed design solutions.
- Requirements for thorough tradeoff analyses, alternative design approaches, tradeoff solutions, cost. Collectively these objectives pinpoint **design realism** for the performance of optimization, identification of technical problems and risk areas, and dollar allocation, among others, on the basis of total system impact.
- A compendium of discipline areas, techniques and tools to assist management **decision-makers** covering a variety of effective measures.

The last two characteristics relate directly to the utility of any technique or tool and are amplified below.

*Program for Advanced Concepts in Electronic Development.

*Performance projection based on quantitative demonstration in laboratory or by experimental device.

Techniques Concept for Technical Management Decisions.

The complexity inherent in the system developments under DOD 3200.9, as well as the number of discipline areas involved require that the technical management structures be spread horizontally over various functions and vertically through tiers of decision-makers. For example, in one major complex ship development there are 15 major subsystems operating in 25 different operational modes with over 1000 equipments. One subsystem alone has over 25 million state conditions in the reliability sense. All the persons involved need help. It is of prime importance to construct the tools and techniques falling under the effectiveness canopy so that the information given to the people responsible indeed helps them in

making their decisions. Figure 2 depicts two techniques for meeting the problem by providing, one, a figure of merit output, such as the probability of successfully completing a mission (P_s), and, two, a variety of effectiveness elements outputs. It is necessary to examine these approaches in some detail relative to "useability," which, after all, is the measure of any technique or model.

Assuming equal time for both concepts, three criteria are considered in making a comparison:

- Responsiveness to actual decisions (Techniques/People Interface)
- Responsiveness to technical management communications requirements (people/people interface)
- Responsiveness to questions (people/techniques interface)

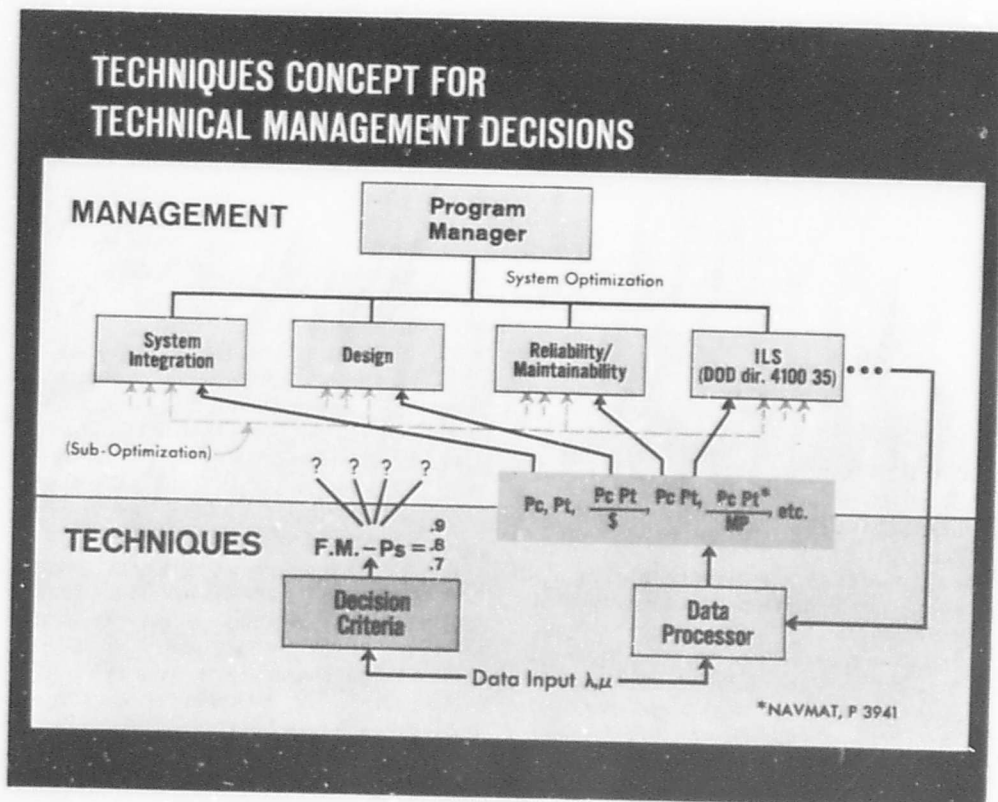


Figure 2

In order to generate decisions the technique or model must be a **data processor** which exercises input data to provide processed data directly related to the discipline or function about which a decision must be made. For example, a logistics acquisition manager, in the Integrated Logistic Support (ILS) context, would base his decisions on the effect that manning/spares/test facilities alternatives would have on total system operational effectiveness or performance. Similarly, designers and reliability/maintainability managers would base their decisions on the effect of configuration and redundancy changes on operational effectiveness or performance. Thus, techniques and models must provide answers for all tiers of decision-makers. On the other hand, the overall figure-of-merit approach makes the model the decisionmaker. Since this loops out all the responsible people, there is no decision-responsiveness, at any level, and worse yet, gives the top program manager information without the benefit of sub-optimization and sensitivity indications.

Responsiveness to technical management communication requires that models provide answers and information in a form that is understandable to management across-the-board. Not only must the processed data relate to an individual on a one-to-one basis, but it must have a common thread to enable committee decisions within the technical management complex. NMC's analytic approach to effectiveness, defined in NAVMAT P3941 (Navy Systems Performance Effectiveness Manual) of May 1967, stipulates "performance" as the required, common thread. This means that (1) the performance parameter (P_C) can be treated separately; or (2) the performance variation with time (P_T) can be treated separately as it is affected by failures, repairs, and logistic support; or (3) they can be treated together ($P_C P_T$); or (4) the resources can be displayed (e.g. $P_C P_T P_C P_T$)

$$\frac{MP}{\$}$$

where MP signifies manpower. Thus specialists can meet and discuss the influence of their specialities on total system performance. An overall effectiveness figure of

merit technique, in effect, replaces committee decisions and actions by the model itself; it cannot serve to aid making tradeoffs between functions (i.e. design versus reliability/maintainability versus I.L.S. etc.) involving more than one decision-maker.

If the tool or technique is responsive to actual decisions to be made, then it is response to questions posed by technical management. Again, a DATA PROCESSOR as a model for processing data into a form directly related to problems to be solved is the recommended approach. For example, people responsible for reliability and maintainability (R/M) are interested in analyzing alternate approaches for achieving R/M requirements. The model must be helpful to these people in arriving at an optimum solution. The "people/model" interface must be basic in carrying out the direction in the DOD 3200.9 policy, namely that systems should be formulated and defined from a foundation of alternatives.

TECHNIQUES PROGRESS

Meeting 3200.9 Challenge — NMC Systems Performance Effectiveness Management

Coordination of Systems Performance Effectiveness (SPE) within NMC is provided by the NMC SPE Steering Committee, chaired by Mr. D. Whitelock.

The Naval Applied Science Laboratory has been assigned NMC lead laboratory in SPE and is performing work for people and programs across-the-board in NMC. This work

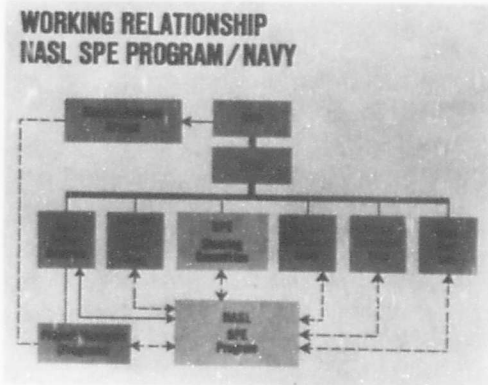


Figure 3

covers both development and application of effectiveness techniques.

Figure 3 shows the working relationship of the Laboratory's SPE Program with the Navy and NMC. The Program's technical scope and breadth made it necessary that it be managed by the NMC SPE Steering Committee. Sponsorship of the techniques development work is provided by Ship Systems Command, Code 03511.

As indicated, involvement includes people support covering consultation, review, and guidance functions rendered to NMC and Systems Command Offices. It also includes program support through active participation in program developments throughout the commands under independent funding and task assignments for each program. The developed techniques are thus applied and validated on real-life programs representative of many different types of systems, electronic and mechanical. From NMC and the individual program viewpoints, third party in-house objectivity is provided on a "quick response" basis for the purpose of developing effectiveness requirements, performing tradeoffs, contractor evaluations, etc.

Management by the NMC Steering Committee (meeting monthly with representation from all Systems Commands as well as from Industry), provides an excellent forum for exchange of ideas and for identification of Navy problems. It also ensures that SPE efforts proceed with maximum NMC coordination and minimum duplication.

SPE at the Naval Applied Science Laboratory is organized as shown in Figure 4, wherein techniques development and techniques application are integrated in one organization. This integration offers enormous payoffs through:

- Management flexibility in utilization of men
- Validation and refinement of techniques within the same organization,
- Feedback from real-world problems requiring new and better techniques such as data requirements, design information retrieval, failure criteria for effectiveness evaluation allowing degraded performance, multi-mission

analysis, multiplicity of modes and states in ship-level applications, etc.

- Competence buildup as capability is increased by means of technical manager experience gained in program participation, and motivation is enhanced, by utilization of one's own ideas.

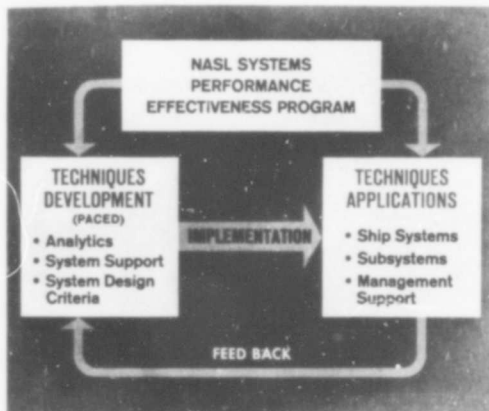


Figure 4

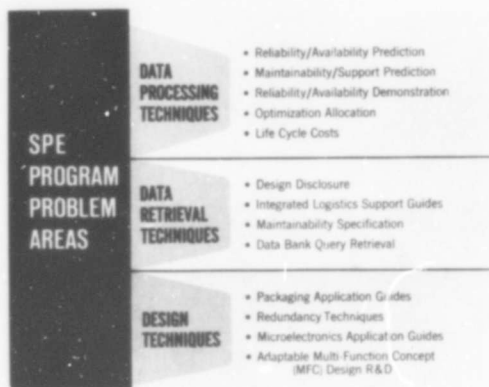


Figure 5

Meeting 3200.9 Challenge — Techniques

Problem areas are determined after coordination and review by the NMC SPE Steering Committee.

Figure 5 presents some of these areas where efforts are underway. They generally fall into three categories:

1. Data Processing Techniques — These encompass methodology, concepts,

mathematical algorithms and computer programs aimed at giving decision-makers specific information on complex systems.

2. **Data Retrieval Techniques** — These include data source guides, design documentation, and data processing compatible input procedures that will present clear, meaningful system information.
3. **Design Techniques** — These include design guidelines, concepts, and specifications for applying state of the art technology in an optimum manner in program developments utilizing effectiveness requirements as criteria, i.e., maintainability, reliability, I.L.S. etc.

Details of two specific and important models falling in the Data Processing Techniques category are given in the following sections, the Generalized Effectiveness Methodology Program (GEM) and a Maintenance Simulation Model. Before proceeding, however, a recapitulation is in order on these and other tools developed by the SPE Program to meet the problems listed in Figure 5:

Under Data Processing, these tools are:

- Generalized Effectiveness Methodology Analysis program (GEM) (details below)
- Maintenance Simulation Model (details below)
- Survey/Evaluation of Effectiveness Computer Programs, a follow-up effort to DOD Survey of September 1965 (OEM 1), aimed at providing information on techniques to Navy program managers; preventing duplication of effort both in the Laboratory and throughout the Navy; and forming a baseline for future advanced techniques developments, with emphasis on cost, optimization, tradeoffs and maintainability. (REF: "Evaluation of Computer Programs for System Performance Effectiveness," final report prepared for NASL by Research Triangle Institute under Contract No. NOO 140 66 C 0499 dated August 1967.)

- Test/Demonstration Technique utilizing Bayesian statistics in order to curtail reliability testing time required by AGREE (Advisory Group for Reliability of Electronic Equipment) (REF: "An Evaluation of a Test Allocation Procedure," prepared for NASL by Kaman Systems under Contract No. NOO-140-66-C-0517, dated Apr 1967.)
- Scenario Simulation Models for performing reliability and availability predictions and R/M allocations as a function of mission requirements during ship system concept formulation and contract definition. (REF: For part of this work — presentation by NASL's S. Friedman "Reliability and Availability on the DX/DXG Program," SPECON 4)

Under Data Retrieval, these tools are:

- MIL-HDBK-226 (NAVY) containing design disclosure techniques directed at improving technical communications at all levels in and between Industry and the Navy during complex system developments.
- R/M Data Source Guide as a first step in alleviating the problem of accessing, retrieving and reducing data currently spread across a multiplicity of data sources. (REF: Reliability and Maintainability Data Source Guide "System Performance Effectiveness Program" NASL Lab. Project 920-72-1, Progress Report 2 of November 1967.)

Under Design Techniques, these tools are:

- NAVMAT P3940 containing a compendium of alternate packaging designs for consideration during concept formulation and contract definition. The objective of NAVMAT P3940 is in consonance with DOD 3200.9 policy.
- Microelectronic (M/E) Application Guidelines containing design and review procedures for evaluating alternate M/E implementation approaches with respect to cost/effectiveness for systems/equipments. These Guidelines are in consonance with DOD statement 17 April 1967 as transmitted by SECNAV Instruction 10550.4

of 1 November 1967. (REF: "System Design Guidelines for Microelectronics," Lab. Project 920-72-3, Technical Memorandum 1 of April 1966).

- Adaptable Multifunction Concept (MFC) Design Technique now in the form of a demonstration kit proving that electronic switching for adapting one module to multifunction operation is feasible and within the state of the art, for ultimate large payoffs in decreasing logistic support (self logistics), improving maintenance (self-test), and increasing commonality intra-system. The technique is also in consonance with the DOD Policy of 17 April 1967.
- Redundancy Application Guidelines containing advanced theory and design approaches for utilizing microelectronics in redundant system design to improve operational effectiveness (self-testing design included) (REF: "Handbook for System Application of Redundancy," Lab. Project 920-72-9 of August 1966, and "Microelectronic Redundancy," Lab. Proj. 920-72-9, Final Report). For further technical information on these techniques, discussion with the Naval Applied Science Laboratory is invited.

The Navy System Performance Effectiveness Manual (NAVMAT P3941) of May 1967 is intended as the single document for SPE techniques, under NMC purview, so that potential users need not continue literature searches. The first updating of NAVMAT P3941 is planned for FY69 in time for SPECON 5 and will contain many new developments, some of which have been described above.

GEM PROGRAM

Generalized Effectiveness Methodology (GEM) is a computerized method for the prediction, evaluation and control of system configuration and system variables in terms of important effectiveness parameters. It is under continuing development.

GEM has been developed to match the techniques and characteristics synthesized

from DOD 3200.9 policy highlights, namely: total system modeling, flexibility, design realism, orientation to decision-makers, coupled with an ability to evaluate effectiveness measures. It is also organized to perform a generalized service to cut down spiralling computer programming and modeling costs.

This section updates and amplifies material presented in SPECON 2—"Predicting Systems Effectiveness" by Paul Giordano, April 1966 and in NAVMAT P3941, and also indicates some of the GEM program applications. A report which contains guidance information on the use of the GEM program, Progress Report I, "Generalized Effectiveness Methodology (GEM) Analysis Program," is available for distribution at this conference (NASL Lab. Project 920-72-1).

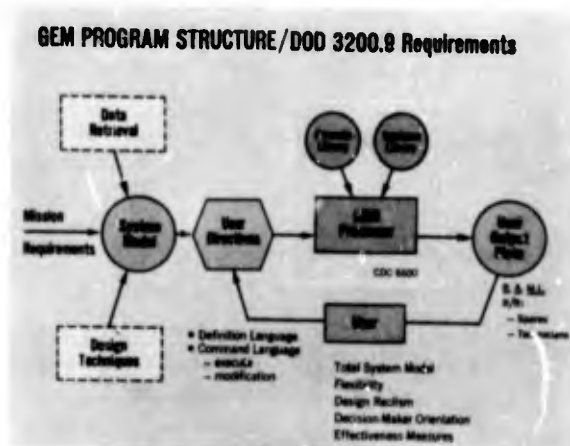


Figure 6

Figure 6 depicts the GEM program structure in the context of DOD 3200.9 requirements. Activities prior to its use encompass: good systems engineering, including definitions of mission, mission tasks, equipment loading per mission task, performance requirements, mission task times failures for full and degraded performance; effectiveness criteria and resource constraints (e.g., reliability, maintainability, logistics manning, etc.); system/equipment alternative and data retrieval. GEM is not a panacea to replace solid engineering; it is a tool for evaluating and analyzing system baselines first established during concept formulation.

The system model is the sum total of the above activities. Given a system description

in this context, a GEM user need only prepare the Users Directions which comprise a Definition Language and a Command Language. The following material gives specifics of present and near term (calendar 1968) GEM capability.

The complexities of FORTRAN programming is avoided. Definition and command instruction are in English-short-hand style, a distinctive factor for orienting the program "user or decision-maker oriented," (see figure 7).

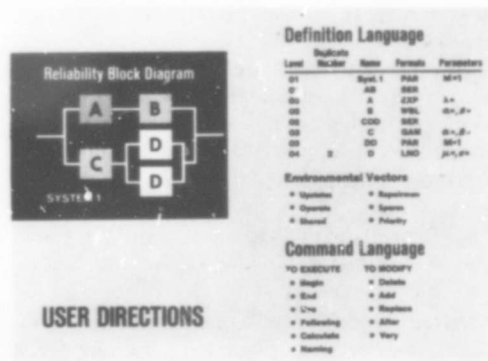


Figure 7

First, the user must transform a system configuration to its related reliability block diagram by using standard procedures. The reliability block diagram is in turn described and resource constraints added, using a prescribed short-hand vocabulary for input into the computer. This vocabulary consists of the following:

- Level (or hierarchial position starting from the apex)
- Duplicate Number (no. of identical system items)
- Name (for identification)
- Formula (relationship of items or failure/repair distribution of lowest level item)
- Parameters (clarifies relationship of items—e.g., for redundancy requirements—or gives failure/repair distribution parameters of lowest level item)

- Environmental Vectors

- Upstates (states complex upstate rules)
- Operate (gives number of identical items operated—remaining identical items in standby redundancy)
- Shared (identifies similar items throughout system)
- Repairmen (designates number of repairmen and items sharing repairmen group)
- Spares (designates number of spares for each spare pool and items serviced by each pool)
- Priority (states strategy when repairmen/spares are shared)

Thus, utilizing an English-language program, a total system for meeting a prescribed performance, including desired repairmen and spares constraints, can be simply described for computer input with design realism reflected in the exactness of the configuration descriptors comprising the definition language.

Second, the user activates the processing through the Command Language which serves to ask the computer questions and to make modifications in the system already described. Once the basic description has been inputted. The command instructions become a dynamic mechanism for exchanges between the machine processor and the user, looped by means of the plot (graphical) output.

Having determined (before using the GEM program) the effectiveness criteria required for evaluating his system against mission needs, the user then chooses a calculation for the machine to obtain a value for the effectiveness measure or criteria. As described earlier, the user can be a technical manager responsible for system design, reliability, or maintainability, or logistics, but the measure must be sensitive to his design responsibilities. The measures in the present and near term (calendar 1968) GEM capability are:

- Reliability without repair
- Interval reliability without repair (within any mission time "window")
- Reliability with repair (applicable to today's highly redundant systems)

- Interval reliability with repair (within any mission time "window")
- Instantaneous availability
- Mission availability (over any specified period of mission time)
- Steady state availability
- Mean time to first system failure
- System restore capability (i.e., probability of restoring a system to an upstate in time t.)

Any particular choice from the available variety of effectiveness measures is then calculated using the simple vocabulary elements of the command language:

- Begin (initiates GEM Program run)
- End (terminates GEM Program run)
- Use System 'X' (start problem or "job" within Program run on System 'X' in System Library or previously described in same run)
- Following (if system is to be described)
- Calculate (R, A . . . T = x) (request to calculate desired measure (R, A, etc.) for mission or time x (if required))
- Naming (name user gives computed answer)

The second part of the Command Language, the scheme for making modifications, is an extremely important attribute of the GEM Program. It permits flexibility for handling changes, variations and alternative design solutions as proposed and inputted by the user, for the purpose of making tradeoff studies, as per 3200.9, and it does it rapidly and efficiently without the need for total reprogramming. The language elements for modification are:

- Delete "____" (removes item named from system description and all of its lower level items)
- Add "____" (adds item named, or system or portion thereof which has been previously described or is in System Library, to the system description)
- Replace "____" (combination of Delete and Add instructions)
- Alter "____" (changes any of the definition language elements, i.e., level,

duplicate, name, formula, parameters, etc., for any of the item entries)

- Vary "____" (varies parameters of distributions and environmental vectors pertinent to item named by stipulated increments)

The Vary command is very useful. With it, the user can perform sensitivity analysis to ascertain the influence on the overall system measures (reliability with and without repair, instantaneous availability, etc.), exerted by any of the following on an item or group of items in the system description: failure rate, repair rate, repairmen allocation, spares allocation, upstate rules, active and standby redundancy, and repair priority; i.e., varying environmental vectors. This is particularly valuable when the 'hard' data ($\lambda\mu$), for any item is questionable.

Figure 7 depicts a simple situation. Reference is made to pp. 30-31 of NASL Report Lab. Project- 920-72-1, for an example showing the definitive language used for a complex realistic design.

After executing the definition and command instructions given to it by the GEM user, the machine communicates the results back to him through an answer table graphical plot output vs. time, for each of the effectiveness measures (except mean time for first system failure giving print output), at the system level. Depending on the measure calculated, the graphical plot becomes the probability of sustained system performance (P_T), or the probability of available system performance, as a function of time. Thus, all the user decision-makers have a common vehicle for tradeoff purposes as changes in design and resources under their control are measured with respect to system performance.

The internal processing and organization, which is completely independent of any user, has been designed and developed to offer a generalized capability in addition to the DOD 3200.9 compatibility described above. A library of formulas contains a set of computer programs for evaluating the formulas used to compute the aforementioned effectiveness measures and has an update program for additions and deletions. A library of systems

records the processed system descriptions, and has a recall capability and an update program. These features enable a manager to file his system and keep its description current as design changes occur. The processor is a translator which allows the computer to accept the system definition and command instructions and to generate and execute an evaluation program. Specifically acting upon the User's instructions, the processor extracts the proper formulas from the Formula Library, generates the routines for the evaluation and, using the hierarchical structure of the described system inputted, executes the evaluation. This generalized capability is significant for two reasons: it avoids piecemeal approach to individual Navy programs in buying and developing analytic and programming work over and over again, and it enables rapid analytic turn-around and early identification of useful areas for engineering analysis and investigation.

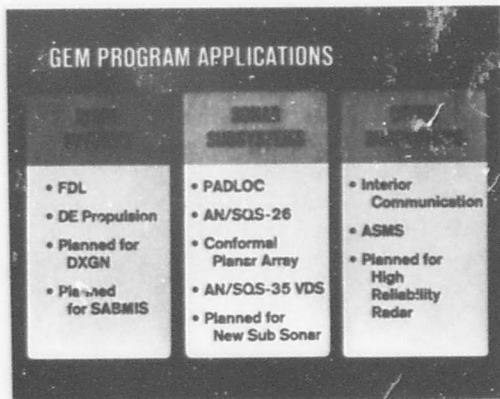


Figure 8

A concurrent validation program is being carried on through application of the GEM program in systems representative of the Navy across-the-board. Figure 8 shows different types of systems and equipments which were selected for applying GEM so that all of GEM's capability could be tested against the desired objectives. Figure 8 depicts past, current, and near term applications covering total ship systems (FDL, D.E. Propulsion, DXGN, SABMIS) as well as Sonar, Radar, Interior Communications and

Missile Subsystems. Further, program participation provides insight on new measures of effectiveness required by the users themselves. Highlight validations to date are:

- Early GEM capability used in the SQS-26AX and BX Backfits indicated the need for additional scan conversion redundancy; suitable action was taken.
- Utilizing Repairman allocation capability, GEM evaluated reliability with repair and availability for the SQS-26. The results showed no incremental improvement in these measures by having more than two maintenance technicians per 8-hour shift.
- Using the Vary command capability, the failure rate of microcircuits in the transmitting subsystem of the Conformal Planar Sonar System was varied widely on either side of the developed norm with little impact on system reliability and availability. This evaluation led to a decision to forego further major effort in determining failure rates with any degree of accuracy greater than an order of 10. (Ref: "Application of SPE Techniques" presented by M. Lubliner of NASL at SPECON 3, May 1967).
- Ship System Reliability without repair and availability calculations were performed for the FDL Project Office.
- Reliability with and without repair and availability evaluations were performed on shipboard propulsion machinery.

Conclusions:

- The GEM program concept for "usability" within the context of DOD 3200.9 of 1 July 1965 has been successfully demonstrated.
- The GEM program concept for "generalized" usage has also been demonstrated.
- The GEM program capability has been shown to be suitable for preliminary comparative studies of shipboard propulsion systems. (Ref: "Ship Propulsion Machinery Reliability and Availability Analysis," R. L. Hamilton,

Proceedings, 1968 Annual Symposium on Reliability of 16, 17, 18 January).

The validation effort also indicated GEM potentials:

- Expansion of capability to handle complex ship-level situations involving millions of up and down state conditions.
- Expansion of effectiveness measurement capability to include multiphase mission problems (Ref: R. L. Hamilton presentation at 1968 Symposium on Reliability).
- Expansion of effectiveness measurement capability to include consideration of allowable maintenance downtimes. (Ref: "Reliability Analysis of Ship Systems During Contact Definition," John R. Lennon, Proceedings 1968 Annual Symposium on Reliability of 16, 17, 18 January).
- Efficiency improvements to reduce computer running times in evaluating availability and interval reliability for complex systems with no technician/spares limitations (to be completed in calendar 1968).

In addition to expansions generated specifically through the validation program, total system tradeoff requirements point to the need for continued GEM expansion in maintainability, logistics, costs, optimization, approximation techniques, etc. All expansions are coordinated and reviewed by the NMC SPE Steering Committee before commitment.

As a last comment, the GEM Program is being run on the Courant Institute CDC 6600 computer at New York University (N.Y.C.). The Naval Applied Science Laboratory is available for consultation on the GEM Program. Contact is recommended via Navy Program Offices.

Maintenance Simulation Model

It is recognized that not all problems lend

themselves to generalized approach. Special programs will still be required with individual computer input instructions. As compared with the deterministic approach offered by the GEM program for analysis, a simulation approach may be necessary. Indeed, when the relationships are so complex that the equations are not readily solvable, or if the relationship cannot be conveniently expressed in mathematical terms, a simulation model must be employed in the effectiveness calculations. The advantages offered by each approach make them complementary for serving 3200.9 requirements during concept formulation/contract definition activities. Analyses of the complex maintenance environment and procedures aboard Navy ships require a simulation method. With this in mind, the Laboratory has developed a Maintenance Simulation Model using the General Purpose Simulation System (GPSS) language.

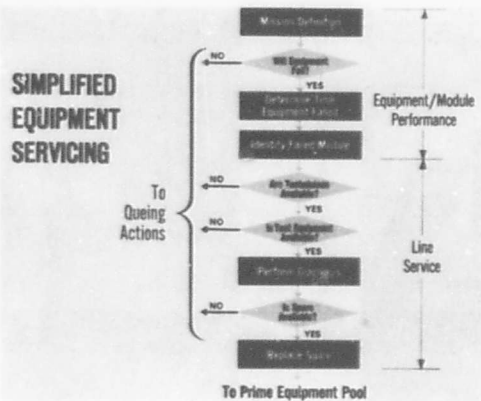


Figure 9

The objective of the model development was to simulate the shipboard behavior of any equipment suit under a variety of servicing conditions for any given length of time typical of mission tasks. The basic model structure and information flow is given in figure 9 for equipment selection, performance and servicing in simplified form. It is sufficient to convey the simulation process. In the actual flow processing there are many

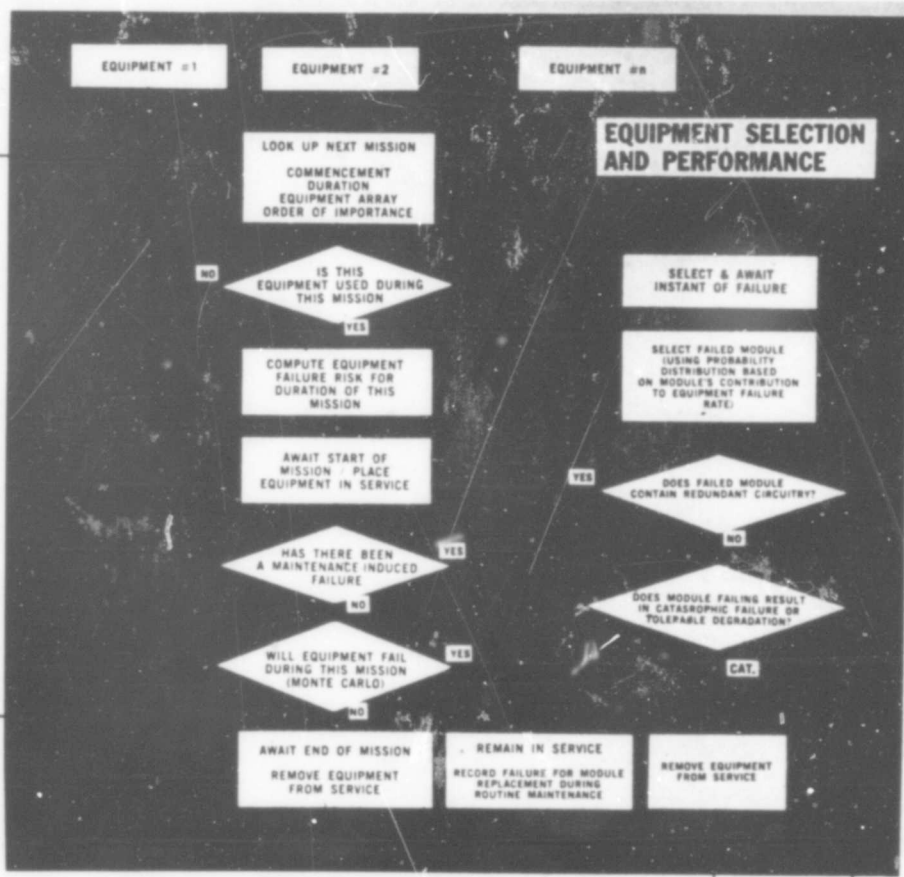


Figure A

more actions and decisions which include considerations of (See Figures 9A and 9B) :

- mission types
- mission duration
- equipment use/mission
- equipment, module failure rate
- maintenance induced failure
- time equipment failed
- catastrophic vs. non-catastrophic failures
- number of tolerable failures
- technician data—types, grades, shifts, rates, etc.
- equipment priority
- test equipment failure
- shop repair of failed test equipment

- shop repair of failed module
- misdiagnosis of modules
- operator cost
- module cost, etc.

Similar comprehensive structuring has been developed for shop activity and module repair on board ship.

The large number of actions and decisions in the model make it very sensitive to actual maintenance procedures and, also, require the user to supply the required input information. For more details on the computer flow and the inputing requirements, reference is made to NASL Lab. Project 920-72-2 Progress Report 3, entitled "A Maintenance Simulation Model."

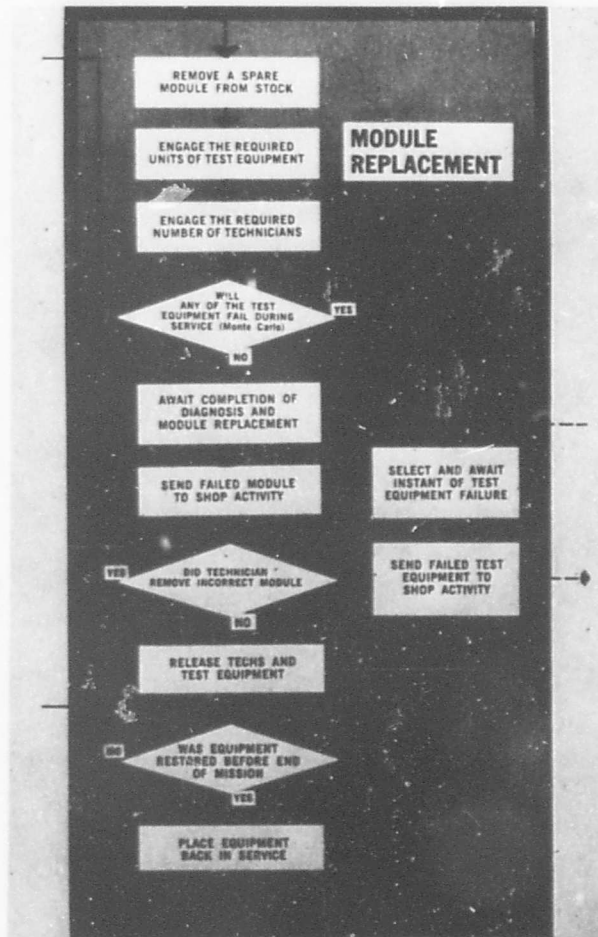


Figure 9B

Because the simulation model exercises and stores myriad maintenance information, it provides, as output to a user, a summary of useful, detailed data as to the availability of the prime equipments as well as utilization of the service facilities and personnel.

Typical outputs currently provided by the Maintenance Simulation Model are:

- Availability of each prime equipment,
- Average and peak utilization of each type of test equipment,
- Maximum and average number of equipments awaiting line service, and average length of wait,
- Maximum and average number of modules awaiting shop service, and average length of wait,
- Average and peak utilization of technicians,
- Labor and material costs accrued in actual line servicing,
- Labor and material costs accrued in actual shop servicing, and
- Labor and material costs of routine maintenance.

A summary of the simulation model data is given in figure 10.

SIMULATION MODEL DATA

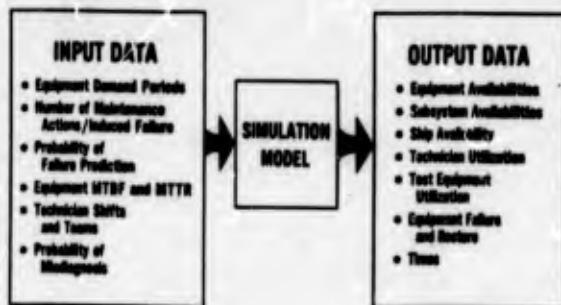


Figure 10

The model has been applied to a Cost Effectiveness Study of a Centralized Test System. Using it in this study enabled a comprehensive analysis to be made of the total shipboard maintenance environment, as well as an assessment of automatic versus general test procedures.

CONCLUSIONS

The techniques and products of the Navy SPE Program have been implemented on going Navy programs with ever increasing impact. This is a testimonial to the techniques

IMPLEMENTATION OF SPE PRODUCTS

PROGRAMS	IMPLEMENTATION OF SPE PRODUCTS							
	MR. 1968-226 SPE	NAVANT P-2000	NAVANT P-2001	MR. 1968-372 MAINTENANCE SIMULATION MODEL	MR. 1968-372 SYSTEMS SIMULATION MODEL	MR. 1968-372 RELIABILITY MANAGER	C/E ARE	
Ship Systems	2	3	2	1			3	
Missile Systems	3	2						
Air Systems	1		1					
Subsystems	1	2	3					
Systems Support	3			1	1	1		1
Sonar	3	6	3	3	3		2	1
Radar	1				1			
TOTAL	14	13	9	5	5	1	3	2

Figure 11

and indicates an acknowledgment by the Navy that Systems Effectiveness considerations will be part of its development programs, as directed by DOD policy.

Figure 11 summarizes the application of SPE products to different types of programs. These programs require either consultation or active participation to facilitate their Systems Effectiveness Analysis. During such implementation the techniques advocated by the SPE branch at NASL are used to provide necessary support to the program office. In addition to the SPE program having fallouts for use by these programs, the programs themselves provide important inputs to the SPE effort in the form of practicality, realism and feedback suggestions for improvement.

THE ROLE OF ASW SYSTEMS ENGINEERING IN WEAPON SYSTEM EFFECTIVENESS

DAVID B. HARRIS



INTRODUCTION

System engineering is a multidisciplinary field and is not amenable to simple definition, as has been indicated by Machol¹, Hall², Shinn³, et al. Machol implies that the principles of system engineering are of interest to those who are concerned with the two broad activities of system design and system analysis. In addition, he states that those systems requiring system engineering, in general, have the following seven characteristics:

- The system is man-made — from equipment, or "hardware."
- The system has integrity — all components contribute to a common purpose, the production of a set of optimum outputs from the given inputs.
- The system is large — in number of parts, in number of identical parts, cost, etc.
- The system is complex — meaning that a change in one variable will affect many other variables in the system, rarely in a linear fashion.
- The system is semi-automatic — meaning that both human beings and computers always perform some of the functions of the system.
- The system inputs are stochastic — meaning that an inability to predict the exact load or performance at any instant in time exists.
- The system is competitive — i.e. the system attempts to reduce the effectiveness of the enemy, and at the same time competes for DOD dollars.

These seven characteristics accurately describe a modern ASW Combat System.

Effective management of the Submarine ASW Combat System involves the application of the principles of system engineering

in the performance of the following Anti-Submarine Warfare Systems Project Office (ASWSPO) functions:

SYSTEM DESIGN FUNCTIONS

- Definition of system.
- Specification of requirements.
- Integration and coordination of subsystems.
- Establishment of system test criteria.

SYSTEM ANALYSIS FUNCTIONS

- Performance/availability/cost trade-offs.
- System test.

Note that the design and analysis functions which have been listed are not the conventional functions which are normally associated with design and analysis of a specific piece of hardware. They are functions which are management-oriented.

The system effectiveness methodology provides the framework for an organized approach to the performance/availability/cost trade-off function, which in turn impinges on the system design functions. The system engineer works very closely with the operations research analyst. Together they develop the "cost/effectiveness" and related analyses necessary to provide the Manager, Anti-Submarine Warfare Systems Project (MASWSP) with the information required for making well-founded decisions.

It is not the intent of this paper to address the entire field of system engineering as related to system effectiveness, but to concentrate on the definition of a fundamental problem, namely:

To bridge the discontinuity which exists between the analytical approach which the system engineer utilizes to specify and judge the performance effectiveness

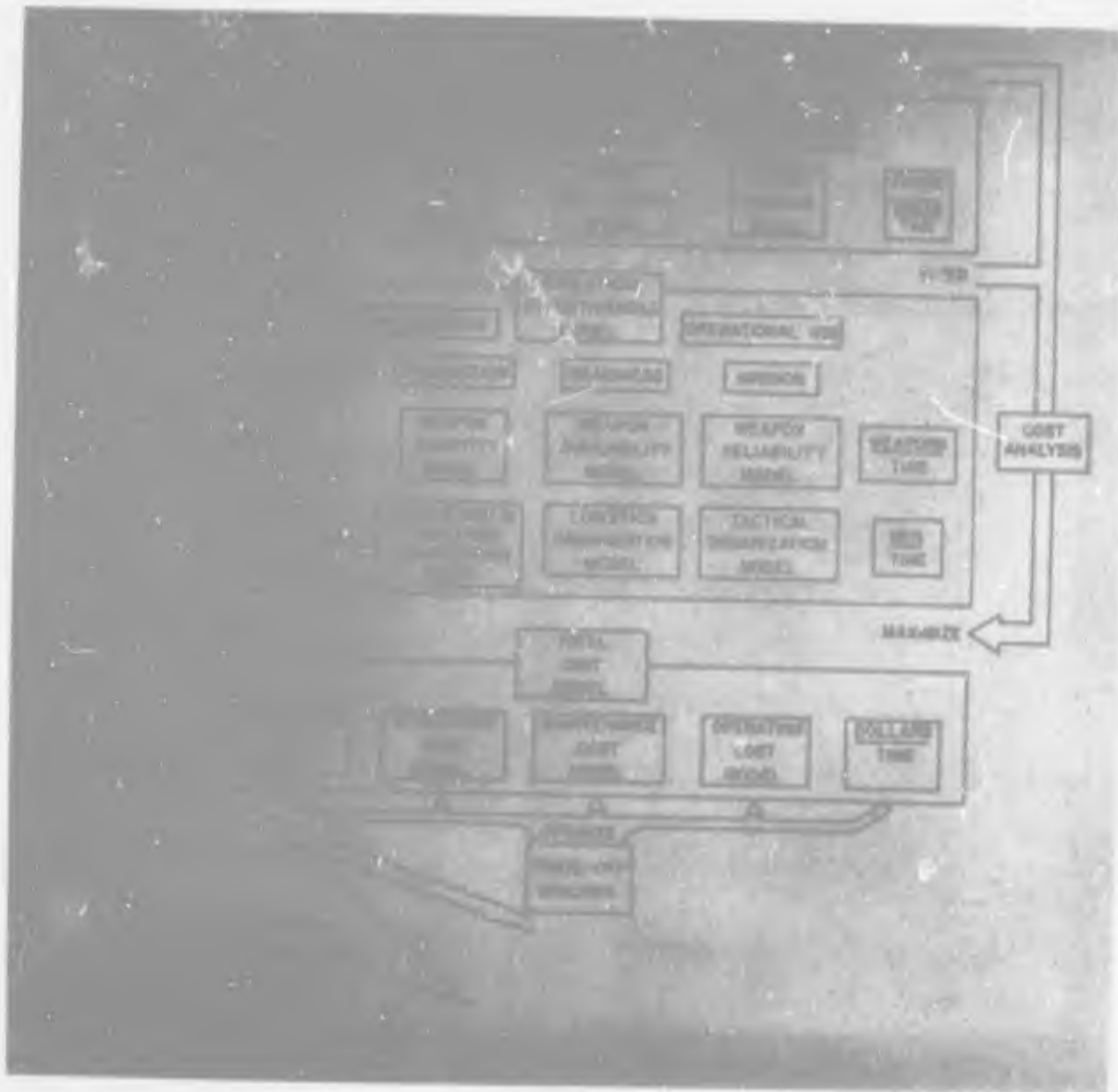


Figure 1

of a combat system and the empirical approach which the operations analyst utilizes to evaluate the performance effectiveness of a combat system.

This discontinuity is represented in figure 1 which portrays the dynamics of a cost/effectiveness analysis. This figure is presented to demonstrate where the gap exists and to indicate the complexities which exist in the overall cost/effectiveness analysis effort for a submarine ASW combat system. Note that there are numerous interactions between the various blocks of figure 1, but these have not been included because they

are not the subject of this paper. The primary concern here is the recognition of the gap between the analytical and operational (or empirical) determinations of submarine ASW combat system effectiveness. The domain of the system engineer is shown in the unshaded region of the figure. The primary functions of the system engineer are:

- To direct the necessary modeling efforts.
- To supply the characteristics of the equipments making up the overall system configuration.
- To supply all input data required for model verification and exercise.

The engineering efforts being applied to the submarine ASW combat system have been divided into:

- The in-service submarine ASW combat system.
- The submarine ASW combat system of the future.

THE IN-SERVICE SUBMARINE ASW COMBAT SYSTEM

The efforts being expended to evaluate the effectiveness of the in-service submarine ASW combat system, are aimed at establishing an effectiveness baseline to illuminate those areas where improvements should be sought. Such a baseline can also be used to

assess the value of initiating new developmental efforts, and to determine the goals toward which such efforts should be directed to improve the overall system effectiveness. For example, this would include a determination as to whether improvement should be sought in a particular sonar, and if so, whether it should be sought by means of improved performance, or whether a reliability/maintainability enhancement program would suffice.

Prior to the establishment of the ASW System Project Office, developmental efforts sometimes proceeded on a particular subsystem or equipment without consideration as to how the overall system performance was

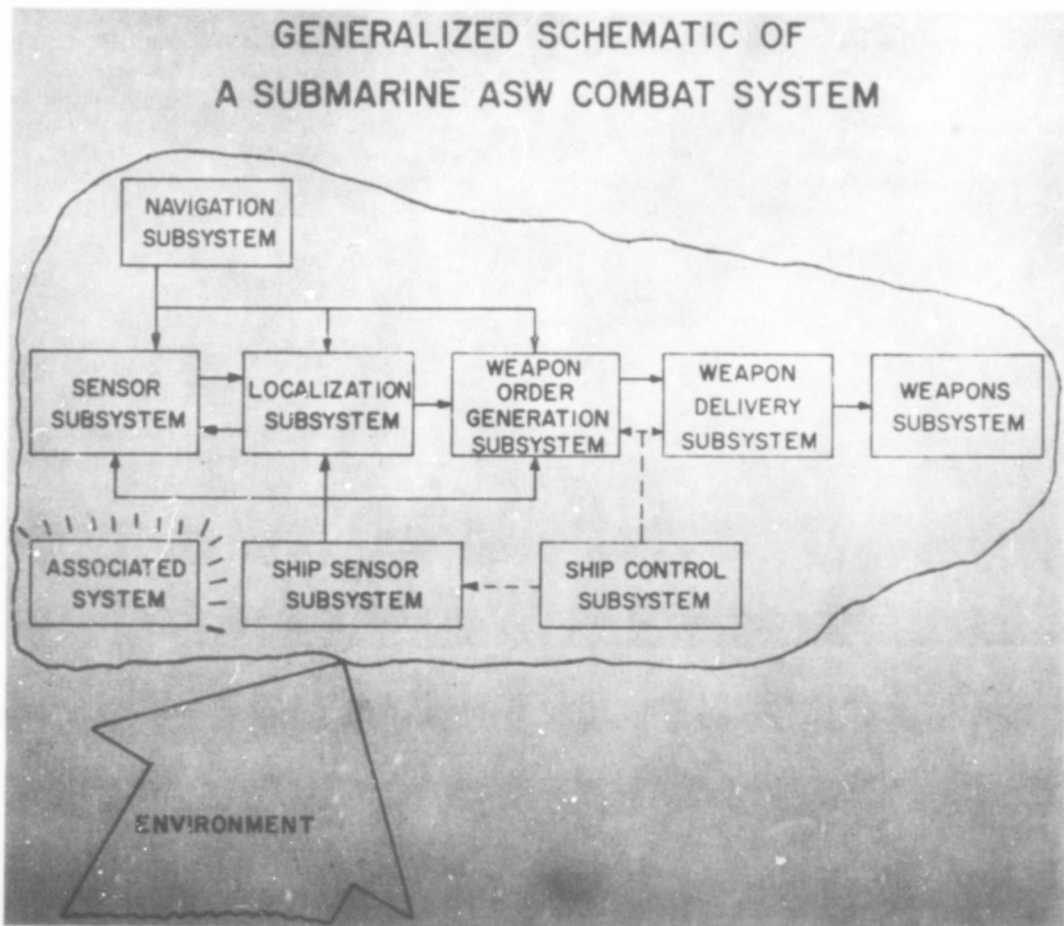


Figure 2

affected. To illustrate, assume that the Fleet indicated a need for improvement in the accuracy of the fire control solution. The cognizant Material Bureau would typically respond by investigating how best to obtain the requested fire control improvement without regard to the overall mission and system performance. In particular, the system forcing function, namely the sonar, may have been ignored, when in fact, the system accuracy may have been sonar-limited. The improvement efforts under such circumstances should have been directed toward the sonar together with the fire control.

In order to establish the effectiveness baseline, it was apparent that an analytical model was needed. The model is currently under development within the framework described in the **Navy Systems Performance Effectiveness Manual**, NAVMAT P3941, wherein system effectiveness is defined as "a measure of the extent to which a system can be expected to complete its assigned mission within an established time frame under stated environmental conditions." Expressed functionally, the definition of Weapon System Effectiveness (WSE) is of the form,

$$WSE = f(P A U)$$

where

P — Index of System Performance — a numerical index expressing system capability assuming a hypothetical 100% availability and utilization of performance capability in actual operation.

A = Index of System Availability — a numerical index of extent to which a system is ready and capable of fully performing its assigned mission(s).

U — Index of System Utilization — a numerical index of the extent to which the performance capability of the system is utilized during the mission.

Other terms may be considered, such as survivability, if desired, but the three terms performance, availability, and utilization, form the essential ingredients of any system effectiveness determination. Although the terms may be defined differently by other agencies, the basic ingredients are identical.

With the basic model framework thus established, consider the schematic representation of an idealized submarine ASW combat system shown in figure 2. No allusion is made to specific types of equipment which eliminates security problems. The first step in the expansion of the analytical model was the development of an overall system error model, without considering the external environment, which includes the ocean and the target. This model is now well in hand and describes the performance of the existing equipments in such a manner that errors can be attributed to the various subsystems and equipments; the total system output error can be determined as well as the sensitivity of the total error to the individual contributors. By appropriate exercise of this error model, it is possible to assess the performance of the individual subsystems relative to their specific figures of merit. It is apparent that this model only addresses the performance factor of WSE, ignoring the availability and utilization factors. Work is continuing to refine the error model and to bring into account the environment and other error contributors to system degradation. Effort is also under way to develop reliability/maintainability/availability models which will be useful in establishing the overall weapon system effectiveness in terms of the PAU equation.

Fleet exercises are used to determine weapon system effectiveness on an empirical basis. In this approach to system effectiveness evaluation, the following probabilistic equation has been applied:

$$WSE = P_D \cdot P_C \cdot P_{A1} \cdot P_{A2} \cdot P_K \cdot (1 - P_V)$$

where

$$P_D = \frac{\text{number of detections of target}}{\text{number of opportunities given}}$$

$$P_C = \frac{\text{number of correct classifications of target}}{\text{number of detections of target given}}$$

$$P_{A1} = \frac{\text{number of attacks made against target}}{\text{number of correct classifications of target given}}$$

$$P_{A2} = \frac{\text{number of accurate attacks made against target}}{\text{number of attacks made against target given}}$$

$$P_K = \frac{\text{number of kills of target}}{\text{number of successful attacks given}}$$

$$P_V = \frac{\text{number of accurate counterattacks by target}}{\text{number of opportunities given}}$$

$$\times P_K (\text{of target's torpedoes})$$

This use of W S E assumes that the detection, classification, attack and kill of one submarine by another is a random phenomenon. For example, it is an empirical phenomenon characterized by the property that its observation under a given set of circumstances is not always the same; there is no deterministic regularity. Since the observed frequencies of these events are actually approximations of the true probabilities, and since the approximations approach the true probabilities only within their limits, a large amount of data must be collected before statistical confidence can be placed in the estimated probabilities. Observe that these probabilities are conditional, and the events are assumed to be mutually independent. In such an empirical approach, we look at system effectiveness only in a broad sense, failing to obtain the insight necessary to specifically pinpoint those equipments which are the principal degraders of system effectiveness.

The distinction between the two approaches to system effectiveness evaluation should be clear at this point. The operational or empirical method gives a good measure of what the real system can actually do in a microscopic sense under controlled conditions. That is, such statistical experiments are feasible only under a limited spectrum of environmental conditions; they are usually conducted with a "tuned-up" system, and the psychological effects on the "man in the system" may not be representative of the actual tactical situation. On the other hand, the analytical or theoretical approach permits a microscopic look at the system, but the results are only as good as the model. Therefore, it is essential that all accountable factors be identified, duly weighted, and properly incorporated into the model if the results are to nearly corroborate the results obtained by the operational methodology. This implies that it is desirable to establish the following equivalence:

$$W S E (P A U) = W S E (P_D \times P_C \times \dots)$$

It is between the two sides of this equation that the gap exists, and it is the role of system engineering to develop the necessary bridge.

Let us consider an example to illustrate the nature of the function which the system engineer must perform in constructing this bridge, namely, the corroboration of P_D . The P_D of a sonar is a function of the receiver signal-to-noise ratio, and in fact, it is possible to plot a curve representing this relationship for a given sonar. What, then, are the subfactors which determine the signal-to-noise ratio? Consider the passive sonar equation in the form:

$$S/N = (L_S - N_w) - (L_N - N_{DI})$$

where

S/N = signal-to-noise ratio, in db

L_S = target signal level at source, in db

N_w = one-way propagation loss, in db

L_N = total background noise level, in db

N_{DI} = receiver directivity index, in db

The factors L_S , N_w , and L_N are dependent on the target, the environment, own-ship noise, etc. The only parameter which is a characteristic of the sonar itself is N_{DI} , which is a design parameter. Therefore, N_{DI} is a sub-factor to be utilized in bridging the gap between the analytical and empirical approaches to the determination of P_D . For a specified target, environment, geometry, sonar, etc., S/N can be calculated directly and P_D subsequently determined.

In many cases, we do not know what the appropriate sub-factors are. Also, in many instances where sub-factors have been identified, we do not know the relationship to the terms of the analytical equation. Furthermore, many of the identified accountable factors are difficult to quantify. These sub-factors can be made quantitative for modeling purposes by using either empirical data, or by subjectively establishing the proper multiplying constants or coefficients.

Care must be exercised in using performance data based on manufacturer's specifications because these are often too optimistic. Performance characteristics derived from tests at research installations also require examination because they are usually derived under controlled conditions that might neglect the man-machine interactions which exist under field conditions. Even field test data can be misleading because such tests may at times be constrained by artificialities imposed

by various peacetime restrictions such as safety regulations and choice of test area.

The discussion has emphasized the performance factor of the WSE equation because this is the area where the greatest amount of work has been done. Availability and utilization could be addressed in the same manner and are equally important. As indicated earlier, work is under way to supply the necessary data for developing the appropriate models for these major factors as they make their impact upon the analytical evaluation of system effectiveness.

THE SUBMARINE ASW COMBAT SYSTEM OF THE FUTURE

When the analytical model is fully developed and validated by the empirical results obtained during the operational evaluation, it can be used to verify the need for an improved system, and to assist in generating the new system requirements. The resulting development process is shown as a feedback system in figure 3. The system inputs are

the requirements and objectives; the output is an optimal physical system. Use of the analytical effectiveness model is intimately involved in this iterative developmental process, particularly in evaluation of the alternative designs and selection of the optimum.

However, during the conceptual design of the new system, a new problem arises, namely, empirical data on the conceptual system does not exist. It is necessary, therefore, to exercise good engineering judgment in extrapolating from known data on existing systems to the system which exists only on paper. The problem of extrapolating can differ in difficulty depending upon the dissimilarity between the old and new systems. This is being considered in the development of the analytical model for the existing system.

It is desirable to have one model which can be used to evaluate all submarine ASW combat systems, regardless of their mechanizations. There is some variation among the existing system, and it is certain that future systems will, in some respects, have radically different configurations. Therefore, future

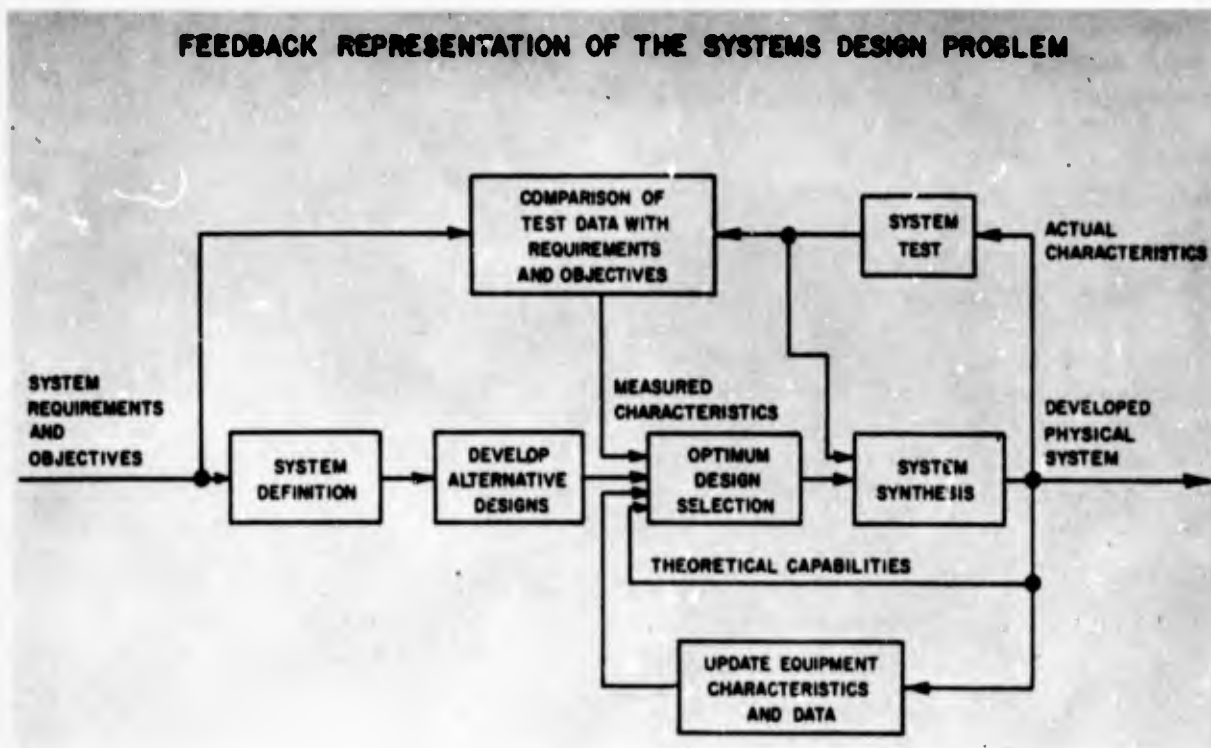


Figure 3

modeling should be based on characteristics which remain constant from system to system. Instead of the changeable characteristic of mechanization, "system functions" should be selected as the basis on which to develop the model. No matter how the functions are performed, a submarine ASW combat system must detect, classify, localize, generate weapon orders, fire a weapon, and destroy a target. Design of a system by the functional method establishes commonality between systems,

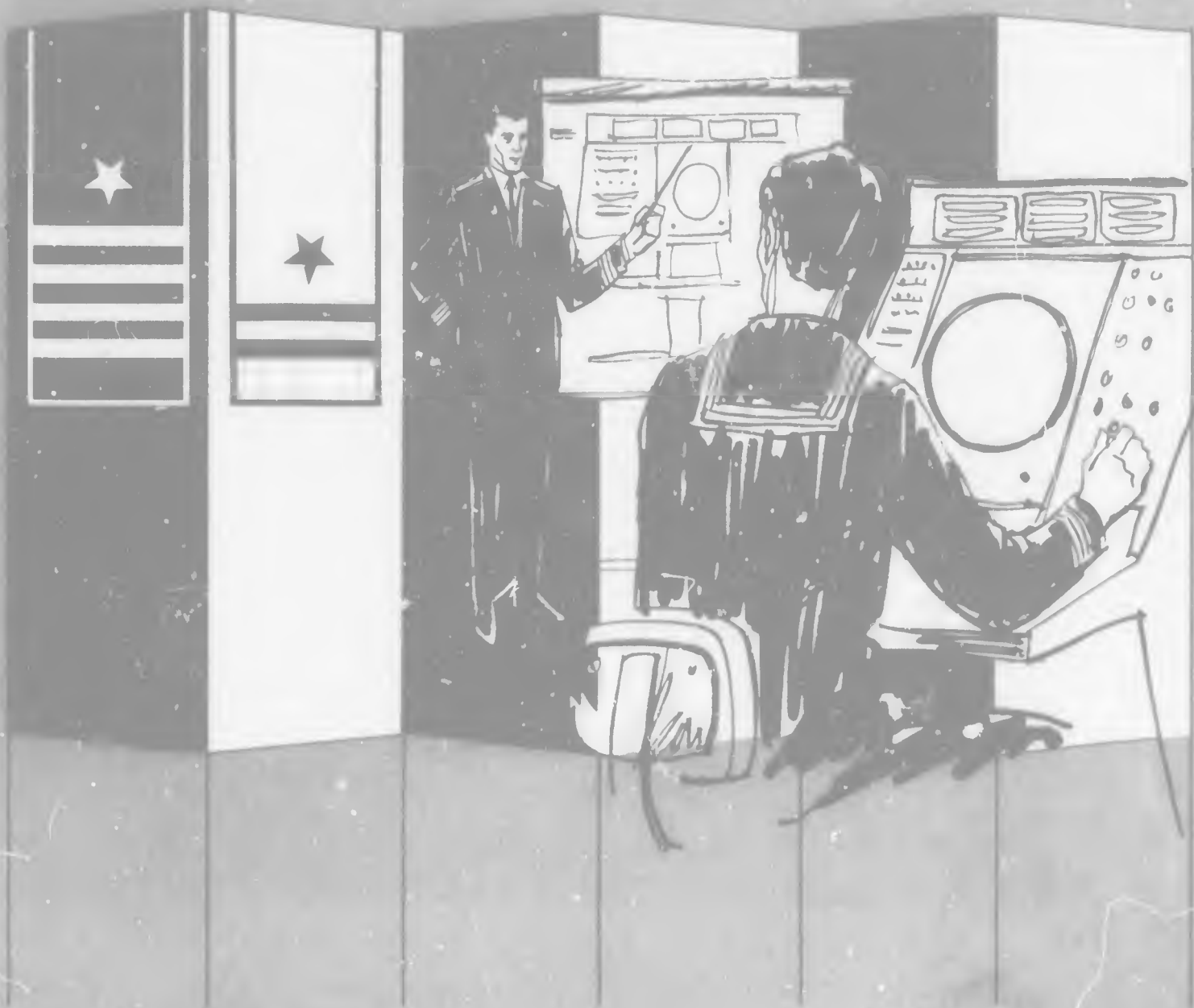
and should make the problem of extrapolation easier to solve.

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PERSONNEL QUALIFICATION STANDARDS

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LT D. C. BALLARD



Prime emphasis has been placed on Systems Effectiveness Engineering and many tools have been developed to measure and evaluate the performance of hardware. Although it is recognized that maintenance and operator personnel are key factors in system effectiveness, relatively little effort has been expended in developing tools to measure and evaluate the quality of their performance in the system.

Although the Bureau of Naval Personnel is currently sponsoring a Personnel Qualification Standards Program to improve and standardize training, it is only recently that the potential of Qual Standards for Navy-wide use, as the long-sought personnel measuring tool, has become apparent.

The evolution of Personnel Qualification Standards is a result of an expanding educational technology in the Navy which is represented by such improvements as the Learning Objective concept, and the Learning Evaluation and Improvement Program. The Personnel Qualification Standards is not a new concept but is a normal outgrowth and refinement of other Navy programs which have formalized the process of qualifying sailors to carry out their individual functions as part of an operational team. One prime example is the formal qual card program which has been used in the Submarine Force for many years.

In the past we have seen projects launched only to be ultimately discarded because they failed to line up the necessary resources before the effort was launched. The 3M program is an example.

We have therefore been "playing Quals Standards in a low key."

Rather than force a new training and personnel management concept on the fleet from Washington, we have been responsive to fleet requests for assistance. Personnel Qualification Standards are equipment oriented, and contain minute task analyses and job descriptions. They appear as a prefabricated format

of precise learning objectives prepared by experienced craftsmen working together with educational technician and engineering assistance.

A Personnel Qualification Standard also describes in detail the knowledge and skills a sailor must learn or develop to be 100 percent qualified, or combat ready, to maintain or operate equipment or a system. It is a well organized task analysis, in learning objective form, with similar questions repeated in the same position in a common format. Properly implemented, the concept can serve the purpose of coordinating shore and shipboard training. It provides a common language for separate activities directly or indirectly involved in training. It tells the sailor what must be learned and provides an easy means for responsible officers and supervisors to monitor the trainees' progress.

Basically, the Quals Standards system establishes two things: first, the knowledge and performance factors required to maintain or operate a specific piece of equipment; second, the knowledge and practical factors required to man a specified watch or battle station. Quals Standards may be written for one piece of equipment, for an entire department (such as engineering in a ship), or for an entire ship.

The concept of Qualification Standards originated in the nuclear power engineering plants where positive assurance was necessary that personnel assigned to a station were qualified. The Bureau of Naval Personnel entered the field in the summer of 1966 when we developed Quals Standards for the AN/URC-32, a single side-band radio receiver common in the fleet. Later we developed Qual Standards for the NC-2 Plotter used in the CIC's of ASW ships to track the DASH helo, and the AN/WLR-1, an electronics countermeasures receiver and direction finder. The purpose of the Quals Standards for these devices was to coordinate the shore and shipboard training effort, and provide commanding officers with documented assurance that

any technician assigned to maintain and/or operate the equipment was qualified to do so. The knowledge and practical factors, stated in terms of learning objectives, were developed by senior enlisted personnel thoroughly experienced in maintenance of the equipment. For example, upon completion of AN/URC-32 training, the technician qualifies by performing a specific alignment with the degree of accuracy prescribed in the tech manual and within a time interval satisfactory to his supervisor. The standards further provide for a number of satisfactory demonstrations of this capability which would be accomplished in the BUPERS formal schools and at least one of which would be accomplished aboard ship.

To completely qualify, a technician reports aboard ship from school with his card (which is simply an accounting sheet, some 80 percent signed off), and completes his training under the direction of the cognizant shipboard officer who appends his signature. The commanding officer then validates the completed Quals Standard Card.

Personnel of the Cruiser-Destroyer Force, Pacific Fleet were enthusiastic about this approach to training and defining user requirements. In February 1967, they asked us to develop Quals Standards for the entire 1200 pounds-per-square-inch propulsion plant in the DLG-28 class ship. These Quals Standards are currently being implemented in USS HORNE which is now deployed to WEST-PAC. The HORNE went through shakedown training with her shipboard training plan for the engineering department based upon the Quals Standards concept; it was favorably received by the Fleet Training Group.

Our first step towards the marriage of Quals Standards to the 3M material and maintenance management system was the development in March 1967 of Quals Standards for the 3M system computer which is used in the Maintenance Data Collection System. It can be noted that Fleet Work Study Group Pacific Fleet participated in this effort.

Last year, there were a series of casualties with the 5"54 gun. The Fleet Work Study Group, Pacific Fleet, was asked to study the gun with a view toward determining the

cause of the casualties, any shortfalls in training or in prescribed procedures. The Commanding Officer asked to develop Quals Standards for the maintenance and operating stations to reveal causes of malfunction. These standards have been placed in nine ships of the Cruiser-Destroyer Force and COMCRUDESPAC was asked to evaluate their effectiveness.

All WW II Destroyers and some cruisers, about 200 ships still in the fleet, have the 600 lb. steam plant. Last summer COMCRUDES-PAC and COMCRUDES-LANT requested that Quals Standards be developed for this plant. They are completed and COMCRUDESPAC has developed its implementation plans. A printing and publication schedule has been developed to meet its requirements for a group of 20 to 30 destroyers for trial this year.

Quals Standards were developed for F-8 aircraft at the request of Commander Carrier Readiness Attack, Wing TWELVE; these were recently implemented. Development of standards for the F-4 aircraft is planned following adequate evaluation of the F-8 standards.

During the course of curriculum review and revision at Teletype Maintenance School in San Diego, it was decided that a Quals Standard approach would be valuable. Subject matter experts were obtained from the San Diego area and joined with Quals Standards experts in a workshop last November. Quals Standards were written for teletype systems and are now used in the Teletype Maintenance School.

A local arrangement was made with the Air Conditioning and Refrigeration School and Quals Standards have been developed for that curriculum. Just completed are Quals Standards for the E-2A aircraft and its avionics, and a request is outstanding to develop Standards for Damage Control in all types of Fleet ships. We plan to start with the CVA because it has the most comprehensive and complicated damage control system. The materials developed for the CVA can be adapted easily to the more simple ship types. As a result of recent training conferences at Service School Command, San Diego, Quals Standards have just been completed on the MK 27

Gyrocompass and Standards are being developed for the EM and IC Class A Schools, and the AN/UPR-2 which is part of the Radio Frequency Propagation and Prediction System.

During the month of February, a group of qualified personnel from the HORNE and from Schools Command in Mare Island convened to complete the development of Qualifications Standards for the DLG-26 Class CIC and Weapons Direction System, and the Missile Fire Control Directors. The Captain of the HORNE is enthusiastic about the concept and will give it a thorough evaluation while his ship serves as a primary air control ship in the Tonkin Gulf.

The content of the Quals Standards developed for the F-8 Aircraft is arranged in nine sections: the F-8 Operator or Pilot, F-8 Cross Rate Indoctrination, Power Plant, Hydraulics, Electrical/Instrumentation, Fire Control/Ordnance, Survival Equipment, Communications/Navigation/Identification, and Structural/Airframe.

By providing the Cross Training Qualification, we are able to package by department so that the Structural Mechanic, for example, does not have to concern himself with the fire control Maintenance Quals. Each package is arranged in the format used for all Quals Standards in the Navy (figure 1).

Through an introduction and glossary, many lines of writing can be saved throughout Qualifications Standards by using common terms. The "100 section" concerns theory. It contains the basic physics theory needed to comprehend and deal with the equipment. This section contains all the theory needed for specific equipment. For example, it might cover some thermodynamics and fluid flow for equipment having chilled water flowing through the output tubes for cooling. Conversely, unrelated theory is omitted. This section has other potential uses. If Qualification Standards were available for most or all equipment in a rating group, the theoretical sections could be laid out and compared. Items appearing most often would be proper topics for that rating's class "A" school. If, for example, transistor theory appeared in only one or two systems, this topic

would be relegated to the appropriate B or C school until required for more equipment. The theory section could also form the basis for an entrance examination for specialized schooling on a particular equipment. Finally, the theory section is useful as a self-study tool for the officer or technician who has not been to school, and who wants advancement.

The "200 section" concerns systems. Each Quals Standards breaks down its equipment into functional systems as the basic building blocks in the learning process. Note that learning is approached through functional systems rather than physical packages such as cabinets, drawers, consoles or units, all of which are based upon manufacturing considerations and not upon functions. Any given system is broken down into two levels. Systems components and parts of one system may be expanded upon as a later system itself because the learning process requires it. The turbo generator may be listed as a component of the ship's service electrical distribution system and then detailed as a separate system for closer study. One key to keeping equipment operating is rapid troubleshooting.

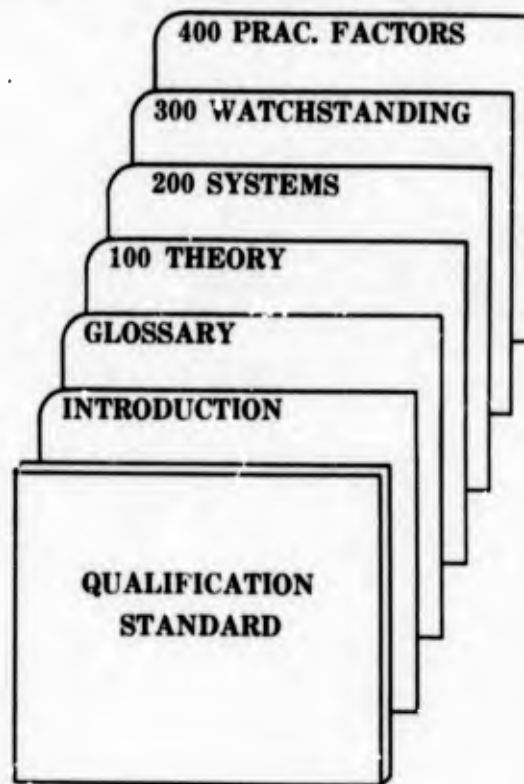


Figure 1

WATCH STATION QUALS CARD

- 7404 **Engineroom Upper Level Watch.**
- 7404.1 **Complete the following system qualifications:**
 7100, 7203, 7204, 7205, 7206, 7207, 7209, 7210,
 7217, 7219, 7220, 7224, 7225, 7226, 7227, 7229,
 7230, 7231, 7232, 7233, 7236, 7237, 7238.
- 7404.2 **Stand a minimum of three (3) satisfactory four-hour training watches.**
- 7404.3 **Perform the following practical factors: (7304.12)**

	INSTRUCTOR	DATE	PTS
.31	Start Main Circulating Pump		2
.32	Stop Main Circulating Pump		1
.33	Warm up Main Steam Line		3
.34	Warm up 600# Auxiliary Steam System		2
.35	Engage Jacking Gear		2
.36	Warm up 150# Reducing		
.37	Start Main Gland Seal Steam System		1
.38	Start Second Stage Main Air Ejector		1
.39	Start Gland Exhaust System		1
.310	Warm up Main Turbines		3
.311	Disengage Jacking Gear		2
.312	Test Main Engine		2
.313	Start Turbogenerator		3
.314	Shift Air Ejector Units		2
.315	Start Lube Oil Purifier		1
.316	Operate Lube Oil Purifier		
	(a) on Main Sump		1
	(b) on Turbogenerator Sump		1
	(c) on Main Feed Pump Sump		1
	(d) on Forced Draft Blower Sump		1
.317	Stop Lube Oil Purifier		1
.318	Secure Tubogenerator		2
.319	Secure Main Air Ejector		1
.320	Secure Gland Seal Steam		1
.321	Secure Gland Exhaust System		1
.322	Secure 150# Reducer		1
.323	Secure Main Steam System		2
.324	Secure 600# Auxiliary Steam System		2
.325	Start Distilling Plant		3
.326	Operate Distilling Plant		
	(a) to Feed Tanks		2
	(b) to Fresh Water Tanks		2
.327	Secure Distilling Plant		2
.328	Start H. P. Air Compressor		2
.329	Operate H. P. Air Compressor		2

Figure 2

A man who has mastered the functional analysis in the system portion of the Qualification Standard knows when the entire equipment is functioning properly. Troubleshooting is then simply a process of recognizing a functional failure, identifying the system component and/or part which is malfunctioning, and repairing it. This section is also an extremely valuable tool in training. With Qualification Standards a trainee can refer to a particular system feature he does not comprehend, and his instructor can be of immediate assistance.

The "300 section" is on "watchstanding." This section considers a sailor to be on watch whenever he is caring for his equipment. This section would contain all the knowledge required by anyone concerned with a ship's boiler. The individual's Qualification Card would specify items for which he must qualify in his current station, and for the station next advanced for which he is in training.

The "400 section" deals with practical factors. Herein are listed, by watch stations, the steps to be performed, stating the number of times each must be completed satisfactorily to demonstrate reasonable proficiency. Performance standards are prescribed in the Tech Manual, or are established by experienced supervisory personnel.

Next are the Operator Qualifications Cards (figure 2) for the sailor assigned to, or in training for, a particular watch station. And finally, the Technician Qualification Cards (figure 3) for the man responsible for maintenance and repair of a system.

When each man has a Quals Card certified for the watch he now stands, and another, showing his progress toward qualifying for the more advanced job for which he is training, his progress can be measured in real quantitative terms. Thus, the commanding officer is provided with a means of formally qualifying his personnel.

Many of the past faults cannot be corrected by Quals Standards. In the future, we believe that it would be helpful if Qual Standards were developed as soon as preliminary engineering drawings are available and prior to any work on technical documentation. In fact, we think that Qual Standards should be

the first chapter of the equipment technical manual. As part of the Technical Manual Improvement Program, we are now working with the Chief of Naval Material on contract specifications for experimental use of the Qual Standards concept during procurement of the AN/SRC-27 UHF Transceiver which is scheduled for fleet-wide utilization. Basically, the Quals Standards will be developed by a committee composed primarily of Navy personnel (instructors, fleet users, MOTU personnel, etc.). The committee will use standard worksheets which contain all the verbiage and require only decisions. This permits rapid development of the Qual Standards (about 2 weeks for the average equipment). The Qual Standard thus produced will pose all the questions that subsequent technical documentation must answer in order for a user to become 100 percent qualified in maintenance and operations of the AN/SRC-27. Given the equipment itself, and the Tech Manual including the Quals Standard, we will have a valid basis for development of curricula for training in the factory, the BUPERS formal school, or the fleet.

The time has come to develop an organization to manage the Personnel Qualifications Standards Program. A major job of management and coordination is upon us. We are therefore ordering a Captain into the Bureau as a staff assistant to the Assistant Chief for Education and Training. We have established at the instructor training school in San Diego 15 billets for Quals Standards writing technicians from various rating groups. We plan to develop a program covering a span of about three years for fleet and school implementation for research. As of now, we have identified three lines of research effort. First, we must examine a means of future marriage of the Personnel Quals Standards to our formal school curricula and to our Qualifications for Advancement in Rating Manual. Perhaps in some rates they are very similar, but in others, such as clerical ratings, there are no qual standards that include theory.

Second, we see a potential means of permanently identifying in our personnel records system the service experience and practical

CIC PERSONNEL READINESS AIR CONTROL SECTION				
	<u>Condition</u>			
	I	III	VI	V
Air Search Radar Operator	200	200	200	
3-D Radar Operator	300	300		
Air Search Radar Maintenance	250	250	250	
3-D Radar Maintenance	250	250		
Class I Air Controller	400	400		
Class I Air Controller	400			
ASW Air Controller	300		300	
Air Plotter #1	100	100	100	50
Air Plotter #2	50			
	-----	-----	-----	-----
	2250	1500	850	50
	-----	-----	-----	-----

Figure 4

qualifications of our men. How these Qualification Card Records are married to our current Navy Manpower Information system or the one of the future will require detailed study.

Finally, perhaps the greatest potential of Qualifications Standards is the measurement of readiness. The ultimate measure of readiness is, of course, performance in battle.

Perhaps the combat readiness of a ship is a reflection of the readiness of the individuals in the ship's company to perform their assigned tasks. We can perhaps quantify these tasks and derive a measure of readiness for individual departments, for individual functions and for the entire ship. For example, if the ship's CIC has a total of 5000 points required in operator and maintenance skills identified by each battle station and function, we can judge overall readiness by totalling up the qualifications of the personnel assigned, and identify the areas of shortfall. If the ship totals only 4500 points because there is no qualified air controller, it is apparent to both the CO and to his immediate superiors, and can be shown to those responsible for assignment of personnel to fill the gap with a new body or train one of the bodies currently on board. For example, using part of the CIC's Air Control Section, requirements are shown for General Quarters Condition I, and Short Duration Steaming, such as

Sea Trials Condition V (figure 4). By comparing requirements against resources we can see the extent and specific area of shortfall, and the current capability of the ship. Is it ready for battle or only for peacetime steaming? Under considerable pressure from the DOD analysts, the Navy has developed the Navy Readiness Analysis System to measure readiness against the Joint Chiefs of Staff criteria of C1, C2, C3 and C4. However, much of the measurement rests with command judgments. Substituting the JCS Readiness Reporting categories, C1 etc., for conditions in the example shown may be the answer, but the qualifying of the various tasks within the various types of ships relative to the prescribed missions and tasks of any one ship represents a formidable research effort.

In conclusion, it is apparent that the Program Manager for Personnel Qualification Standards will have a formidable task for the next few years. He will not only have to develop guidance for the research effort but will have to generate acceptance and preferably enthusiasm for the Quals Standards concept throughout the Naval establishment, and show that a standard tool is urgently required to measure and evaluate the contribution of personnel performance to overall system effectiveness.

SEABEE TACTICALLY INSTALLED, NAVY GENERATED ENGINEER RESOURCES SYSTEM (STINGER)

CDR D. R. WILE

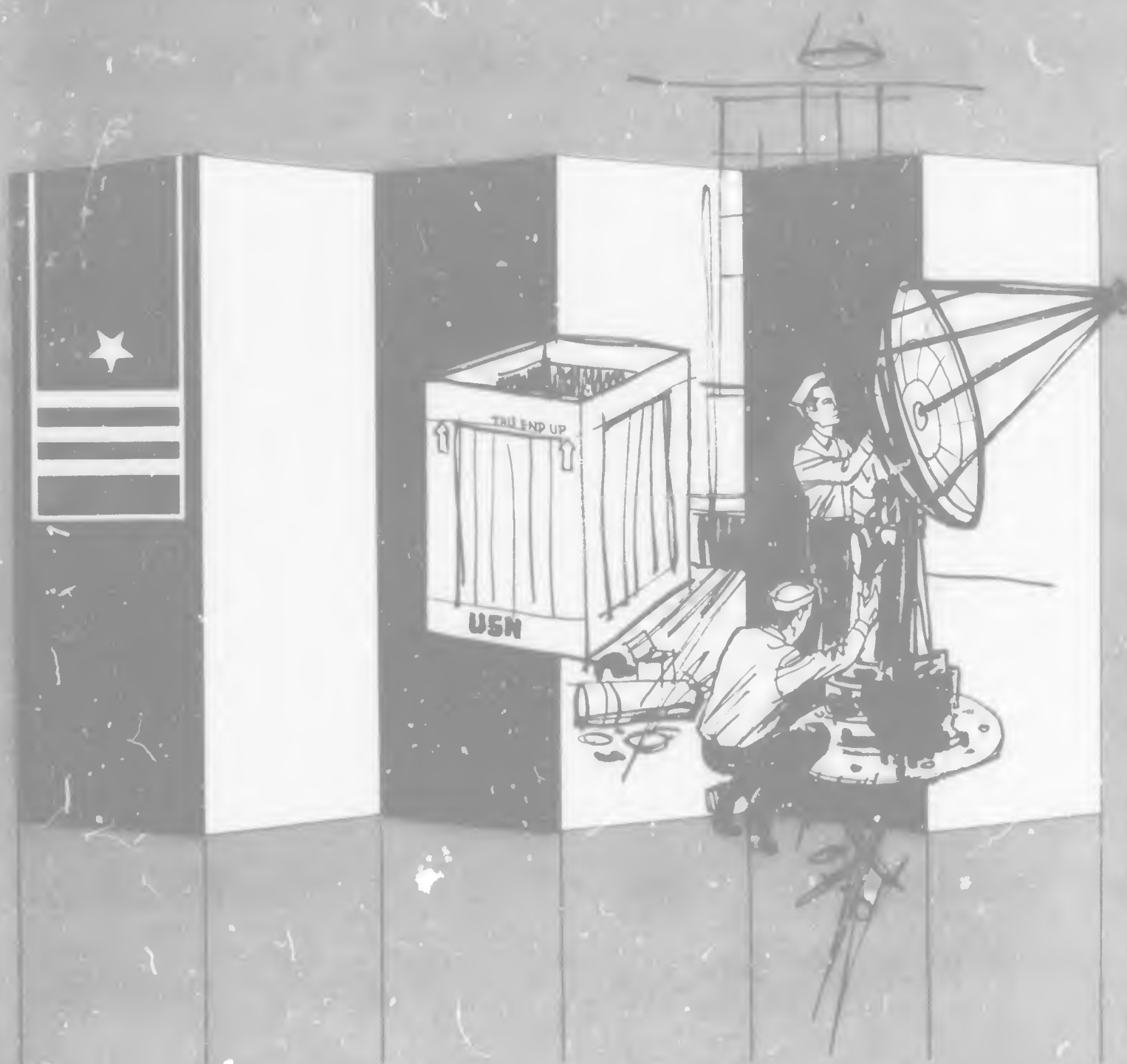




Figure 1

Figure 1 — Stinger

The acronym **STINGER** means **SEABEE** Tactically Installed, Navy Generated, Engineer Resources. The **STINGER** System has been developed for the Navy's **SEABEES**.

This paper will indicate what the **STINGER** system is, discuss the simulation model developed for the System, and indicate possible application of the **STINGER** concept in other Navy programs.

The **STINGER** System and its simulation model addresses solutions to problems which have been with the Navy for some time in planning and programming for facility and material support of contingencies, such as Vietnam.

SEABEE CAPABILITY COVERS THE ENTIRE SPECTRUM OF NAVAL MISSIONS REQUIRING CONSTRUCTION

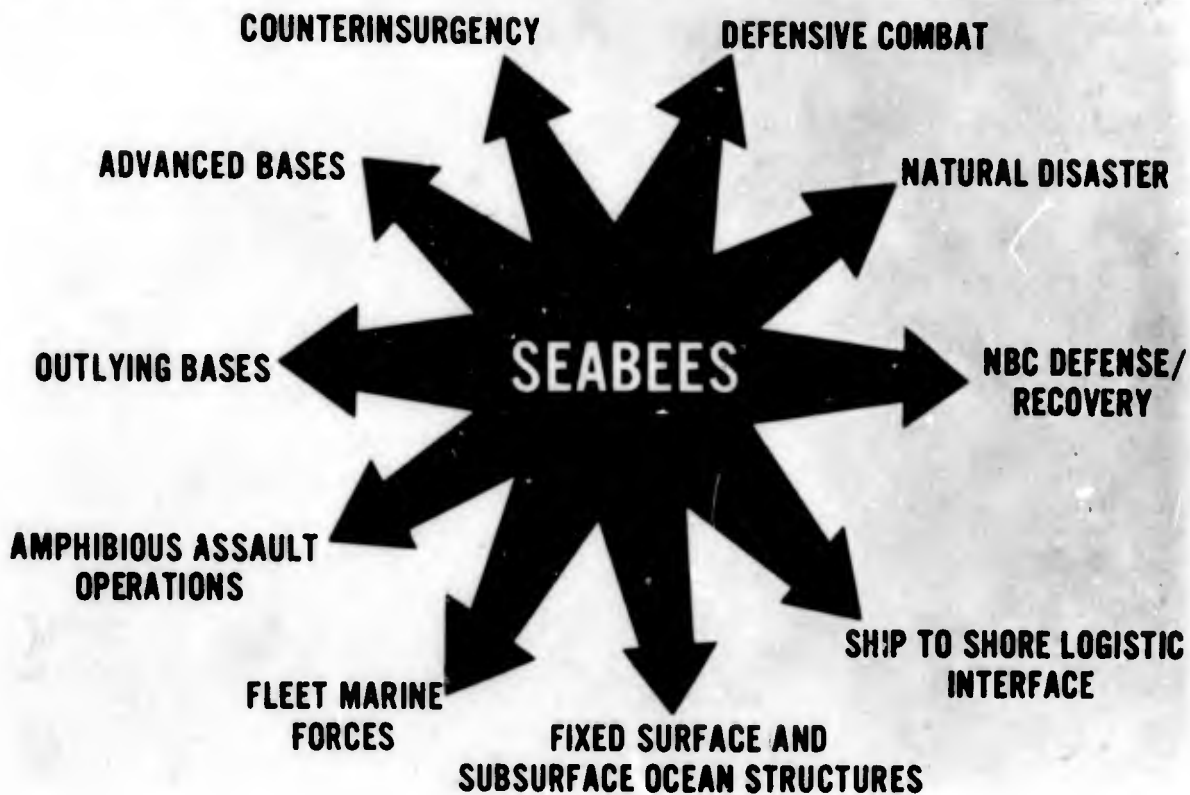


Figure 2

Figure 2 — Mission

The STINGER System is made up of the Naval Construction Forces—the SEABEES—and the various Naval Offices and commands that contribute to command control and the accomplishment of the Naval combat construction mission.

The SEABEES are the Force for Navy and Marine combat construction and are, as such, trained and equipped for construction tasks in consonance with the requirements of the broad range of Naval missions as depicted in this figure.

SEABEE COMBAT CONSTRUCTION

MILITARY & CONSTRUCTION SUPPORT INCLUDES

● TACTICAL SUPPORT

Close Military Engineering Support of Marine Line-Combat Units, Amphibious Assault Landings, Naval Inshore Warfare and Riverine Operations.

- ACB - Amphibious Construction Battalion
- MCB - Mobile Construction Battalion

● BASE CONSTRUCTION

Construction of Base Complexes for Operational & Logistic Support of Marine & Naval Forces.

- MCB - Mobile Construction Battalion

● BASE MAINTENANCE

Maintenance & Operation of Major Base Complexes.

- CBMU - Construction Battalion Maintenance Unit

● COUNTERINSURGENCY

Direct Support of any U. S. Agency Counterinsurgency Effort Involving Military Civic Action Programs.

- Seabee Teams
- ACB, MCB, CBMU

Figure 3

Figure 3 — Seabee Combat Construction

Employment of the Naval construction forces within the broad spectrum of Navy missions can be considered as being primarily in these four categories:

First, for tactical support of the combatant or ordnance-delivering forces.

Second, for base construction in the forward or outlying areas. Here we are referring to the logistic complex of the Danang or Okinawa type as compared with the tactical or combat base such as that built by the SEABEES at Dong Ha, for example.

Third, base facilities, either combat or logistic in nature, must be maintained once they are built.

Fourth, the base facilities must be upgraded to meet changing operational requirements. Base maintenance and upgrading, therefore, are important SEABEE missions.

The "other war" has emerged as a most vital portion of the total Naval mission. The SEABEE Team program has provided a most meaningful addition to Navy capability in this area. SEABEE teams are the only Navy force specifically organized and trained for counterinsurgency/civic action programs.

STINGER SYSTEM

BASE VS. TACTICAL CONSTRUCTION

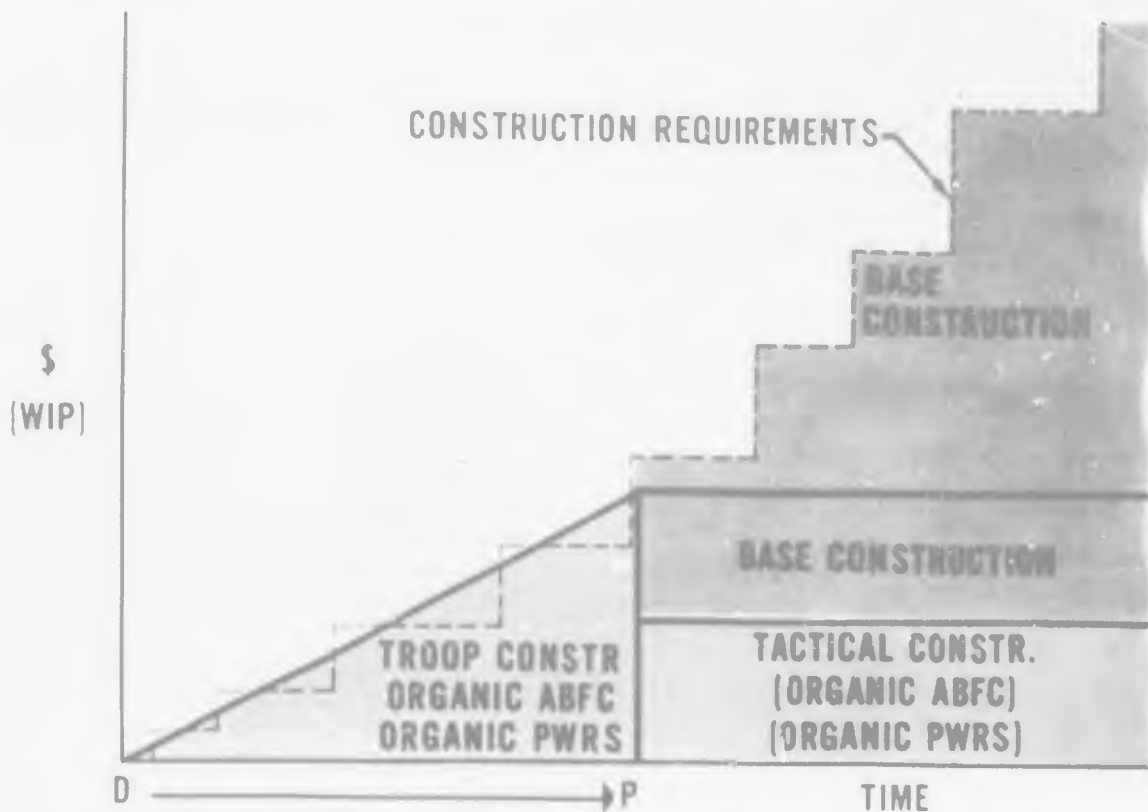


Figure 4

Figure 4 — Base vs. Tactical

Our experience in Vietnam has indicated that a major contingency of extended duration may require the utilization of both military and civilian construction capabilities.

It is acknowledged that the presence of significant contractor capability was a fortuitous circumstance in the Vietnam situation. Therefore, the SEABEE position is that primary dependence, in the D to P time frame for construction required to establish operational Navy and Marine capability, must be on troop (SEABEE) construction forces. It is further felt that this early construction is tactical and organic capability a prerequisite to it.

In the follow-on period — after P day — base complex construction may be accomplished in part by SEABEES, in part by civilian contractors.

In addition, the follow-on period will require tactical base construction in the combat area outside the tactical area of responsibility. This in turn, will require continuing organic SEABEE material capability throughout the emergency, or as long as combat forces are deployed against the enemy.

The Stinger System

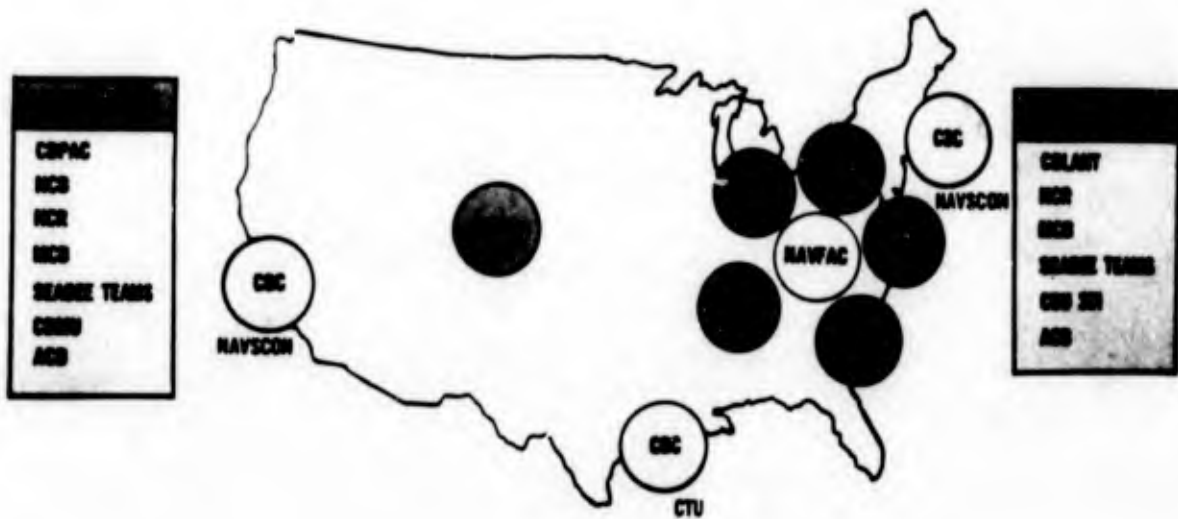


Figure 5

Figure 5 — Organization

The diversity of tasks implicit in the SEABEE mission poses difficult management and coordination problems that must be overcome to ensure that the proper mix of STINGER system capability be made to the Fleet Commander.

The Commander, Naval Facilities Engineering Command, as the Chief of Civil Engineers of the Navy, is the principal advisor to the Chief of Naval Operations for SEABEES. His office is the focal point for the coordination of SEABEE operations and support.

The variety of the SEABEE units and their deployment, together with the various command and support chains involved in the STINGER system, as shown in this figure, requires that this coordination be exercised in a systematic manner.

The Stinger System

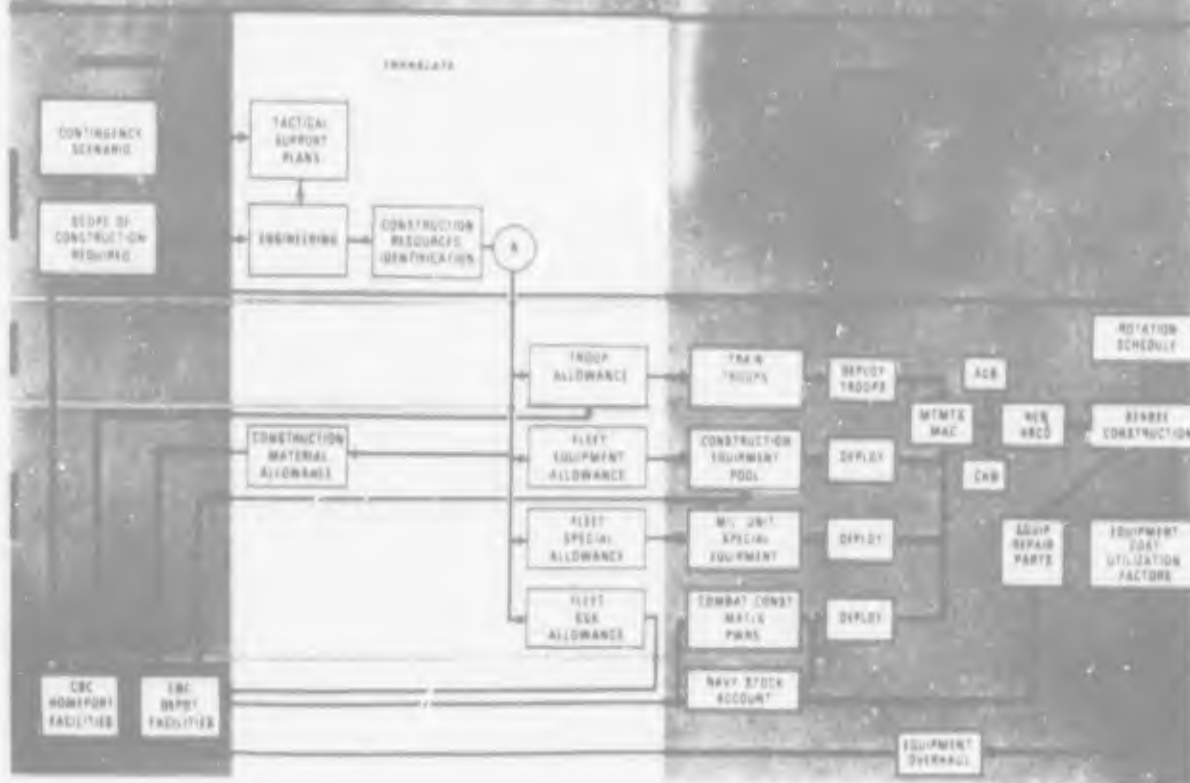


Figure 6

Figure 6 — The Stinger System Diagram

This figure in simplified form, shows the STINGER system envelope.

It traces the flow of actions and activities from (1) the generation of requirements for construction resources to (2) the translation of those requirements to the naval SEABEE force necessary to accomplish the construction required, in terms of facility support, material, troops, and engineering, to (3) the operational aspects which place the construction force capability in the field.

The system is a closed one in that it involves the rotation of forces and their equipment through homeport or depot facilities.

Not shown in this figure in their entirety, are the interfaces with the various commands which contribute to the material and operational capability of the system.

The STINGER system is thus defined as being composed of the Naval Construction Forces, and those Commands, Offices, and Bureaus which contribute to the accomplishment of the combat construction required by the Fleet Commander.

STINGER SIMULATION MODEL

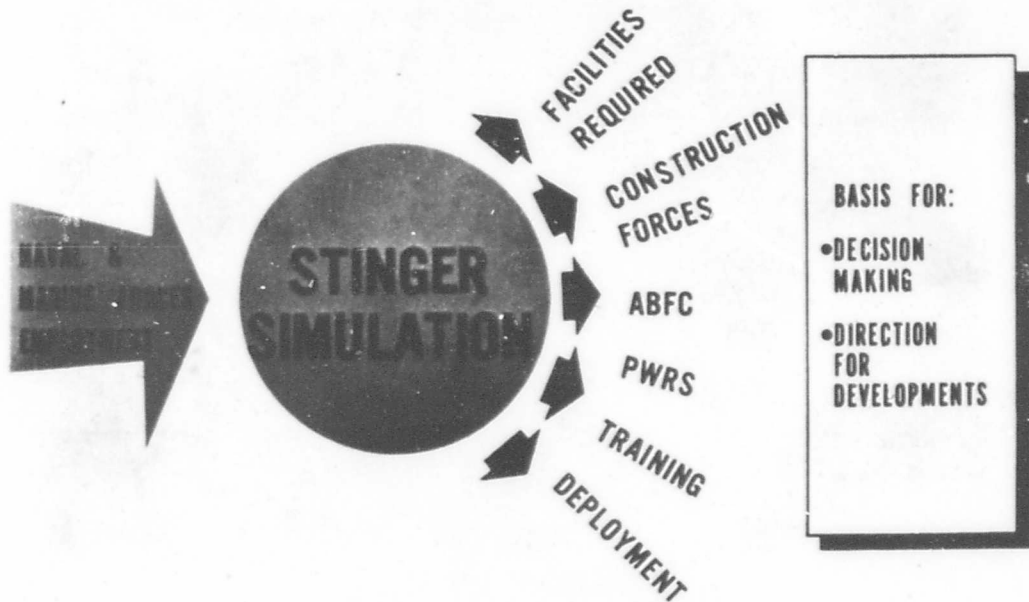


Figure 7

Figure 7 — Simulation Model

The next major effort was the development of a simulation model of the real-life STINGER system to help in the coordination/management area of responsibility.

A basic problem was encountered in this development: the input to the simulation model must be in terms of combat construction required. That this information is not readily available is unfortunate but true. It has been a problem to the Navy for some time. For example, programming and funding for the NCF and the material to support them has been difficult because planning has neither defined precisely, nor supported the facility requirements of the various contingency plans.

The computer program has been structured, therefore, in an effort to solve both of these problems. The simulation model is designed first, to permit the identification of construction requirements, and second, to permit analysis of the best way to structure and outfit a NCF which will fulfill the construction requirements of the Operational Commander.

Model input considers the contingency scenario in terms of forces and their employment.

The outputs of the simulation include: facility requirements, the Naval Construction Forces necessary to build and maintain the facilities, the material resources required in terms of advanced base function components, the prepositioning requirements of the PWRS, and the training and deployment requirements of these forces. In addition, the outputs assist in the identification of new hardware, homeport facility and operational requirements, and the need for improved construction and operational techniques.

STINGER SIMULATION MODEL SUB PROGRAMS

- **FORWARD AREA FACILITIES REQUIREMENTS**
- **STINGER SYSTEM FACILITIES REQUIREMENTS**
- **PERSONNEL READINESS CAPABILITIES PROGRAM**
- **UNIT ROTATION AND HOMEPORTING**
- **CONSTRUCTION MATERIAL**
- **CONSTRUCTION EQUIPMENT**

Figure 8

Figure 8 — Major Subprograms

This figure spells out the major subprograms now in the simulation model.

The first of these, the forward area facilities requirements subprogram, derives facility requirements from scenario information on Forces.

The output of this subprogram is used in analysis of: facilities requirements of the STINGER System, training and personnel planning, rotation and homeporting studies, material and outfitting policy determinations.

FORWARD AREA FACILITIES SUBPROGRAM

INPUTS



ENGAGED FORCES



EMPLOYMENT

Figure 9

Figure 9 — Facilities Subprogram — Input

As was indicated before, the forward area facilities subprogram is basic to STINGER system simulation because it permits the rapid determination of construction requirements.

The inputs to this subprogram are the engaged Forces and their employment. In developing the initial computer program, the Connolly Non-Nuclear Ordnance Scenario was utilized because of its widespread acceptance in Navy. This scenario addresses the employment of Marine Expeditionary Forces (MEF) ashore. Although what follows is, therefore, couched in terms of the MEF, attention is directed to the fact that the logic of the program is constructed so as to permit input of any Naval force and any scenario.

FORWARD AREA FACILITIES SUBPROGRAM

DATA BANK STORAGE



Figure 10

Figure 10 — Data Bank Storage

The basic facilities subprogram data bank stores information required for each basic organizational element of the employed Force.

Thus, information stored in the program is related not to the division and the wing — in the case of the MEF — but to the various subforce elements (battalions) that make up the division. In the case of a riverine warfare scenario, the basic elements would be the PBR squadron and other assigned naval units.

The program is, therefore, extremely flexible in that various Forces of varying character and makeup may be readily considered.

FORWARD AREA FACILITIES SUBPROGRAM

FIRST PHASE OUTPUT

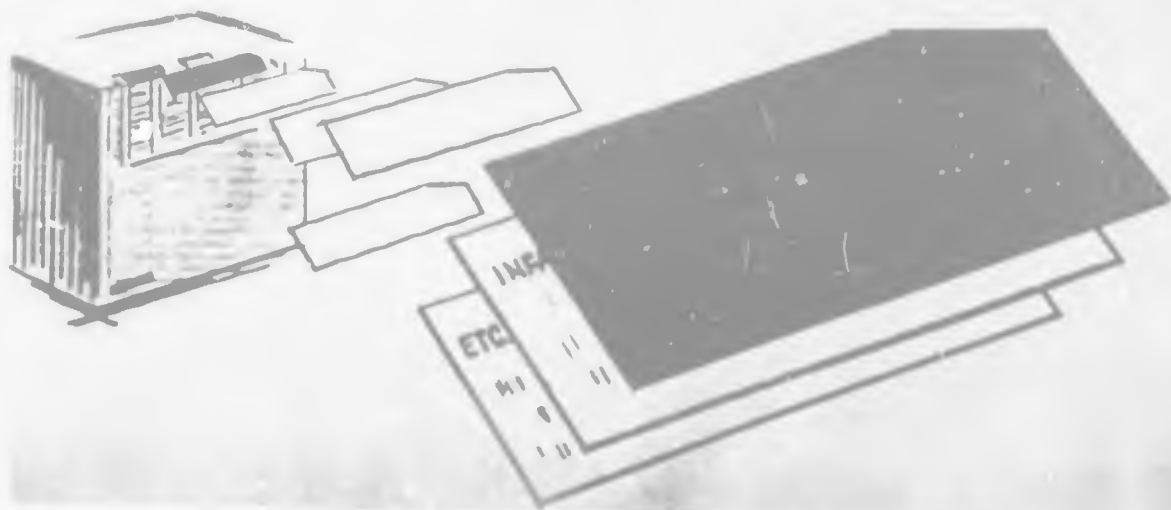


Figure 11

Figure 11 — First Phase Output

The first phase output of the subprogram identifies, for each of the individual Force units employed, facility requirements in terms of advanced base functional components.

Thus, for this HQ battalion, the subprogram has identified certain facility support for berthing, messing, administration, POL, ammunition storage, etc.

While this information is helpful, it is not complete from a planning point of view. No unit operates in complete independence from others in the Force. Nor is it rational to assume that each unit will have its own ammunition or POL storage complex, for example.

The simulation, therefore, takes the first phase output and relates it to the scenario outline of events.

FORWARD AREA FACILITIES SUBPROGRAM

SECOND PHASE OPERATION

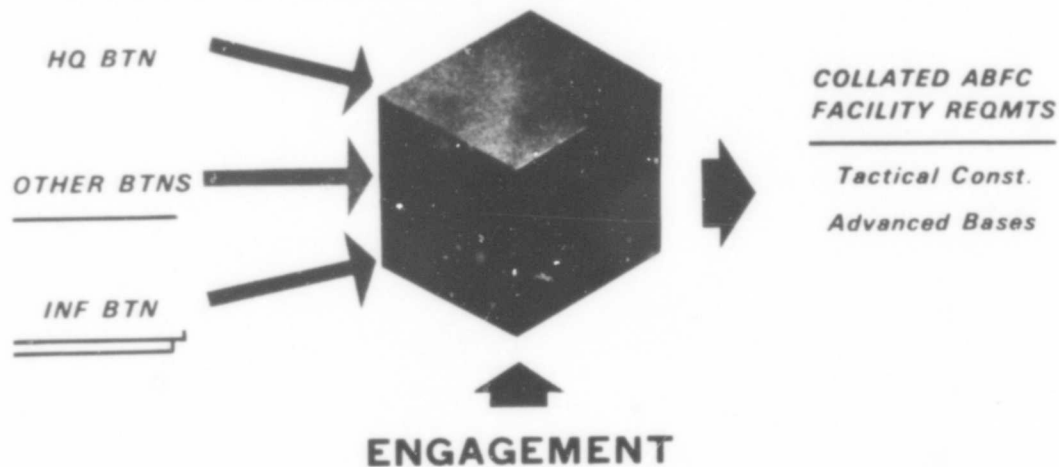


Figure 12

Figure 12 — Second Phase Operation

The second phase of the Facilities subprogram relates the individual unit facility requirements to the engagement described in the scenario. It collates these facility requirements to develop the construction of depot warehousing, fuel storage, port facilities, major cantonments and the like into advanced bases and tactical construction.

It should be mentioned at this point that the machine is not operating independently in this process. The military planner is very much a part of it, and the program is so written as to allow the planner to recycle the various phases to compare, for example, alternative patterns of advance base development. The program also permits the identification and input of unusual features of the employment, terrain, etc., which may be of significance in the scenario under consideration.

FORWARD AREA FACILITIES SUBPROGRAM

FINAL OUTPUT

- **Advanced Base Construction Requirements**
- **NCF Requirements**
- **Time Phased Construction**
- **Logistics Data**

Figure 13

Figure 13 — Final Output

The final output of the facilities subprogram provides:

- Advanced base construction requirements in the forward area expressed in terms of ABFC.
- The Naval construction forces required to accomplish the construction identified.
- The time-phased placement of facilities and deployment of SEABEES to meet the Operational Commander's requirements, and
- Detailed logistic data associated with the construction program (because requirements are expressed in ABFC terms).

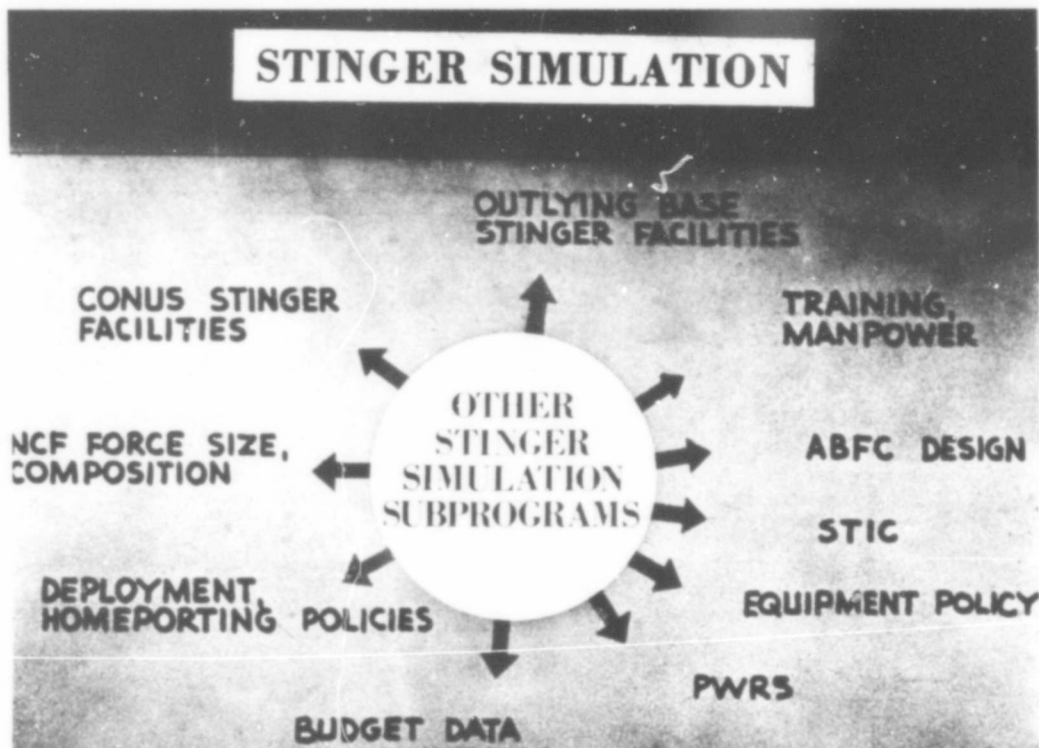


Figure 14

Figure 14 — STINGER Simulation

The output of the facilities subprogram is then utilized to study and assess the STINGER system which must be prepared to accomplish the construction specified.

Since the parameters associated with the output are cost (in terms of forces, time, and dollars), trade-off studies can be made to provide the decision maker with alternative courses of action.

Consideration of a single scenario permits the "what if" type question; i.e., "what happens if material deliveries are late;" or, "what happens if the required completion dates of certain facilities is advanced or extended."

By iteration of many scenarios, it will be possible to look in depth at the real-life STINGER system and evaluate such questions as:

1. Is the P-25 MCB most effectively composed of the proper mix of men, equipment and skills to accomplish the construction required? If not, what should the mix be? How many battalions are required to properly support the Fleet Commander?

2. For a given STINGER system, what are the homeport facility requirements? What is the most effective policy for advanced base construction depots, and construction equipment overhaul?

3. What should be the magnitude of prepositioned stocks of material, equipment, and SEABEE tactically installed components; and where should they be?

Other important policy and doctrine decisions regarding training, deployment, and budget information can be more rationally determined using the simulation model.

Thus, the simulation model will allow "war gaming" the real-life STINGER system to establish the best way to ensure that the SEABEES are ready to support the military and construction needs of Naval warfare.

CONTINGENCY REQUIREMENTS FOR COMBAT SYSTEMS

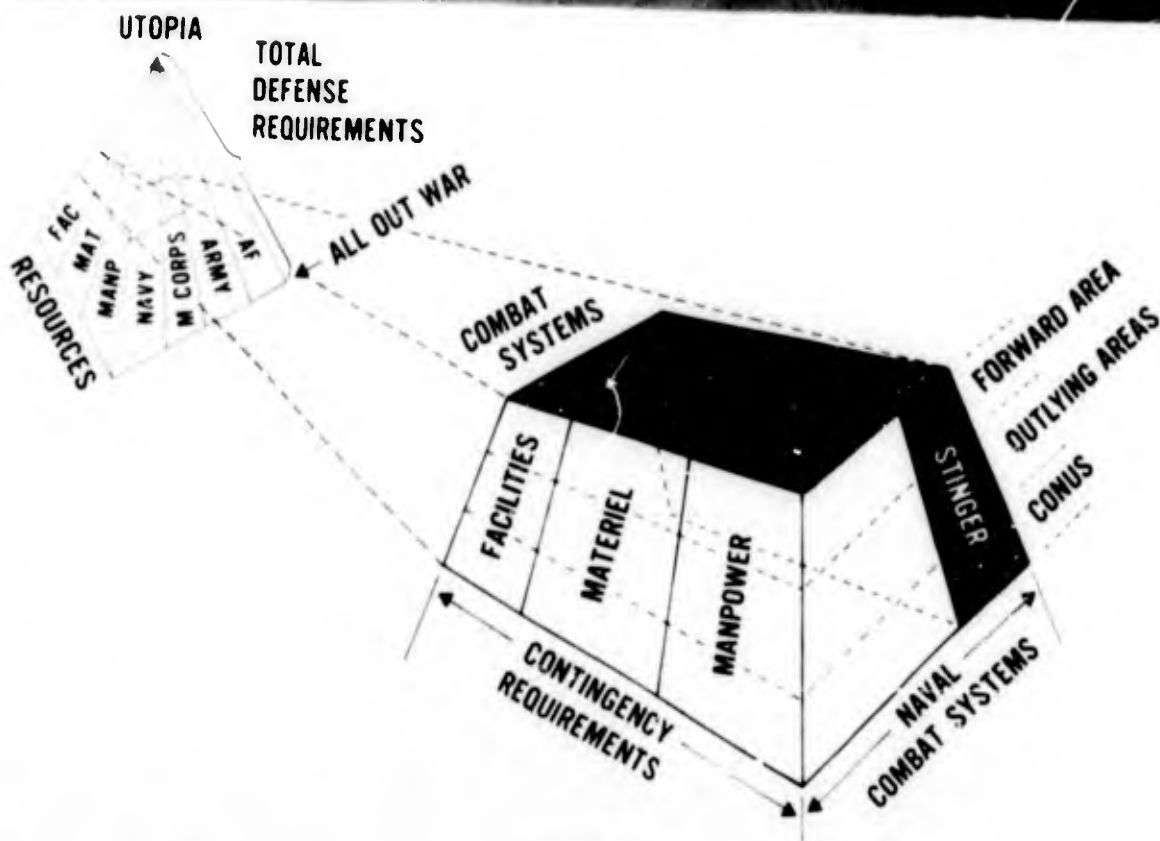


Figure 16

Figure 16 — The Warfare Pyramid

Thus far, we have (1) indicated what the STINGER system is, and (2) described in general terms its simulation model.

The third point is to illustrate the possible usefulness of the STINGER concept in other Navy programs.

Consider the warfare pyramid shown, with defense posture ranging from total war at the base to peaceful Utopia at the apex. Vertical slices through the left face represent basic resource requirements for combat systems for all contingencies. Vertical slices through the right face represent resources in the spectrum of combat systems that **might** be involved. Horizontal slices through the pyramid will cut out "blocks" of requirements for a given contingency. One of these blocks is represented in the foreground.

For this given contingency, STINGER simulation permits the study of all requirements — men, material, and facilities — for the STINGER system; not only in the forward area, but also in the outlying base area and in Continental United States. (CONUS).

The STINGER simulation will also identify time-phased construction requirements for the tactical forces and support elements, but only for the forward area. If the other specialized logistics system (i.e., Medical, Ordnance, Ships) were to utilize the STINGER concept of simulation, it could be possible to identify all requirements for all combat systems from the forward area to the CONUS base. Iteration of the simulation model for many scenarios would lend credibility, among other things, to information included in such basic planning documents as the NSP; and provide a firm basis for programming and funding of the PWRS program.

STINGER SYSTEM SUMMARY

Simulation Model Provides:

- IMPROVED STINGER SYSTEM MANAGEMENT
- MORE RATIONAL, BELIEVABLE INPUT SUMMARIES FOR NAVY PLANNING
- RAPID DETERMINATION OF CONTINGENCY CONSTR. REQMTS.
- ASSIST TO PROGRAMMING & BUDGETING
- POSSIBLE APPLICATION TO OTHER NAVAL COMBAT SYSTEMS

Figure 17

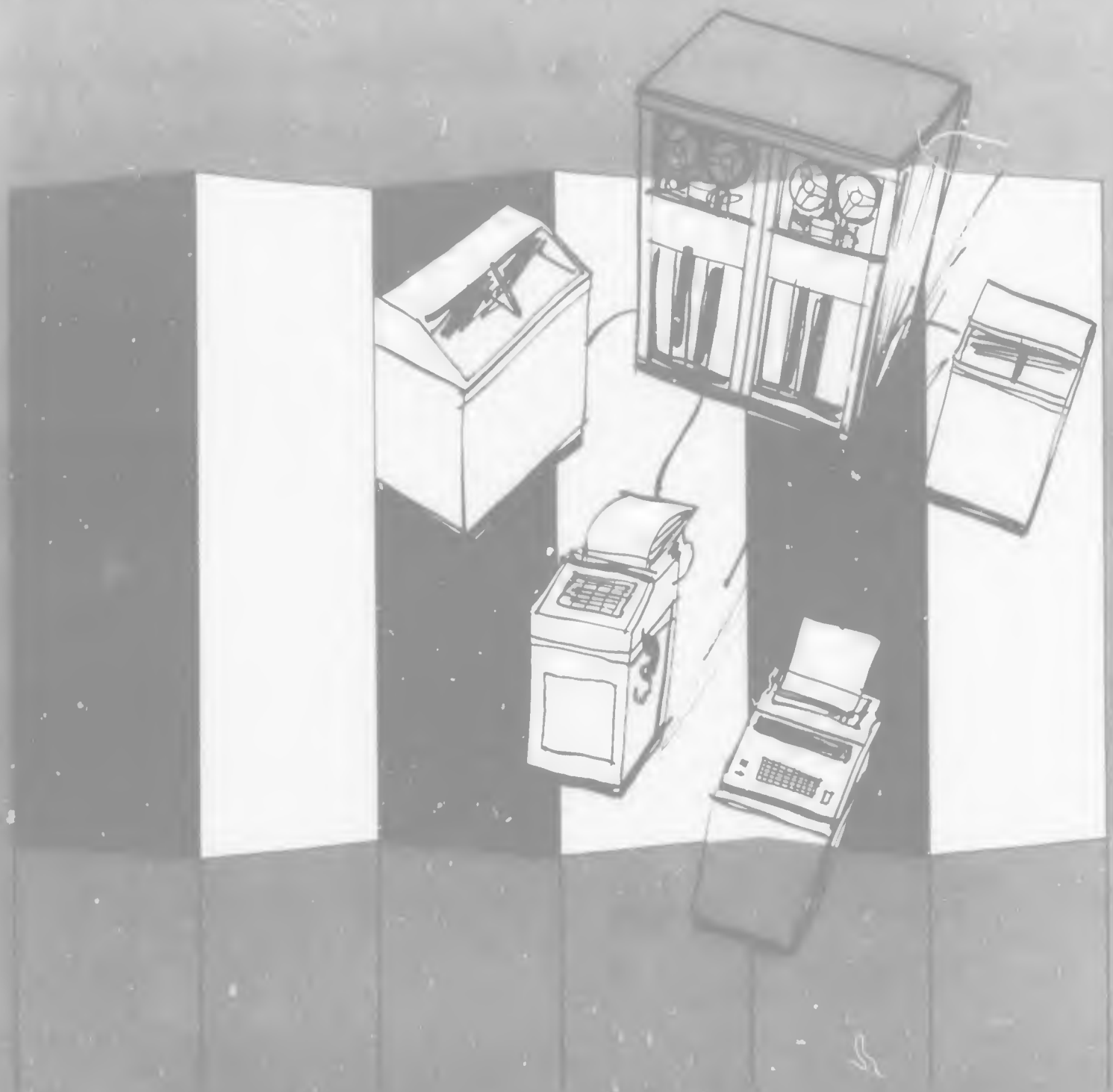
Figure 17 — STINGER Summary

In summary, the STINGER simulation model provides:

- Improved STINGER system management,
- Rapid determination of construction requirements for contingencies,
- More rational, believable input for Navy planning,
- An assist to programming and budgeting for NCF, PWRS, etc.,
- Possible application in other Naval combat systems planning.

UNIFORM AUTOMATIC DATA PROCESSING SYSTEM FOR INVENTORY CONTROL POINTS

MR. J. W. PRICHARD



INTRODUCTION

A major, long range task of the Naval Supply Systems Command since 1961 has been the design and installation of a series of automated management information and decision making systems. These systems are intended to permit rapid, largely mechanical processing of great quantities of supply data at all echelons in the supply system, inventory control point (ICP), stocking point, and ship, or shore station. One of these, the Uniform Automatic Data Processing System for Inventory Control Points, consists of the computer programs and supporting manual procedures needed to perform the bookkeeping and much of the routine decision making at the Navy's three ICPs.

The missions of each ICP are to compute or assist in computing requirements for stocked repair parts and components at all supply and maintenance echelons in the Navy and to purchase and position material in the wholesale system in anticipation of issue to combat, industrial, and training units. Owning no stock and operating no warehouses, ICPs are nevertheless responsible for maintaining sufficient stocks of some 850,000 technical items in the Navy's major stocking activities to assure timely, economical support of the fleet and the shore establishments. In addition, they provide numerous supply aids and recommend stocking levels to hundreds of ships and industrial shore activities.

Several factors contributed to the decision to establish the uniform computer programs for the ICPs. Among these were the diversity of operating methods within the ICPs and the multiplicity of procedures imposed on stocking activities and customers by the ICPs. This rendered communication with budget review officials, hardware systems commands, and project managers difficult and confused, in daily operations at both stock points and customer installations. Furthermore, the use of a single type of hardware and a single set of programs permits economies of scale in

the layout of files, in the design and coding of programs, and in the research and testing of decision rules to be incorporated in computer programs.

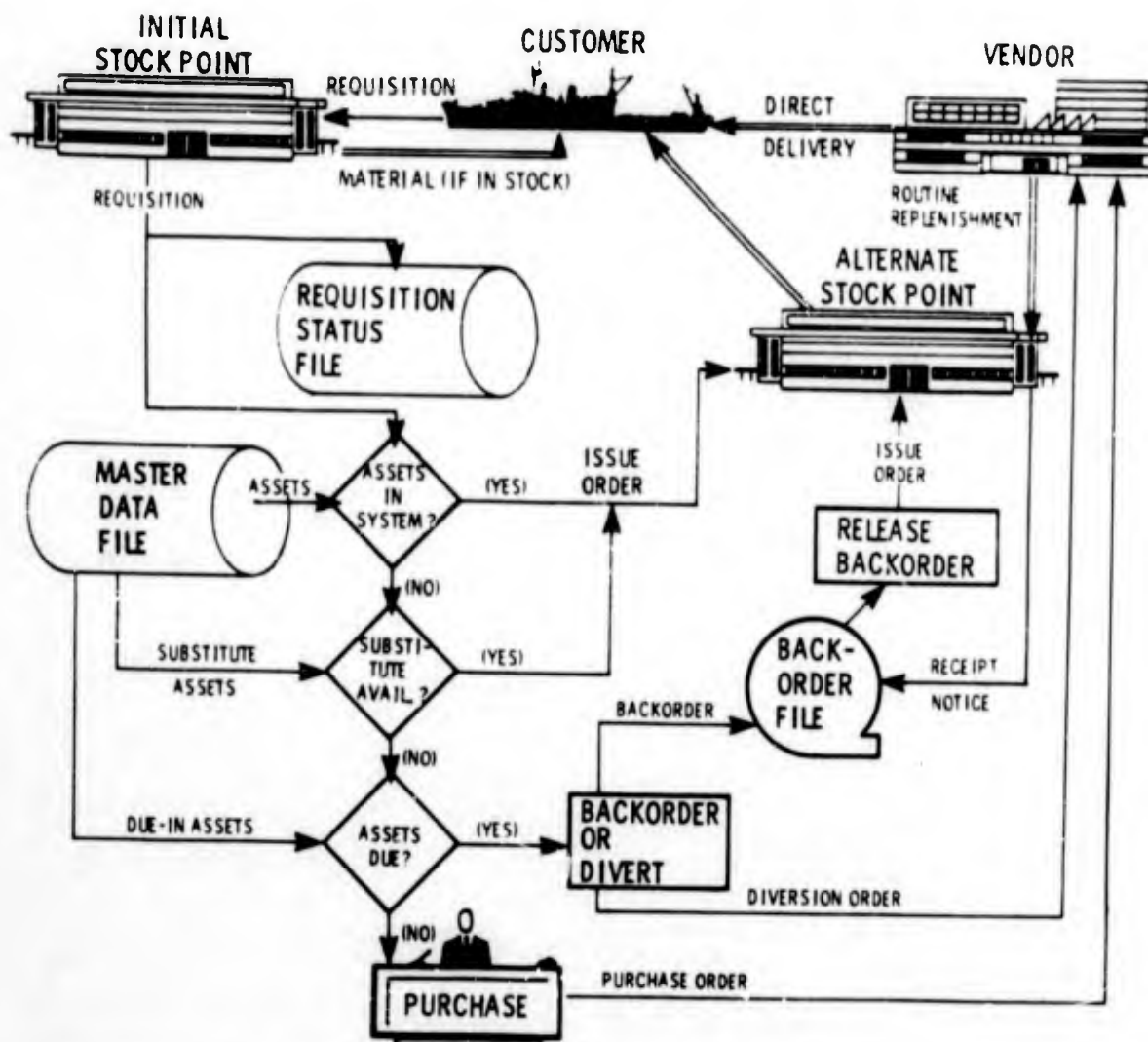
The Uniform Automatic Data Processing System for ICPs embraces some 160 operations, each involving one or more distinct computer programs. These operations can be divided into two major groups or "packages": the inventory control package, and the weapons system package. The inventory control package constitutes all those programs needed to assure adequate, but not excessive, material at the wholesale stock points. The purposes of the weapons system package are twofold: to provide supply and semi-technical data to hardware systems commands, project managers, and the ICP itself, and to produce supply aids and stocking recommendations for customers and intermediate stocking activities, such as carriers, tenders, and fleet issue ships. The separation between the two packages is not complete, inasmuch as they share several data files and some computational techniques. However, the main distinction is clear. The inventory control package helps the ICP perform the purchasing and stock positioning functions which are its direct responsibilities; the weapons system package contributes primarily, but not entirely, to functions which designers and users of material must perform.

INVENTORY CONTROL PACKAGE

Any large computer system, of which the uniform ICP system is no exception, performs the following functions:

- It establishes and maintains records for accounting and decision making.
- It computes or makes decisions automatically.
- It organizes, displays, and possibly analyzes data to support human judgments.

The remainder of this presentation describes how each of the uniform ICP packages accomplishes these three functions.



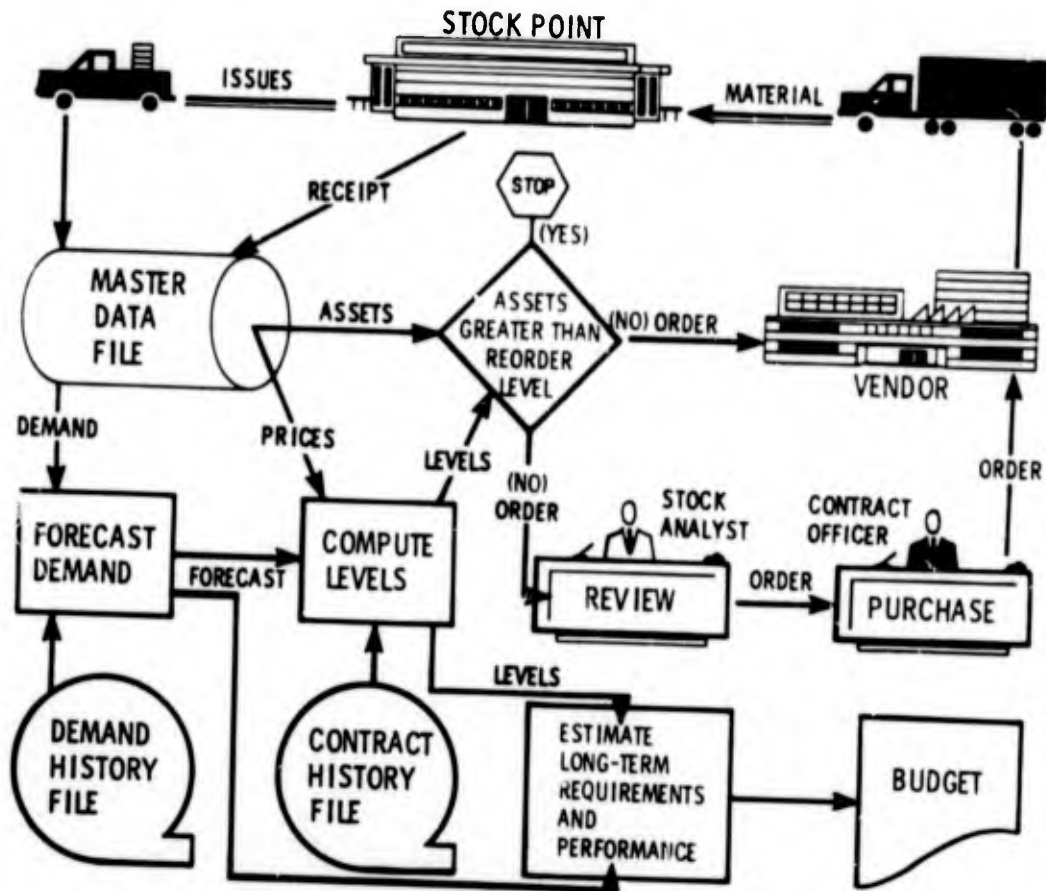
PROCESSING CUSTOMER'S REQUISITIONS IN UICP PROGRAM

Figure 1

Files

As its name implies, the Master Data File is the repository for almost all the information needed in the inventory control package for automatic and manual decision making. Its contents include supply data, such as assets information, demand estimates, unit prices, lead times, and procurement levels; and technical data, as well as manufacturers' part numbers, application and population information, minimum replacement unit and source, maintenance and recoverability codes. Randomly arranged on magnetic drums for almost instantaneous access, the file contains an average of 340 words or 10,000 binary digits of information about each of the 850,000

stock-numbered items managed by the ICPs. This seems an incredibly large amount of supply information about a single item until one considers that an item may conceivably be stored at 40 locations, that the material may be in a dozen different physical conditions, including ready for issue condition, and that a portion of ready for issue material may be earmarked for half a dozen special programs, in addition to unrestricted issue. Similarly, demand figures include those resulting from routine maintenance, those resulting from complete overhauls, those occasioned, not by usage, but by the need to increase stock levels at using and intermediate points, and those "negative demands" caused



COMPUTING LEVELS, ORDERING AND BUDGETING IN UICP PROGRAM
Figure 2

by the return to the depot level of material not fit for issue but capable of repair.

The remaining files in the inventory control package for the most part contain details intended to back up information in the Master Data File. The file titles are generally indicative of their contents:

- Due In—Due Out File (covering stock due into or ordered shipped out of each stocking activity).
- Demand History File (containing summarized demand for the past eight calendar quarters).
- Contract Status File (involving contracts still in force).
- Contract History File.
- Pricing Analysis File.
- Procurement Data File.
- Requisition Back Order File.

- Planned Program Requirements File.
- Transaction History File.
- Requisition Status File.

Decision Making Operations

The principal decision making efforts of the computer revolve around the satisfaction of individual customer requests for material and the determination of when to replenish (by purchase, repair, transfer from another service, or salvage), how much to replenish, and how much to discard. Normally, a customer's requisition is satisfied with stock at the first stocking activity to receive his request. See figure 1. However, if that activity cannot satisfy the request because of lack of material or restrictions on issue, the request is forwarded directly to the ICP having cognizance of the material. Here, the computer attempts to satisfy the requisition by considering what substitutes are available,

where inventories are located with respect to the customer, what material may be due in from purchase, repair, or other sources, and what restrictions the ICP has placed on the purchase or issue of the item. In unusually difficult situations the computer will turn the request over to a stock analyst, with or without recommendation, for final resolution.

The computer makes stock replenishment decisions in three phases. Quarterly, it estimates the rate at which demand is occurring and, in the case of a recoverable component, the rate at which repairable carcasses are becoming available. The new demand estimates are combined with current estimates of procurement lead time, repair turnaround time, and replacement and repair costs to compute a reorder level and requisitioning objective. Then, after each transaction involving a change in the item's inventory, on hand, on order, or under repair, the computer compares the remaining assets with the reorder level. If assets are at or below the reorder level, the computer orders the purchase or repair of sufficient material to bring total assets up to the requisitioning objective. In some cases, the computer automatically prepares an order to mail to the vendor; in other cases the computer's recommendation is reviewed by a stock analyst and purchasing officer before the order is placed. See figure 2.

Estimates of current demand, procurement lead times, and repair times are all computed by exponential smoothing of past observations. Future demands, on which the reorder level and requisitioning objective are based, are projected on one of three assumptions:

- Average quarterly demand for units will remain the same as it has been in the recent past.
- Average quarterly demand per unit installed will remain constant but the units installed will change in accordance with program information provided by the Chief of Naval Operations, hardware systems command, or project manager.
- Average demand per flying hour or steaming hour will remain constant, and the number of flying or steaming

hours in future periods will be provided through program information.

Of course, none of these assumptions is appropriate for an item newly established in the inventory, for the simple reason that there has been no past demand. For these items, forecasts are based on technical estimates made at provisioning or on the mean family replacement factor (MRF), which is the average demand for existing items with the same noun name and similar application.

A procurement reorder level and a procurement requisitioning objective which is the sum of the reorder level and the operating quantity, are computed for every item. Repair level and repair quantity are also computed for each repairable item. The objective in setting both the repair level and the reorder level is to minimize the number of requisitions that cannot be immediately satisfied by material in stock. The objective in computing the order quantity and the repair batch size is to minimize the number of purchases and the number of repairs in a year. Despite these objectives the order quantity (or repair batch) for many items is one unit and the reorder levels for other items are quite low. The reason for this is that all levels must be constrained by funds available for purchase of new material.

Data Analyses

Many problems cannot be structured in advance precisely enough to permit programming of a specific decision rule. In these situations the computer will organize the data, may possibly make an elementary analysis, and may even offer a tentative recommendation. Then it will submit the data to the stock analyst, technician, procurement officer, or financial manager for final resolution of the problem. Here are some examples of joint man-machine efforts:

- The computer will not back order a high-priority requisition without checking with the stock analyst.
- Any order exceeding \$250 must be reviewed by a contracting officer before it is sent to the vendor.

- The computer will assemble and print pertinent basic information for a technician to use in determining whether competitive procurement would be feasible and what additional information must be gathered to encourage it.
- The stratification program and the Computation and Research Evaluation System (CARES) program supply basic data for inventory managers and financial managers to use in preparing budget requests and in deciding how funds actually appropriated can best be spent.

WEAPONS SYSTEM PACKAGE

Within the past year the design and installation of the Weapons System Package has been given increased attention in the uniform data processing program for ICP. This is caused by the recognition that as the ICP's wholesale procurement responsibilities diminish with the transfer of purchase functions to the Defense Supply Agency, and the increase in program responsibilities in support of combatant ships, aircraft tenders, and shore stations loom larger. Intensified interest in specific weapon systems and the establishment of Chief of Naval Material Project Managers, has made it necessary for ICPs to respond rapidly to queries about the status of weapon system support. Major emphasis on the weapon system package is made possible by the acquisition of additional high-speed computing and data storage devices and by progress in completing the Inventory Control Package, which is now almost entirely designed and is partially installed at all ICPs.

Like the Inventory Control Package, the Weapons System Package is divided into three parts: data banks, decision-making routines, and displays of information for subsequent manual decision-making. Unlike the Inventory Control Package, the Weapons System Package deals largely with problems that are not always the primary responsibility of the ICP but of other organizations: type commanders, ships, hardware systems commands, project managers.

Data Banks

Almost as large as the Master File itself, the Weapons System File, the central data bank in the Weapons System Package, is also stored on magnetic drums for rapid, random access. Whereas the Master Data File lists parts and components in stock, the Weapons Systems File is an inventory of systems, equipment, and components installed in stations, ships, and aircraft.

The file is divided into three overlapping levels, so that it is possible to enter the file at almost any level of indenture and determine what subcomponents make up the item and what ships or systems contain it. Level A, the highest level, is arranged by ship, station, and aircraft nomenclature. Under each entry are listed the systems or services, and the equipment or components installed within each system or service.

The second level, Level B, is entered by knowing the nomenclature of a system or equipment. Information contained in this level of the file includes the ships and aircraft in which the equipment is installed and the components that go to make up the equipment. The quantity of each component in the equipment, its military importance, the manufacturer's name and designation, security classification, and the federal stock number, are also given.

The lowest level, Level C, is arranged by component designator and indicates the ships, aircraft, systems, and equipments in which the component appears and the subcomponents, alteration kits, and piece parts contained in the component.

The Weapons System File, then, can be used to construct a bill of materials for all the systems and equipments in a ship, aircraft, or station. Once the list of parts is constructed, the additional technical and supply information applicable to each part which is needed to compute the recommended allowance for the ship or station can be extracted from other files in the Uniform ICP System. If the part is managed by the ICP constructing the bill of materials, information about the item's price, weight, cube, and technical characteristics appear in the Master Data File. The Master Data File

also contains the maintenance plan, established by the appropriate Hardware Systems Command. If the part is not managed by the ICP, the data will appear in one of two data banks in the Weapons System Package: the Program Support Interest File, if the item has a stock number but is managed by another Navy ICP or by the Defense Supply Agency; or the Technical Reference File, if the item does not have a stock number. These files, identical except for the presence of a federal stock number in the former, contain information needed to compute allowance and load quantities and to query the responsible control point about stock status.

Other major files in the Weapons System Package are:

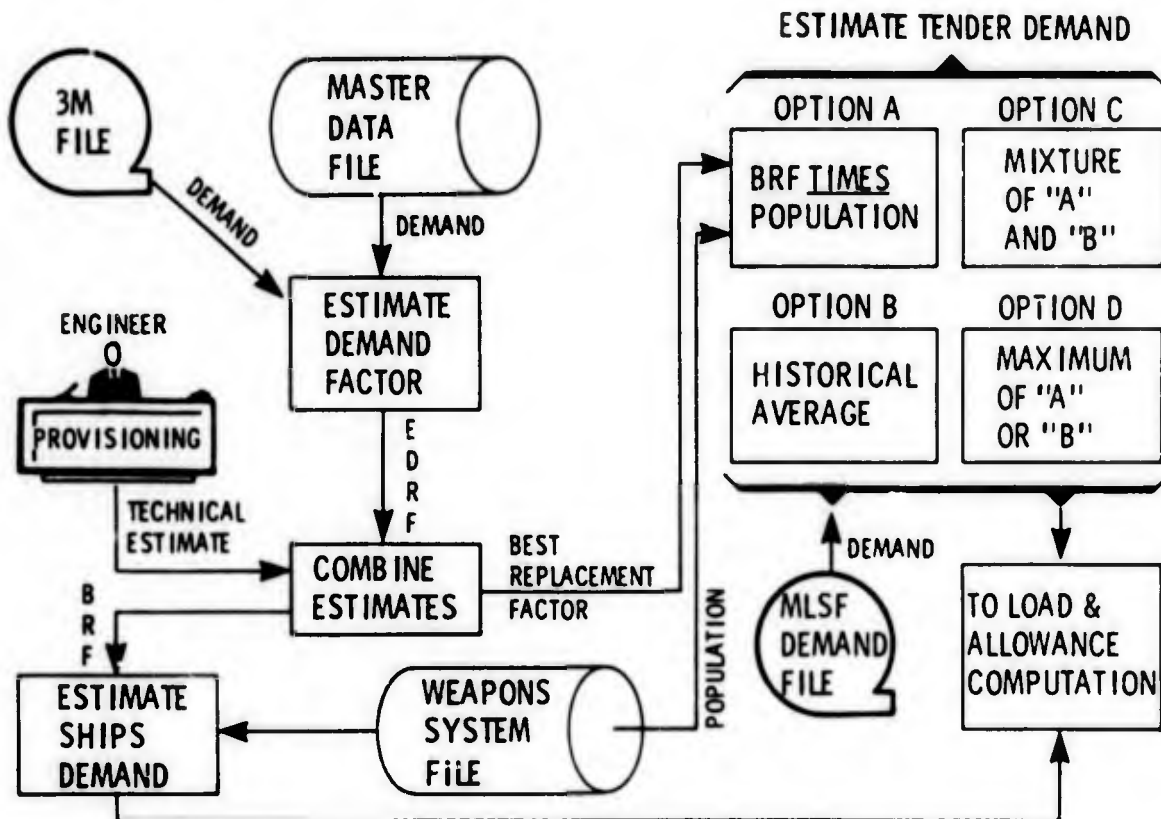
- Ships' history and inventory records,

containing the current allowances for each item on each ship.

- Load list file, containing the authorized quantities for material carried in store aboard tenders and repair ships.
- Mobile logistics support demand file, containing the demands registered aboard each tender, repair ship, and fleet issue ship for the past 24 months.

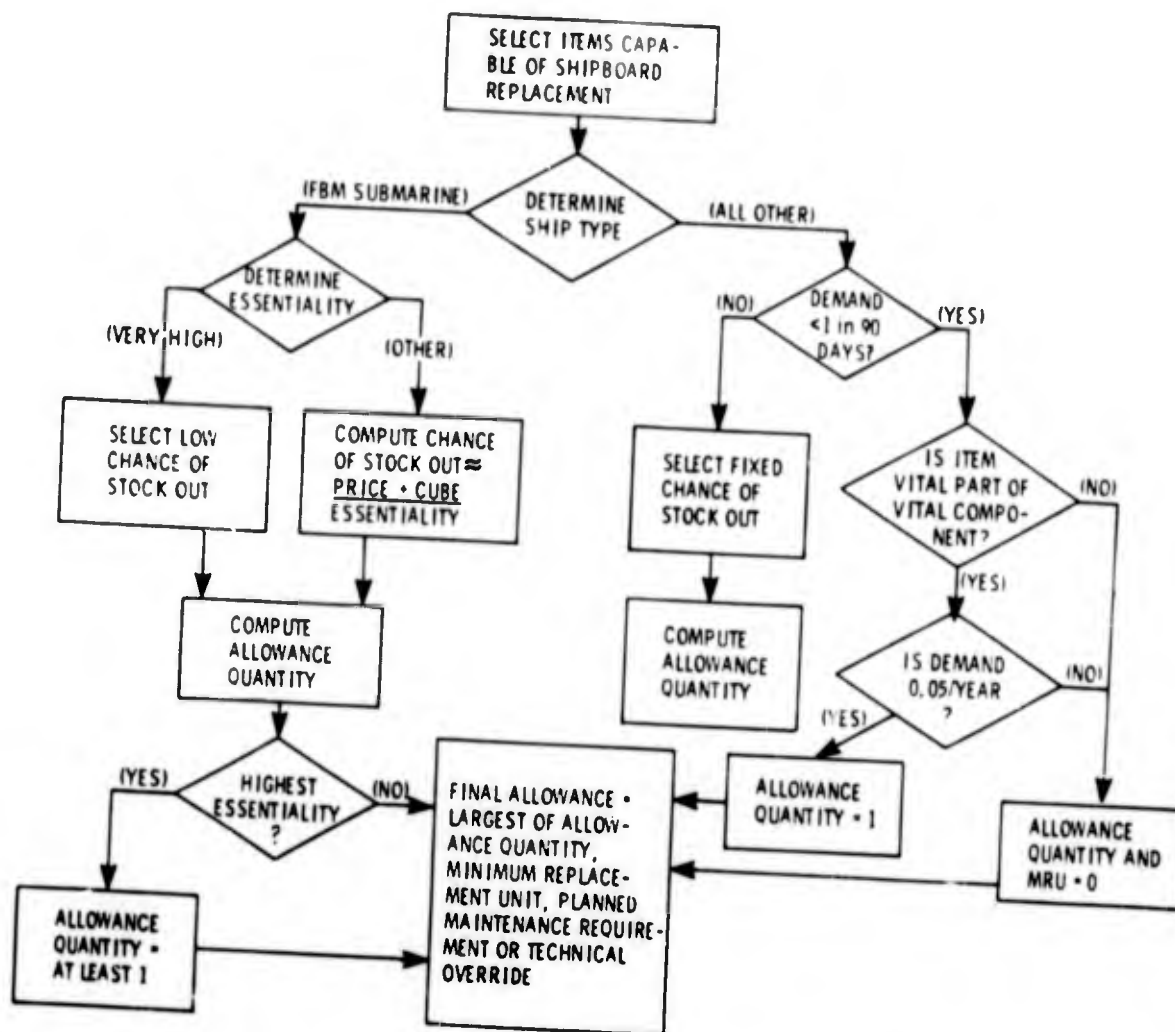
Allowance, Load, and Provisioning Computations

The decision making functions in the Weapons System Package can be divided into the same three processes as those in the Inventory Control Package: demand estimation, levels computation, and comparison of levels with assets. See figure 3. Demand estimation and levels computation will



ESTIMATING DEMAND FOR COMBATANT AND MOBILE LOGISTICS SUPPORT FORCE SHIPS

Figure 3



SCHEMATIC OF ALLOWANCE LIST COMPUTATION

Figure 4

be discussed in subsequent paragraphs. By reference to the Ships History and Inventory Record or the Load List File, the computer is able to compare computed levels with assets actually aboard a ship in the recent past. This comparison leads to the production of various supply aids for newly added items and "add and delete" lists to facilitate off-loading or requisitioning material.

The basic forecasting technique involves the estimation of a best replacement factor (BRF) for each item which is expressed in units during a quarter or a flight-hour. The BRF is the sum of the original technical estimate of demand or the mean family replacement factor (weighted) and the demand

actually observed and reported for the item (also weighted). The two weights are so constructed that they always sum to unity and as the installed population of the item increases and as the length of time on the stock list increases, the weight assigned to the original technical estimate diminishes. The source of observed demand is either old stock transactions as reported to the Master Data File or usage information collected through the Navy's Standard Maintenance and Material Management System.

The expected demand for an item aboard a particular ship is simply the product of the BRF and the installed population. Expected demand for a tender, repair ship, or

fleet issue ship can be estimated in several ways.

- The product of BRF and the installed population on supported ships.
- The moving average of the past eight quarters demand reported by the mobile logistics support force ship.
- A combination of these two methods.

Shipboard allowance quantities, see figure 4, are computed according to OFNAVINST 4441.12 (for surface ships and conventional submarines) and OPNAVINST 04000.57B (for fleet ballistic missile submarines). The first instruction limits shipboard stocking to items with at least one unit of expected demand in 90 days and to those with at least one demand in 20 years, provided the item is necessary for the function of an equipment vital to the ship's mission. Sufficient depth of stocked items is maintained to assure that all demands arising in a 90-day cruise will be met. Of course, all computed quantities are in consonance with the maintenance plan of the Hardware Systems Command.

Fleet ballistic missile items are handled somewhat differently. First the necessity of the item is determined on a 1 to 58 scale by procedures external to the Uniform ICP Program. Items with very high priority are stocked in a depth sufficient to assure a specified, high probability that all demands will be met during a patrol; other items are stocked to minimize the number of units (or requisitions) unsatisfied during a patrol, subject to constraints of funds and space available for spares.

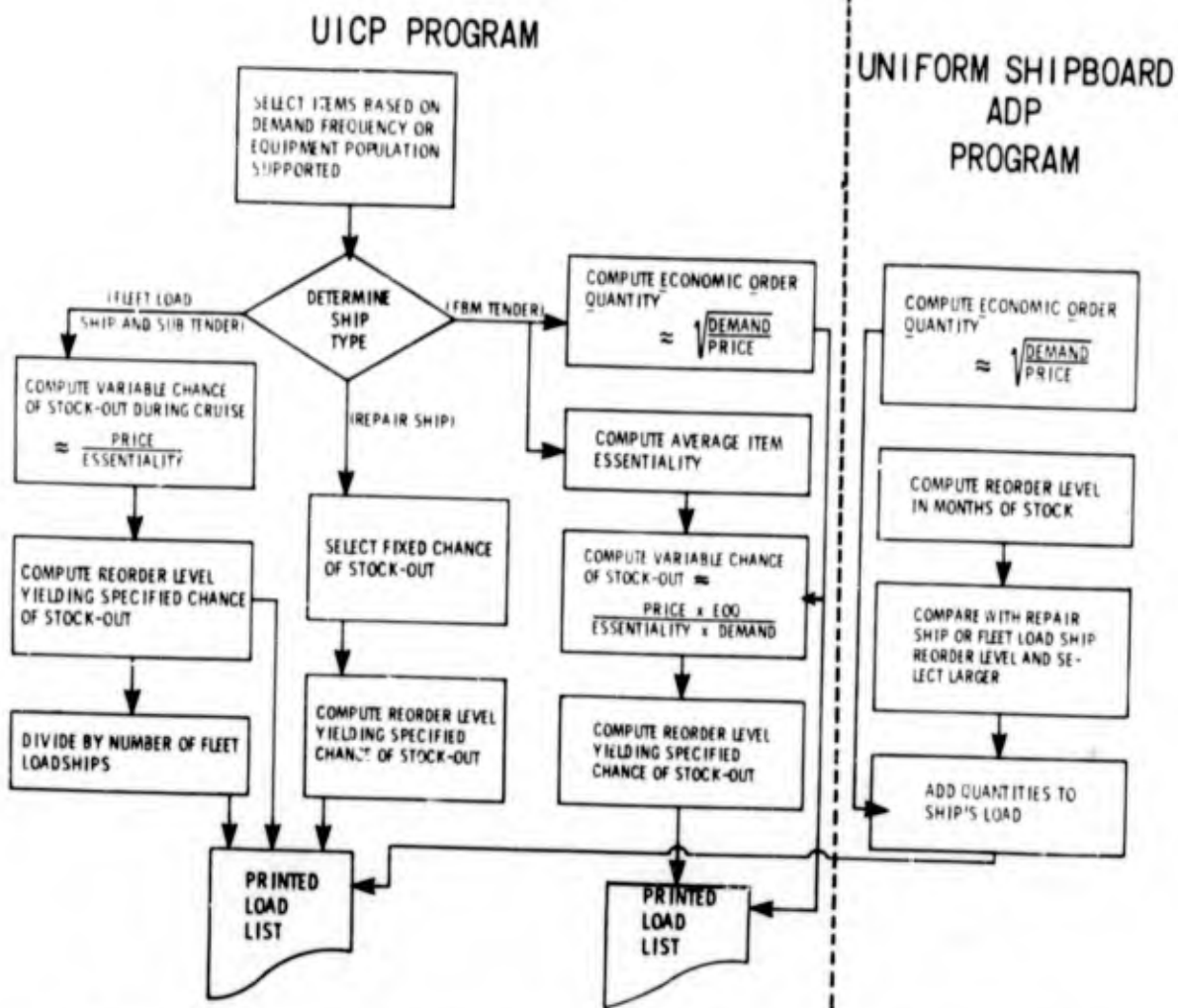
These two OPNAV instructions give the rules for calculating range and depth for material carried aboard submarine tenders, repair ships, and fleet issue ships. For fleet ballistic missile tenders both a recommended order quantity and a recommended reorder level are computed in the Uniform ICP Program. Computation techniques are essentially the same as those to arrive at system stock quantities. For other ships in the Mobile Logistics Support Force, the Uniform ICP Program computes only a war reserve stock, based on either a fixed or variable

risk of running out of stock. Additional safety stocks (if any) and operating stocks for fast moving items are computed by shipboard personnel in accordance with routines available in the Uniform Shipboard Automatic Data Processing System.

When a new ship or aircraft is built or when a new item of government furnished equipment is purchased by the Navy, it must be provisioned. See figure 5. This process involves the collection or estimation of great amounts of technical and supply data and the computation of quantities of parts to be purchased in support of the end item. Obviously, the provisioning process causes major changes in the Weapons System File and other data banks in the Weapons System Package. The provisioning process is also a source of a significant number of additions to the Master Data File. Once a limited amount of data about the item and its parts have been entered in the files, routines developed for the Uniform ICP Program can be used to estimate remaining data elements, decide whether each component is to be handled as repairable or consumable (if this has not been previously determined), and to compute quantities of repair parts to be stocked in the system and aboard ship.

For example, demand can be derived either from a technical estimate or from the mean family replacement factor, previously discussed. The standard deviation of demand, needed in computing allowance quantities and reorder levels, can be constructed from estimating relationships once the mean demand is developed. Computation of levels follows rules described earlier in this presentation. The classification of an item as repairable or throwaway depends on which classification results in the lesser total cost of acquisition and support over the life of the equipment. The decision to repair or throwaway depends on at least these factors:

- Acquisition cost and repair cost,
- Transportation cost,
- Gross demand rate and recovery rate,
- Program life,
- Special repair equipment cost,



COMPUTING LOAD QUANTITIES FOR MOBILE LOGISTICS SUPPORT FORCE SHIPS

Figure 5

- Procurement leadtime and repair time,
- Cost to establish new items of supply, and
- Similar data about each piece part used in repair.

Weapons System Products.

Possibly the most important outputs of the entire Weapons System Package are the listings used by ships, project managers, and systems commands in completing supply actions, in assessing current supply status, and in taking subsequent action. Some of these, such as supply aids and "add and

delete" lists, have been mentioned earlier. Other major outputs are:

- FBM Applicability Deck — listing all parts required to support all FBM forces.
- DSA Weapons System Support Items — containing all items managed by the Defense Supply Agency and needed in support of high-priority Navy weapon systems.
- Quality Review Listings — used in assessing the completeness of component and equipment inventories for a particular ship.

- Weapon System Repair Part Support List — comprising all the repair parts in a particular equipment and the current stock position of each part managed by the Navy.

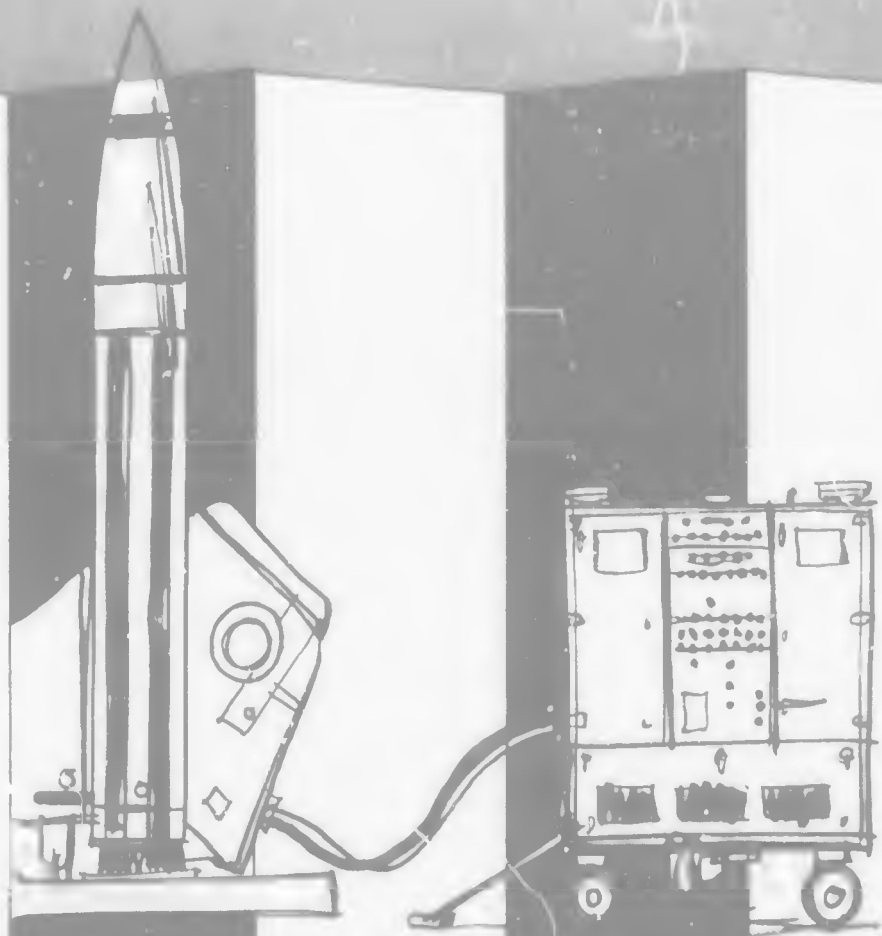
SUMMARY

The Uniform Automatic Data Processing System for Inventory Control Points is a comprehensive man-machine system designed to help Navy ICPs meet both their responsibility to supply the parts and components they manage and to provide program support for end items and equipments

assigned them. The system employs advanced mathematical techniques for forecasting and selecting stock levels to achieve optimum results within fund and space limitations. For its forecasting and decision making the system relies on supply and technical information originally estimated during the provisioning process and modified as observed data becomes available. Clearly the effectiveness of the system depends on the true worth of the "optimal" results and on the accuracy of the "observed" supply and technical data on which all the decisions are based.

CONTRIBUTION OF DSOT TO READINESS

CAPT V. WARRINER



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Shipboard missile systems are extremely complicated electronic systems comprised of radars, computers, missile launchers, guided missiles, and various ancillary equipment. The sophistication of this equipment renders certainty of operability status, at any given instant, highly desirable but difficult to achieve. Therefore, some form of built-in method for sensing faults in the systems operation is essential. The ultimate method would be a continuous self-monitoring that would instantly indicate a failure in the system at the time it occurs.

A manual procedure was used until 1966. It monitored only portions of the system at a time by static tests. This system, known as the Interim Daily Systems Operability Test, was slow and time-consuming at best. Improvements in the state-of-the-art permitted evolution to the Daily Systems Operability Test which monitors the entire system rapidly. All equipments are in a dynamic operational state during the test.

The test goals to which the Daily Systems Operability Test was designed are as follows:

- System dynamic test which will include the entire system, from end to end
- Measure performance of individual equipment
- Indicate that a failure has occurred rather than locate the specific cause of the failure, in primary mode
- Brevity, enabling frequent testing. Daily Systems Operability Test requires 15—20 minutes vice two to three hours for Interim Daily Systems Operability Test
- A dynamic test of target tracking
- Test in all weather, either by day or night. No personnel required on deck.
- Cease testing and conduct combat operation instantaneously
- No electromagnetic radiation external to ship in the course of the test

- Easy interpretation of test results for purposes of brevity and evaluation by the ship's personnel
- Test equipment to be accurate and reliable, enhancing credibility. No special meters or other ancillary test equipment is required
- Fail-safe test equipment that would not adversely affect the missile system.

The test equipment utilized by Daily Systems Operability Test is comprised of the System Dynamic Tester, SDT MK-37; the Test Set, TS MK-474; and the Training Missile, TSAM MK-16.

The System Dynamic Tester generates the path of one artificial target and evaluates test results. It provides a stationary target for testing transmission of target position from the Weapon Direction Equipment, and a repeatable dynamic target for fire control solution and firing circuit evaluation. Computed quantities are sent to it during the tracking/computing phase of the test, evaluated, and the results displayed by indicator lamps. During the firing phase, it verifies continuity of firing and order circuits to the missile. It also provides for subsystem testing by simulating the radar, radar-director, or the launcher. In addition, it can simulate targets, without evaluating test results, in a one-dimensional sense: in range only, bearing only, or elevation only, for exploratory testing.

The Test Set MK-474 receives target position and trajectory information from the System Dynamic Tester, and generates video for transmission to the radar. This video gives a very realistic representation of a live target. Its intensity varies with range and angle tracking error, and it may contain a controllable amount of noise. The Test Set MK-474 thus causes the radar to perform, in this test, in a completely normal fashion from video level through test completion. In addition, the Test Set MK-474 will generate video for five target trajectories, for local testing

of the fire control radar and director. These linear targets simulate a spectrum of target performance from large slow aircraft to high performance fighters. Optional jamming may be used, either in Daily Systems Operability Test or with the local targets, for training, or radar evaluation.

The Training Missile, loaded on the rail of the launcher during testing, has been revised to fit the intentions of Daily Systems Operability Test. After launcher loading, it provides an automatic code stepping check, and verification of continuity of circuits carrying quantitative information to various missile sections. In addition, the Training Missile contains a test panel with measuring points for diagnostic measurements. However, during Daily Systems Operability Test, the weather deck launcher area need not be manned.

The firing circuit to the missile is monitored to verify presence of sufficient power to cause propulsion ignition. In addition, the Weapons Direction Equipment contains a Daily Systems Operability Test indicating panel which displays system status and various test results for the use of the test conductor.

When a system failure is indicated by a

status lamp, the System Dynamic Tester may be switched to sub-mode which interrogates radar, director, or computer as to operability. Then, using the equipment in conjunction with Preventive Maintenance System (PMS) fault isolation aids, the exact equipment component that failed can be determined.

Although the material advantages of Daily Systems Operability Tests are realized in training, troubleshooting and verification of system status for weapons systems, "the proof of the pudding is in the firing"

Figure 1 illustrates the marked improvement of missile flight success experienced by TARTAR ships after installation of Daily System Operability Test. The flight conditions for the two sets of data were not controlled to assure a fully equivalent measurement of effectiveness. An equal number of flights, before and after installation of DSOT are considered, and these flights represent similar types of targets, trajectories, and environmental conditions. Other factors may not be the same. Therefore, the 20% improvement is a "ballpark" number that merely shows a significant improvement is attributable to DSOT.

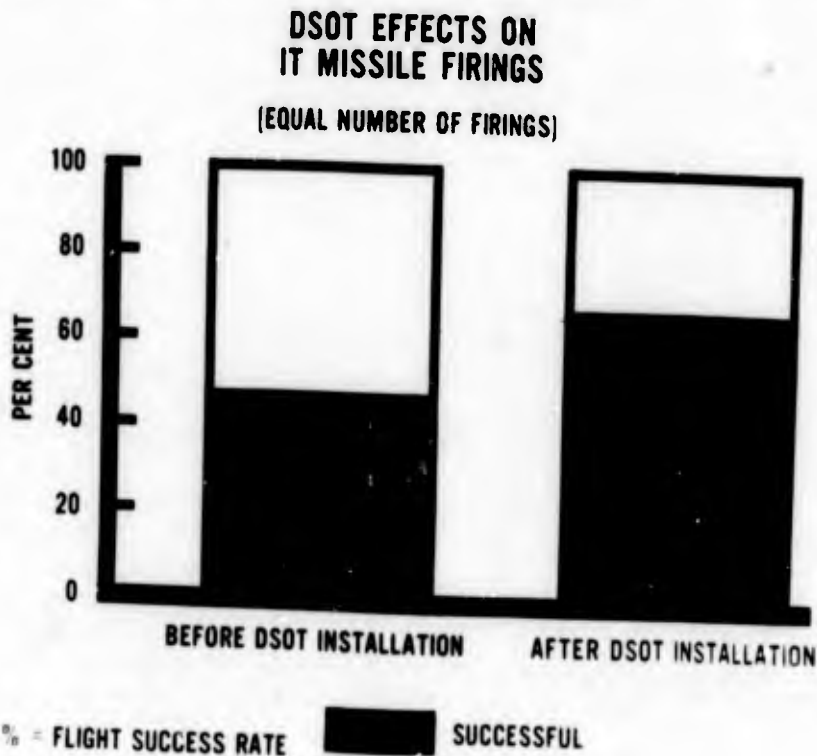


Figure 1

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INTRODUCTION

The DX/DXG Program is aimed at the definition and acquisition of escort ships to meet the needs of the U.S. Navy of the future. During the concept formulation phase of this program, total ship reliability and availability goals were tentatively established. The U.S. Naval Applied Science Laboratory (NASL) was requested to assist and support the DX/DXG Ships Acquisition Project Office in the area of reliability and maintainability. Major effort was to be directed to (1) interpretation of these reliability and availability goals and requirements, (2) allocation of subsidiary goals to major ships functions, (3) assessment of the feasibility of achievement and (4) determination of critical functions, i.e., those least likely to be achieved in terms of present ship design. An initial effort prior to phase A of contract definition was to be followed by further updating and refinement throughout phase A, culminating as an input to phase B (contractor's efforts), of contract definition. This

paper describes the techniques used in achieving the aforementioned aims. Quantitative results and conclusions regarding major ships functions will not be disclosed, in keeping with the sensitivity of the program and the security level of this conference.

APPROACH. The steps taken to achieve the stated aims of NASL in the DX/DXG Program are summarized in Figure 1. The nature and purpose of each step is amplified below.

Mission Definition and Description. General missions were prescribed for the DX/DXG. Additional specificity, however, was required to ensure unambiguous determinations of ship reliability and availability under conditions exercising the major primary modes of ship's operation. This is provided for by the mission descriptions.

Baseline Ships. Selected to provide the basis for modelling and prediction, baseline ships must be of well established design,

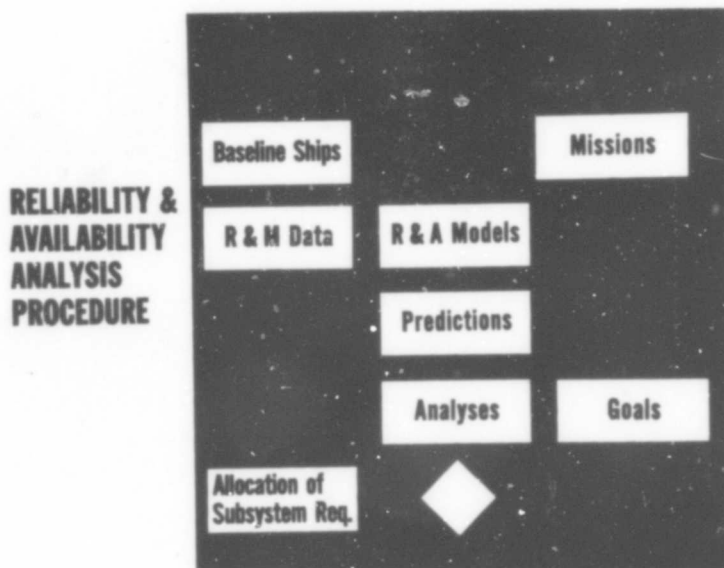


Figure 1

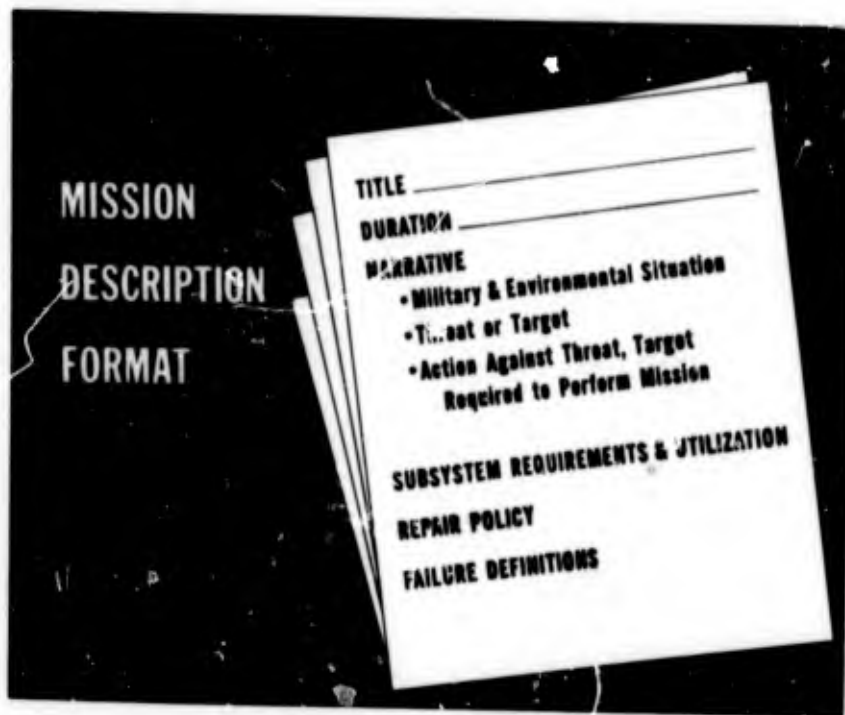


Figure 2

SHIPS SUBSYSTEM NOMENCLATURE

Table 1

COMMAND/DECISION	NAVIGATION
COMMUNICATIONS	SURVEILLANCE (SUB)
SHIP CONTROL	SURVEILLANCE (SUR, AIR, ECM)
PROPULSION	WEAPONS CONTROL
ELECTRICAL PWR. GEN. & DIST.	WEAPONS

inherently capable of performing the missions required of the DX/DXG.

Models. Both availability and reliability models must be generated for each mission, using the appropriate baseline design. The models must contain sufficient detail to reflect major equipment reliability and availability and all quantitative prediction of these parameters for the ship upon insertion of appropriate quantitative data.

R&D Data. These data are quantitative estimates or predictions of the parameters of each element of the baseline ship design that are contained in the models. They are combined by the model to arrive at overall ship reliability and availability.

Predictions, Analyses and Allocations. Predictions of reliability and availability were determined from the lowest meaningful level to the ship level for each mission. The analysis was concerned with comparison of predictions to goals and the identification of critical subsystems, while the allocation was aimed at the assignment of goals and requirements to the subsystem level.

RESULTS

The format of the missions generated as a basis for analysis is shown in Figure 2. The subsystems used to define each mission are listed in Table 1. Conceivably, this could be considered a first step towards modelling rather than a mission definition, since the latter should consist of operational needs rather than system requirements. In the interests of getting the job done, however, this fine distinction was ignored. The main purpose of the narrative portion of the mission description was to form the basis for a dialogue with those primarily concerned with ships operation, a procedure requisite to establishing mission descriptions acceptable to both user and builder.

The repair policy is a simple statement of whether repairs are permitted prior to or during a mission. Repairs were, as a matter of fact, permitted prior to a mission, but not during short duration engagements. Question of the validity of the latter decision is largely academic, in view of the minor impact of allowable repair on mission reliability

predictions for short duration missions. Repairs were permitted however, during longer duration missions.

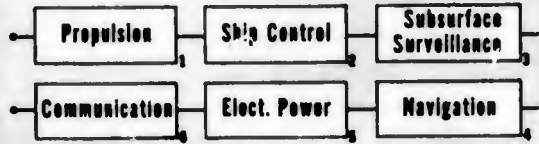
The definitions of failure were made a part of the subsystem requirements and repair policy. Failure was defined as a subsystem not meeting its performance requirement during the mission for a period greater than specified for the mission and subsystem, i.e., allowed down time. Thus, failure of the propulsion subsystem for a particular mission could be defined as the inability to proceed at half power for more than one hour. For shorter duration missions, no down time was allowed.

The baseline ship designs initially chosen for the exercise were of the DE and DLG types. They represent existing designs of ships in recent shipbuilding programs that most closely meet the objectives of the DX/DXG program. Design information was readily obtained from the ships specifications and contract guidance plans. As concept formulation progressed and the DX/DXG ships suite became more rigidly defined, the baseline ship became a hybrid affair: selected portions of the suite replaced portions functionally equivalent to them in the original design. In addition, the baseline ship was modified by the inclusion of functions and capability not possessed by the original ship.

The reliability and maintainability data on the major equipments making up each of the subsystems were obtained from a variety of sources; **indirect sources:** prior relevant studies conducted by NASL and others; **direct sources:** NAVSEC, NORDIV and others in analyzing MOCS fleet data, OP-TEVFOR reports, Naval Laboratory T&E reports, contractor reliability demonstration test reports, reliability and maintainability predictions, and procurement specification requirements. In general, fleet usage data were regarded as most suitable for our purpose, in the sequence given above for direct sources. Data acquisition is by no means a simple undertaking, as everyone knows who has been involved in it. Program time commitments usually determine the end of this phase of the exercise.

**SHIPS
RELIABILITY
BLOCK
DIAGRAMS**

INDEPENDENT SUBSYSTEMS

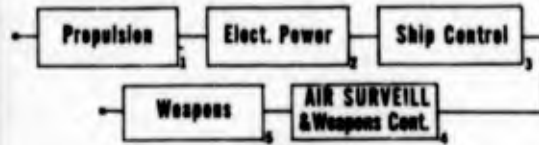


$$R_3 = R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5 \cdot R_6$$

$$A_3 = A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5 \cdot A_6$$

Figure 3

AIR SURVEILLANCE AND WEAPON CONTROL DEPENDENT

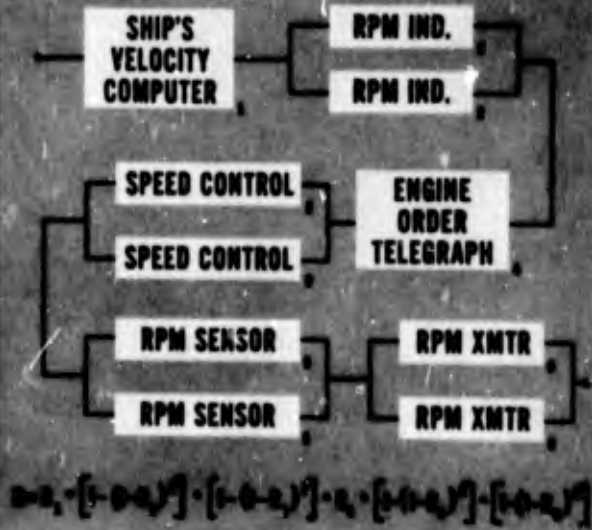


$$R_3 = R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5$$

$$A_3 = A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5$$

Figure 4

**SHIP
SPEED
CONTROL
RELIABILITY
BLOCK
DIAGRAM**



The reliability and availability models generated for each mission followed established theory. A ground rule in all modeling efforts was to model only the primary mode of ship's operation. Fallback modes were eliminated because they required consideration of the performance capability of the various modes of operation in an overall effectiveness model. This decision was in line with the interpretation of the reliability goals. However, where an alternate mode was deemed to be as effective as the primary mode, it was brought into the model.

In most instances, each of the subsystems required for a particular mission was treated independently and serially from a reliability and availability standpoint. In some instances, subsystems, as defined, could not be considered independent of others and were combined into one larger, independent subsystem. Figure 3 depicts the reliability and availability block diagrams and equations at the subsystem level for both situations.

The next level of modeling consisted of availability and reliability models of each subsystem for each mission in terms of the major equipments assigned to each subsystem. For availability and reliability without repair, the block diagrams and equations were those depicted for a hypothetical but realistic ship course control subsystem. This is shown in Figure 4. Note that this model is expressed in terms of levels of equipment to which meaningful values of MTBF and MTTR can be assigned. The equations given in Figure 4 express the subsystem reliability and availability in terms of the individual equipment reliability and availability. This is computed as follows:

$$\text{Equipment Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

$$\text{Equipment Reliability without repairs} = \exp(-UT/\text{MTBF})$$

where MTBF and MTTR have their usual meanings. T is the mission duration and U is the fraction of the mission duration that the equipment is in actual use. Note that the availability formula yields steady-state availability. Transient effects are ignored in this analysis.

The formulae apply to equipments that are in constant use prior to a mission and have time dependent reliabilities. Some equipments are quiescent prior to the onset of a mission, and may be assumed to have a mission availability of 1. Other equipments are not used continuously during a mission but for only a very short duration (termed a cycle) and have failure probabilities related to the MCBF, i.e., the mean number of cycles between failure. The reliability for one cycle may be approximated from the equation:

$$\text{Reliability} = 1 - \frac{1}{\text{MCBF}}$$

Still other equipments are only used once during a mission and have reliabilities independent of the duration of their use. For these, the values of reliability must be inserted directly into the subsystem reliability equation.

The assignment of an availability of 1 to equipments that are quiescent prior to a mission and that have time independent failure probabilities in use, is a valid approach from an overall mission effectiveness viewpoint. Such is not the case, however, where availability is the prime concern. In the latter instance, it is better to consider the failure probability as the **unavailability** rather than as the **unreliability**. In other words, overall mission effectiveness remains the same, but the ships availability prediction incorporates these equipments.

Missions which permit repair and allow a maximum down time for each subsystem, require a different approach to reliability computation. Analytically, it can be shown that the reliability under these conditions is:

$$\text{Reliability with repair} = \exp - \frac{(1-M)t}{\text{MTBF}}$$

where t is the duration of use of the equipment and M is the probability of effecting a repair of the equipment within a given down time. M may be calculated from the equation:

$$M = 1 - \exp \left[- \frac{t_0}{\text{MTTR}} \right]$$

where t_0 is the allowed down time. This may be applied to a subsystem which consists of

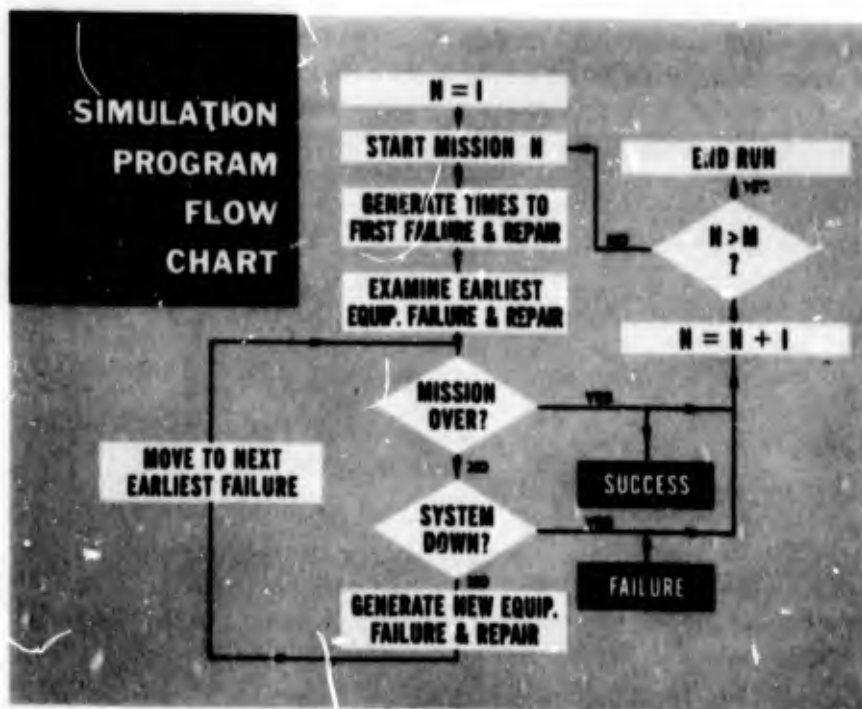


Figure 5

N equipments in series by using a subsystem MTBF and MTTR:

$$\text{Subsystem MTBF} = 1 / \sum_{i=1}^N \frac{1}{(\text{MTBF})_i}$$

$$\text{Subsystem MTTR} = (\text{Subsystem MTBF}) \times \sum_{i=1}^N \frac{\text{MTTR}}{\text{MTBF}}$$

wherein the subscripts designate the individual equipment. These formulae were applied to the propulsion subsystem by ignoring the portions of the subsystem containing some redundancy, and considering only the purely serial elements. Justification for this assumption lies in the relatively high reliability of the former category. Predictions were essentially the same as those derived from a more elaborate simulation technique. However, this need not be generally true; later predictions used the simulation approach, which will now be described.

The general analytic solution of reliability with repair and an allowed down time, presents mathematical and computational difficulties that may be avoided by using Monte Carlo simulation. A simplified flow chart of

the simulation program used to predict reliability for some of the missions is shown in Figure 5. Inputs are the equivalent of the subsystem reliability block diagram: mission time, system down time allowed during the mission, the MTBF and MTTR of each equipment, and the numbers of missions to be simulated. Individual equipment time to failure and time to repair were assumed to be exponentially distributed. Based on the MTBF and MTTR values given, a pseudo random number generator in the program was used to generate "times to first failure" and "first repair" for each equipment. The program then required the system to be examined during the time the first equipment was down. If system failure occurred based on the reliability block diagram and allowed down time, the mission was terminated and registered as a failure. If the first equipment failure occurred at a time greater than the mission duration, the mission was terminated and registered as a success. If the system was not down during the first equipment down time, a second failure and repair time was randomly generated for this equipment. The program then progressed to the next earliest equipment failure and repeated the above

process until the mission was terminated as either a success or a failure. A second mission was then started in a manner identical to the first and the whole process repeated until the desired number of missions was simulated. Outputs of the program were: total missions simulated, total unsuccessful missions, and a detailed failure and repair history for each mission. Mission reliability is simply the ratio of the number of successful missions to the total number of missions. Obviously, the greater the number of missions run and the greater the number of mission failures, the greater the statistical confidence in the estimated reliability.

Having completed the models of each mission, the reliability and availability for each mission were computed for the total ship, each subsystem and each equipment. The results were then compared to the ships goals. In those cases where predictions were less than the goals, investigation was made to determine the subsystem or equipment to which most of the responsibility could be assigned. It was found that one or two subsystems were primarily responsible in each case. The criticality could generally be further isolated to relatively few equipments within each subsystem. This was also found to be true for subsystems with a higher mission reliability and availability. That is, relatively few equipments within each subsystem were primarily responsible for the subsystem unreliability or unavailability.

Reliability and availability goals were also allocated to each subsystem for each mission, to assure that total ship reliability and availability would meet the desired goal if the subsystem values were as assigned. For initial allocation, the following procedure was used:

Assume that the predicted reliability is less than the desired goal for the ship. The quantity α is determined as follows:

$$\text{Ships Reliability goal} = (\text{Ships Reliability Prediction})^\alpha$$

For example, assume the goal is 0.99 and the prediction is 0.97. The value of α becomes:

$$\alpha = \frac{\log 0.99}{\log 0.97} = 0.33$$

Each subsystem goal is then found from the subsystem prediction by the following relationship:

$$\text{Subsystem goal} = (\text{Subsystem Prediction})^\alpha$$

In elaboration of the previous example, suppose a particular subsystem has a predicted reliability of 0.995. The allocated reliability would be:

$$\begin{aligned} \text{Subsystem Reliability Goal} &= (0.995)^{0.33} \\ &= 0.9983. \end{aligned}$$

Essentially the same procedure is followed for Availability. The subsystem allocations for each mission are then compared and the highest of these taken as the subsystem goal. It may be obvious that such a procedure will yield subsystem allocations to enable the ship to meet or exceed its assigned goals (were the subsystem goals to be achieved). The justification for the procedure, however, may not be clear. This justification is spelled out in the Appendix, immediately following this paper.

Initial allocations did not recognize any constraints in the hardware or configuration. However, many major equipments have been prescribed. To allocate goals properly, one must take account of this factor. Referring to our previous numerical example, suppose that the subsystem, which had an allocated reliability goal of 0.9983, is required to use some equipment, independent of the rest of the subsystem, that has a predicted reliability of 0.999. The goal for the rest of the subsystem is then obtained from:

$$\begin{aligned} \text{Unconstrained portion goal} &= \frac{0.9983}{0.999} \\ &= 0.9993. \end{aligned}$$

For this procedure to work, the reliability (or availability) of the constrained equipment must exceed the allocated subsystem goal. Otherwise, a more elaborate procedure must be invoked at the ship level. Here, the reliability or availability of all prescribed equipment may be lumped together and then divided into the total ship goal and prediction, in order to arrive at goals and predictions applicable to the unprescribed portions of the ship. Allocations may then be made in a manner identical to example previously described. However, the prescribed equipment

reliability or availability must still exceed the total ship goal if the method is to apply.

Using the results of the analyses and allocations as described, the feasibility of achieving the ships goals was assessed. Goals were then revised in accordance with these assessments, and goals and requirements established for the mission oriented subsystems as defined. The analysis presently forms part of the basis for phases A and B, contract definition effort, in reliability and availability.

APPENDIX A

The procedure used in this study for allocation of goals is necessarily based on certain assumptions: the more complex the equipment, the more difficult or costly it is to achieve a given MTBF. Conversely, the MTBF is a good measure of complexity; the lower the MTBF, the greater the complexity. To quantify these assumptions for purposes of allocation, we can say that the cost of improving the MTBF of an existing equipment:

... is proportional to the percentage increase in the MTBF

... is inversely proportional to the present MTBF

... has a universal proportionality constant C_0 .

Expressing this mathematically for a system containing n equipments we obtain:

$$\text{Cost Increase} = C = C_0 \sum_{i=1}^n \frac{T_i^* - T_i}{T_i^*},$$

where T_i is the existing MTBF of the i 'th equipment and T_i^* is the improved MTBF.

The object of any allocation is to achieve a given reliability (or availability) at minimum cost. Thus, we must also express the reliability as a function of the various values of T_i^* . To do this, additional assumptions are necessary, namely that the system reliability R^* be given by:

$$R^* = R_1^* \cdot R_2^* \cdot R_3^* \cdots R_n^*$$

where R_i^* is the reliability of the i 'th independent subsystem and each R_i^* is related to a T_i^* by

$$R_i^* = \exp[-t/T_i^*]$$

where t is the mission duration and T_i^* is the effective MTBF of the i 'th subsystem.

The problem then resolves itself to find those values of T_i^* that minimize C , subject to the constraint that R^* achieve a given value. The classical Lagrange method of undetermined multipliers is directly applicable to this problem. Using the undetermined multiplier K , the function $(C - KR_g^*)$ is minimized. This yields the set of equations:

$$\frac{C_0}{T_i^2} = \frac{KtR_i^*}{(T_i^*)^2}; i = 1, 2, \dots, n.$$

From these equations, the factors C_0 , K and t may be eliminated and it becomes merely a matter of further algebraic manipulation to show that:

$$T_i^* = T_i \left[\frac{\log R}{\log R^*} \right] \quad i = 1, 2, \dots, n.$$

R is the predicted system reliability given by

$$R = R_1 \cdot R_2 \cdots R_n$$

wherein

$$R_i = \exp[-t/T_i].$$

These equations imply that each predicted MTBF is to be multiplied by the same numerical factor, $\log R / \log R^*$, to arrive at the allocated MTBF. This factor is $1/\alpha$, where α has the same meaning as in the main body of the text (\log of reliability goal divided by the \log of reliability prediction).

Since

$$\begin{aligned} R^* &= R^\alpha \\ \log R^* &= \alpha \log R, \end{aligned}$$

which yields

$$\frac{1}{\alpha} = \frac{\log R}{\log R^*}$$

Multiplying the predicted subsystem MTBF by $1/\alpha$ is equivalent to raising the predicted reliability of the subsystem to the power of α : thus:

$$\begin{aligned} R_i^* &= \exp[-t/T_i^*] = \exp[-t/\frac{1}{\alpha} \cdot T_i] \\ &= \exp[-\alpha t/T_i] = [\exp(-t/T_i)]^\alpha \\ &= R_i^\alpha \end{aligned}$$

This is precisely the allocation procedure described in the main text. Thus, the proof for Reliability allocation, under admittedly restrictive conditions, is completed.

As for availability allocation, the procedure described for reliability carries over provided that the following assumptions are made:

- ... availability improvement is to be achieved solely by MTBF improvement;
- ... all subsystems have approximately the same MTTR
- ... the MTTR/MTBF ratio is much less than unity.

The last assumption is required in order to relate availability functionally to MTBF, as well as reliability. To see this, we have:

$$A = \frac{MTBF}{MTBF + MTTR} = \frac{1}{1 + \frac{MTTR}{MTBF}}$$

$$\approx 1 - \frac{MTTR}{MTBF} + \dots$$

$$\approx \exp \left[-\frac{MTTR}{MTBF} \right]$$

The derivation described above is not intended to provide the ultimate justification for the allocation procedure. What is proposed here is that the allocation procedure is a valid first step. Nor is any claim made for originality; it is essentially the method in current use.

ELECTRICAL AND MECHANICAL SYSTEM DESIGN REVIEW— A SYSTEM EFFECT- IVENESS TOOL

MR. H. LEVINE
MR. A. GOODMAN
MR. D. WALTERS



INTRODUCTION

The complexity of modern day systems is such that it is most difficult to obtain from production equipment the same performance obtained from experimental systems or breadboard devices operated by design engineers.

The transfer of the technical concept from the developmental laboratory to the equipment design and production activity must be made via the specification. This transfer of knowledge must be made in such a way that the engineering design and production agent have some freedom to permit the incorporation of latest engineering advances.

Government design review offers a practical method to ensure that a contractor has fully complied with specifications and to allow him to implement the latest engineering advances in his design.

The AN/SQS-26 is a multimode high power sonar system. Three basic propagation paths can be exploited by the active system. The three paths are Surface Duct, Bottom Bounce, and Convergence Zone, (figure 1).

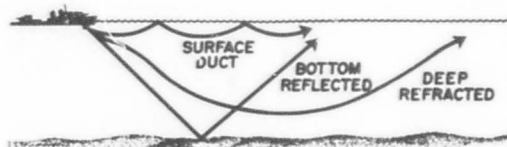


Figure 1

The Surface Duct can be insonified with either a 360 degree Omnidirectional Transmission (ODT) or a 120 degree directional transmission which is called Processed Directional Transmission (PDT). The Bottom Bounce and Convergence Zone paths are insonified over a 120 degree arc. Simultaneous operation of Bottom Bounce and ODT, or Convergence Zone and ODT, or PDT and ODT is possible.

In addition to the active modes of operation, a passive capability is provided. The passive mode can be operated simultaneously with any active mode. There are several models of the SQS-26. The models are XN-1, XN-2, 26, AX, BX, AX Retrofit and CX.

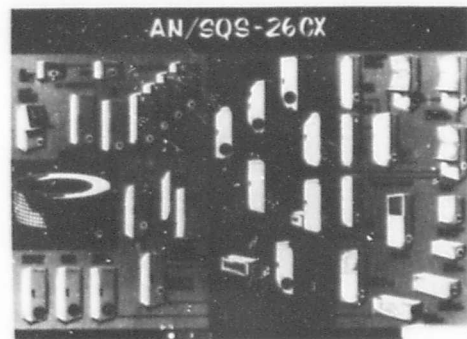


Figure 2

Figure 2 is a block diagram of the CX equipment. The design review of SQS-26's started with the BX equipment. The BX equipment had been partially designed when Underwater Sound Laboratory started the design review. The design review of the BX began with an electrical and a transducer design review only. It was soon learned that a mechanical and a human factors design review was a necessity. At the same time that the Laboratory was conducting the design review of the BX, an at-sea evaluation was being performed on the XN-2 equipment. The knowledge gained by the at-sea evaluation was added to the AX Retrofit and the CX equipment. Thus, the design review of the AXR and CX benefited not only from the experience with the BX, but also from the results of the at-sea tests. The growth of design review was in both the number of personnel and in knowledge.

There are many elements that govern the well known learning curve, some of which are: state-of-the-art components such as

vacuum tubes vs semi-conductors; knowledge of overall system concepts; and in this case, design review experience.

The overall SQS-26 system size, as judged by the number of components used, has grown by a factor of three from AX to CX, and yet the system MTBF has increased by a factor of ten from AX to CX. The CX equipment reliability far exceeded the contract acceptable levels.

The AX reliability tests were conducted on a barge; the CX reliability tests were conducted in the factory. But this difference has little significance. If anything, the CX equipment was subjected to much more rigid test criteria.

It is difficult to determine which element of the learning process contributed the most to the equipment success; however, it is felt that design review was a major contributor.

WHAT IS DESIGN REVIEW?

Design review can best be defined as a critical appraisal of all phases of a design. Some of the rewards that are realizable from a design review are: higher probability of a product meeting the contractual requirements; lowest cost; most reliable, state-of-the-art design. In general, the design will be the optimum one for the specific need.

Many companies that are involved in military contracts will usually conduct a design review. The purpose of this review is to ensure that the piece of equipment they build will be competitive in both value and performance.

Industrial design review is usually divided into three distinct phases: conceptual review, detailed review, and design follow-up. The conceptual review is conducted at the proposal stage and is usually qualitative in nature. It proves that the conceptual design meets the specifications and that the approach has been optimized. This may be the most important part of a design review because important system problems may be uncovered. Any change at this point in design is usually inexpensive.

The detailed design review is quantitative in nature. This review is conducted at the electrical circuit level and mechanical cabinet

level. The emphasis is on over or under design, cost reduction, performance, reliability, safety, state-of-the-art approach, human factors, etc. For this review to be effective, it should be coincident with the design phase.

The final design review is held prior to release to the factory for production. It is based upon final schematics and layout drawings, and determines that the system will meet all performance and reliability requirements. Any changes at this point, due to errors found during the design review, are more expensive because all layouts and parts lists are in finalized form.

INDUSTRIAL DESIGN REVIEW APPROACH

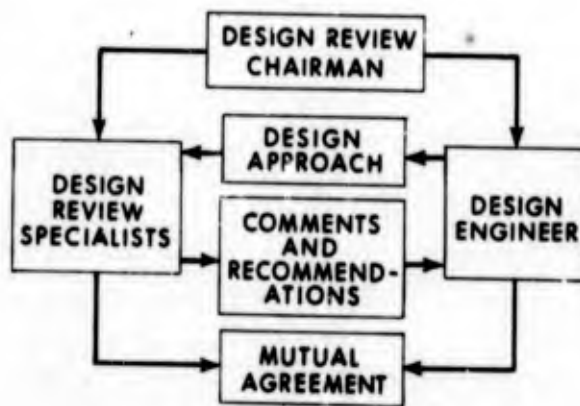


Figure 3

The majority of the companies conducting a design review use the Chairman-Committee approach, (figure 3). This is essentially a design review team consisting of design specialists (i.e., system, circuit, reliability, maintainability, human factors, value engineering, etc.) that is headed by a design review chairman. The members of the design review team must be highly skilled in their particular fields and must be objective in their review of a design.

A design review meeting is scheduled by the chairman and he assembles all the pertinent people involved in the area being reviewed. At the meeting, the design engineer must present his design to the group and justify the approach he has taken. The design review group evaluates the design, using cost, reliability, state-of-the-art, etc.,

as factors, and makes any recommendations which the group feels are justified. The design engineer and design review team must then resolve any differences over the recommendations made.

The design review described tends to optimize system performance, and includes cost as a major factor.

Design review is beneficial to the government as well as to industry. The government, however, stresses a review based upon contract requirements and not upon profit incentives.

The need for a design review in the SQS-26 sonar program was accepted late in the spring of 1964. Early in 1962, tests had begun on the XN-2 sonar system on the USS WILKINSON, but technical evaluation was not seriously attempted until November 1962. In 1963, the detection capability of the XN-2 was improved through changes in signal processing techniques and displays, but reliability remained poor. The technical evaluation was terminated in the winter of 1963/64 and the WILKINSON was then turned over to COMOPTEVFOR for a short operational evaluation.

The problems discovered during the technical evaluation prompted the design review of the AN/SQS-26BX sonar system.

In performing the SQS-26BX review, Laboratory personnel realized that reliability, maintainability, human factors and mechanical design review were needed. In addition, the need for an overall system review was recognized, to ensure both the contractor and the government that the system design concept conformed to contract specifications before any hardware was constructed. For these reasons, the design review of the AN/SQS-26AX Retrofit and the AN/SQS-26CX was divided into the following major categories.

- Electrical
- Mechanical
- Human Factors
- Maintainability
- Reliability

The latter two categories were discussed in Specon 3* and will not be discussed here.

MAJOR CATEGORIES FOR DESIGN REVIEW
OF THE AN/SQS-26
SONAR SYSTEMS (BX, AX RETROFIT, CX)

	BX	AXR AND CX
I. ELECTRICAL	X	X
II. MECHANICAL		X
III. HUMAN FACTORS		X
IV. MAINTAINABILITY		X
V. RELIABILITY		X
X-REVIEWED		

Figure 4

Figure 4 is a comparison of the areas reviewed in the BX sonar system and the AX Retrofit and CX sonar system.

ELECTRICAL DESIGN REVIEW

The electrical design review as performed by USL entailed:

1. The review of system and subsystem design philosophy and verification that the contractor had accurately implemented the requirements of the intended meaning of the specifications.
2. The evaluation of the designed subsystem, and modules (circuit boards, electromechanical units, etc.) for compliance with the specifications, including military standards and accepted engineering practices.
3. The review of the functional or block diagrams to ensure that sound approaches were used.
4. Commencement of circuit review once it was assured that the proposed design conformed both functionally and practically to the specifications.

*Proceedings of the NMC Third System Performance Effectiveness Conference, May 17-18, 1967: "Reliability System Design Review," by N. Cooper et al., p. 115; "Maintainability System Design Review," by V. Iacono, p. 127.

The circuit review was broken down into the following categories:

- Parts analysis
- Digital circuit analysis
- Analog circuit analysis

The parts analysis answered the following types of questions:

1. Resistors — Are the correct values of resistance, wattage, and tolerance used?
2. Capacitors — Is the appropriate type, in addition to the appropriate value, used; what is the dielectric material, leakage, breakdown voltage, etc.?
3. Transistors—With worst case characteristics, how does the transistor behave at the temperatures required by specifications? Does its application require special characteristics, and if so, would a different transistor fill the requirements better? What is the power being dissipated, etc.?

Similar efforts and calculations were made to verify the tolerance and use factors for other components such as filters, inductors, transformers, synchros, etc.

The digital circuit analysis answered the following types of questions:

1. What temperature and frequency stability does the circuit require, and what is achieved?
2. Is it state-of-the-art?
3. What is the noise immunity?
4. What are the switching thresholds?
5. Is the logic design uniform?

The analog circuit analysis answered the following types of questions:

1. Does the circuit drift with temperature, and if so, how much?
2. If feedback is used, is the circuit stable? What is the gain margin? What is the phase margin?
3. Does the circuit have the correct dynamic range?
4. What is the noise figure of the circuits?
5. What is the circuit gain, distortion, etc.?

MECHANICAL DESIGN REVIEW

The mechanical design review as performed by USL entailed:

- The review of the mechanical mounting philosophy (hard or soft mounts).

- The evaluation of the mechanical attributes of the cabinets, drawers and printed circuit boards for compliance with the specifications, including military specifications, NAVSHIPS specifications, and accepted engineering practices.

The mechanical review was broken up into five main areas:

1. Layout
 - a. Printed circuit board
 - b. Electromechanical and mechanical
 - c. Wiring
2. Equipment enclosures
3. Hardware
4. Mechanical Shock and Vibration
5. Environmental
 - a. RFI
 - b. Humidity
 - c. Heat

Some of the factors considered in the review were:

1. Layout
 - a. Have all heat-sensitive or dissipating circuit board parts been suitably heat sunk?
 - b. Have all gears been pinned (by setscrews)?
 - c. Is wiring that passes between two structural members mechanically flexible and securely clamped to each member with sufficient slack to prevent mechanical strain?
2. Equipment enclosures — Have suitable materials been selected based upon strength, weight, electrical factors, producibility, and environmental stress?
3. Hardware—Are all part mountings, fasteners, etc. suitable for environmental conditions?
4. Mechanical Shock and Vibration — Have all electronic part mountings been designed to ensure that there will be no relative motion between parts and part leads?
5. Environmental
 - a. Have metal bonding gaskets under positive pressure been installed on all access doors and drawers?
 - b. Have moisture resistant platings and coatings been applied to protect exposed surfaces?

c. Has adequate heat removal apparatus been employed for the expected thermal environment?

HUMAN FACTORS DESIGN REVIEW

The human factors design review as performed by USL was broken up into two main categories: displays and controls.

In evaluating the displays, the human factors engineer checked such things as:

1. Frame Rate — Does the frame rate match the operator so that it will be flicker free?

2. Display to display uniformity—Are the displays matched for color and brightness to prevent any operator confusion when he shifts his attention between displays on a single console?

In evaluating the controls, the human factors engineer checked such things as:

1. Layout — Are the controls laid out so that each display control knob is near the display controlled? Are infrequently used controls placed on back panels?

2. Color — Is pushbutton labeling color coded for function?

3. Labeling — Are all controls correctly and unambiguously labeled?

DESIGN REVIEW PROCEDURES

The most important asset of a successful design review is a good government-contractor relationship. The excellent contractor-Navy working relationship on the AXR and CX design reviews coincided with the inception of the design review. An initial meeting was held with the contractor to establish ground rules: i.e., the handling of non-standard parts, Military Specifications, fault location and fault recognition philosophy, and design review data. As a result of this meeting, the contractor, at his own initiative, generated a project data book which contained a set of design standards. Once these ground rules were established, a design approval cycle was formulated. Figure 5 shows this cycle.

The contractor provided the design review package preview which consisted of rough schematics, parts lists, cabinet physical layouts, etc. This enabled the Design Review Engineer to stay with the design as it progressed and saved time in system schedules

since it allowed time for required design corrections.

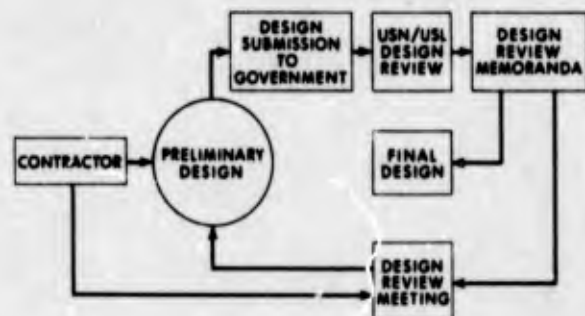
PRE-PRODUCTION TESTING

Design review played a major role in one of the most important areas of the CX program, preproduction testing.

This included the review of all cabinet and system test specifications and the witnessing of these tests on the first preproduction unit. The system tests were in the areas of Reliability/Maintainability/Availability (R/M/A), Environmental, Acoustic, and Electrical Compliance. Since Design Review personnel at USL were intimately familiar with the CX equipment, it was their job to review the test specifications submitted by the contractor in the above areas to witness these tests.

The R/M/A test specifications were reviewed by both the Naval Applied Science Laboratory (NASL) and USL. During these tests, there was a Test Evaluation Board, comprised of representatives from NASL and USL.

The environment tests included such tests as temperature and humidity, salt spray, shock and vibration, audible air-borne noise, etc. Electrical compliance tests were conducted on the CX system to determine if the system met its specification. This test was in essence an in-plant technical evaluation. The acoustic tests were conducted on a barge to determine, for example, system source levels, receive and transmit beam patterns.



DESIGN REVIEW FLOW CHART

Figure 5

The tests described cover a wide area and require thorough system knowledge of the equipment. Design Review personnel obtained this knowledge through the review of the CX equipment and were thus able to evaluate the test specifications as well as the tests themselves in an objective manner.

ADVANTAGES OF DESIGN REVIEW

Design review can be advantageous to both industry and the government. Some significant consequences of a design review conducted by a contractor are: its management will constantly be kept aware of the status of a project, it aids engineering in identifying design problems at various stages of a design, standards for in-house design are

easily established, and the design will tend to be optimized for cost effectiveness.

A government conducted design review will assure the government that the equipment meets both its contractual requirements and its delivery dates. Some other important benefits to the government are the following: since the equipment has been thoroughly scrutinized, it will be more reliable and easier to maintain; the government is constantly kept aware of any technical problems that the contractor may be having, the review process will train personnel in systems analysis, the personnel associated with the review will be intimately familiar with the equipment and can thus prepare for any major test program.

TORPEDO FIRING
REPORT PROGRAM-
WEAPON SYSTEM
EFFECTIVENESS FACTOR

BY W. H. DYER



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INTRODUCTION

The subject of this paper is the Program and techniques currently in use at the Naval Underwater Weapons Research and Engineering Station (NUWS), under the direction of the Naval Ordnance Systems Command, for assessing the existing effectiveness of underwater weapon systems, and for isolating and correcting system deficiencies by the use of data obtained during Fleet exercises.

First, it should be recognized that the measurements derived from analyses of the results of Fleet firings is not a total system effectiveness measurement within the definition of System Effectiveness. It is, however, a measurement of the effectiveness of the system in accomplishing its mission "Hit and Detonate Against a Target," provided the weapon is fired. It is not a measurement of equipment availability, nor does it measure totally the effectiveness of those systems functions which must be performed to arrive at the decision to fire a weapon. However, it is a real life measurement of one of the primary factors inherent in any integrated measurement of total system effectiveness. We are able to apply this concept of measurement since the commodity, underwater weapon system, we are dealing with, is to be used by the Fleet.

BACKGROUND

The Station NUWS is a component of the Navy Laboratory System and is responsible for a wide variety of efforts associated with the research and development and in-service engineering aspects of underwater weapon systems. It is located in Newport, R. I.

The title of this paper is "Torpedo Weapon Systems."

PROGRAM

Historically, the Program was developed to fulfill a need for systematically using the results of the gross quantity of Fleet exercise data to assess the performance of these systems under actual user conditions. Prior to

the institution of this Program, systematic procedure existed for developing this overall picture. Feedback on the Fleet performance of these systems was accumulated from various sources using a variety of techniques. We did not, however, have one standardized systematic technique for assessing the Fleet effectiveness of these weapon systems, for determining the significance of the deficiencies being encountered, or for weighing the effect of the multiplicity of conditions that play a part in affecting their performance.

The Program provides a systematic procedure for collecting and analyzing the pertinent data accumulated during Fleet firings to provide answers to the following basic questions:

"How well are our systems performing?"

"What are the significant deficiencies?"

"How do conditions, such as environment, target variables, employment decisions, and system configuration, affect system performance?"

The "closed loop" of information within the Program is shown in figure 1.

- A standardized reporting form is issued with each weapon scheduled for firing. This form provides basic identification information as to the configuration of the weapon.
- Information is accumulated during the firing and entered on the reporting form. This data includes information on the environment, target, employment conditions and procedures, and post firing assessment of the exercise.
- The report is returned to the post-firing activity together with the weapon for reduction of data and assessment of material conditions.
- All reports are then forwarded to a centralized agency, NUWS, for analysis and scoring of the individual firing and from the results of all firings; assessment of the overall effectiveness

TORPEDO FIRING REPORT PROGRAM

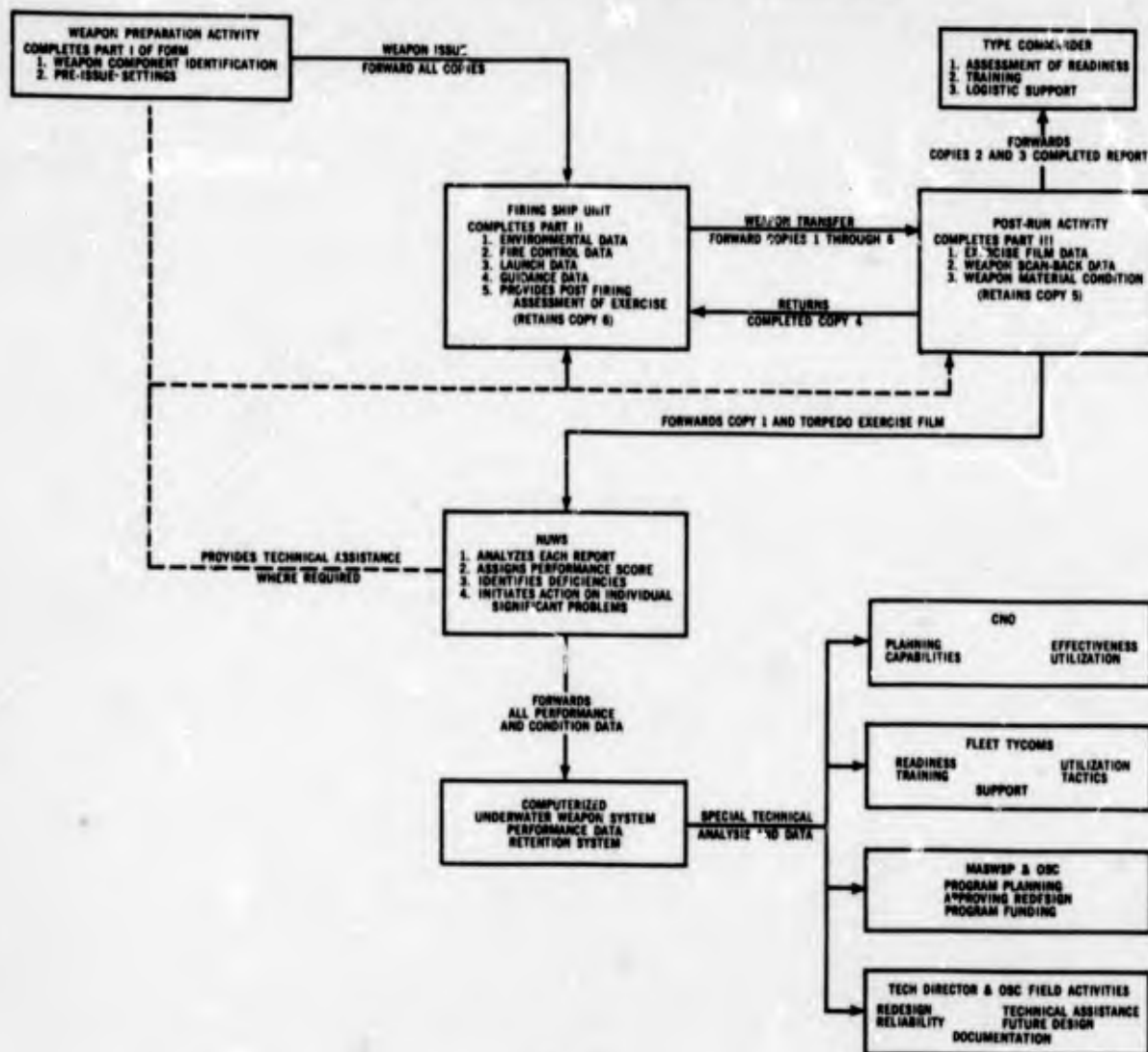


Figure 1

of the weapon system. Where necessary, specific action is taken on individual problems.

- Management products are given to various operational and technical managers to be issued as decision making tools for maintaining or improving the readiness and effectiveness of the weapon system.

Measurement and Analysis Techniques

This presentation describes the techniques used to analyze these data in order to obtain measurements of the effectiveness of the weapon systems and to identify deficiencies and conditions affecting their overall system performance.

Technique

The technique used for measuring the effectiveness of these systems is described below.

First, however, we must establish three basic definitions.

Weapon System Effectiveness Factor (WSEF). This is a measurement of weapon system performance when a command decision to fire a weapon is made. It is expressed as the probability that the system will operate without failure during a mission under Fleet operational conditions. It presupposes that the target has been detected, classified, tracked, and the weapon system has been

brought to the point in the mission where a decision to fire a weapon is made.

Weapon System. The system measured is the combination of integrated equipment necessary to detonate a weapon on the intended target. The weapon system includes the sensors, fire control equipment, launcher, and weapon as well as the personnel responsible for the maintenance, preparation and employment of the equipment.

Mission, defined as the successful completion of all stages of the profile as they pertain to a particular weapon, begins with launch of the weapon and ends with its detonation on the target.

MODEL

The traditional method of modeling for System Effectiveness is to divide the system into discrete hardware elements, then measure effectiveness as the product of separately determined hardware values.

For WSEF, system effectiveness is modelled by dividing the mission profile into distinct functional or performance phases which must be completed in sequence to be successful. Within each stage, the concurrent and interdependent operations of man, machine and environment contribute to the final result. A typical functional mode is shown in figure 2.

The following procedures were used during the development of this model as well as other weapon system functional models:

- The overall system mission was divided into a number of logical stages, each of which was assigned a numerical value.

- These functional stages were arranged into the sequence of normal mission performance. That is to say, they were arranged in such an order that accomplishment of any stage occurred only after a preceding stage had been completed.
- The probability of success of any stage was established as basically independent of all other stages, provided that all prior stages were successful.
- Limits for, and specific criteria to be applied to, each stage were established.

A model of this type allows maximum use of the data obtained during Fleet exercise of these weapon systems, allows better identification of system deficiencies, and most important, relates these deficiencies to the total effectiveness of the weapon systems.

ANALYSIS PROCESSING

The procedures used in developing the system performance measurements follow.

First; the conduct, conditions, and results of each Fleet firing are reported in a systematic manner on a Torpedo Firing Report Form, together with the instrumentation records.

The form provides for:

- The reporting of data associated with the preparation and configuration of the weapon being fired;
- All data associated with the actual firing including: environment, the problem situation, ship configuration, firing techniques, and launching and target data;

WPN. SYSTEM = (Launch) → (PROG. PERF.) → (PLACM.) → (ACQ.) → (ATTACK) → (HIT) → (EXPL. ACT.) → (EXPLOSION)

SYSTEM SUCCESS = $P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6 \times P_7 \times P_8$

Figure 2

ANALYSIS LOGIC FLOW DIAGRAM

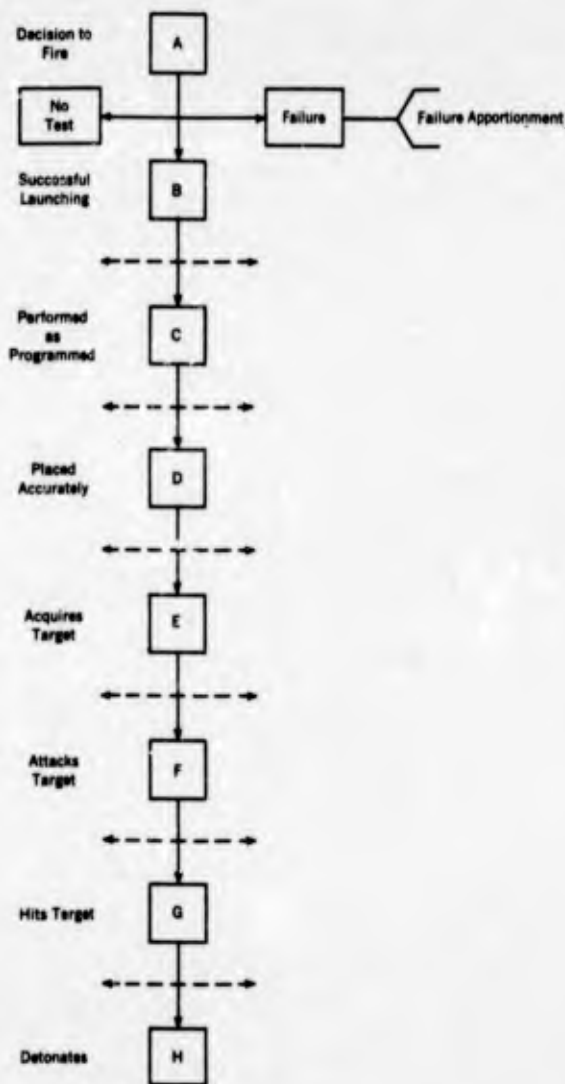


Figure 3

- Torpedo post-run and instrumentation information.

With these data, measurement can be made of the success of the system by the delivery of payload.

Second, total accumulated data on each firing are analyzed and the performance during each mission stage compared with established success criteria. A pass, fail, or no-test score is assigned each performance stage.

Figure 3 is a flow chart that illustrates the basic logic applied to each firing. System operation, which is dependent upon the successful completion of the preceding mission stage,

is subjected to the success criteria of the following stage. If the system does not satisfy the requirements for this stage, it is assigned a failure or no-test score.

No-test scores are assigned only when insufficient information is available to determine whether the performance did or did not satisfy the pertinent success criteria, or, when failure to achieve success is related to features that are peculiar strictly to the exercise configuration of the system. To ensure that optimistic bias is not introduced, all firings which do not meet the objective of the firing exercise are assigned a failure at the most appropriate stage, based on the best available information and independent of whether the cause or deficiency can be identified.

The summation of scores from the individual analyses is expressed:

$$\text{SUMMATION} = \frac{\text{SUCCESSES}}{\text{OPPORTUNITIES}}$$

where OPPORTUNITIES = number of SUCCESSES + number of FAILURES.

This is the best estimate of effectiveness for each stage and is interpreted as a probability of success (Probability Factor P) for that stage provided the previous stage was successful. The WSEF for a particular system is, then, the product of all the individual Probability Factors that apply.

FAILURE APPORTIONMENT

In order to obtain concrete benefits from any program of this type, it is necessary to use the available information not only to measure the performance of the system, but also to identify and isolate deficiencies that are degrading system effectiveness.

To reach this objective, each firing that does not successfully achieve its goal, is subjected to a failure apportionment procedure related to that phase of the mission where the failure occurred.

To maximize use of the information (recognizing that not every unsuccessful firing can be associated with a particular cause),

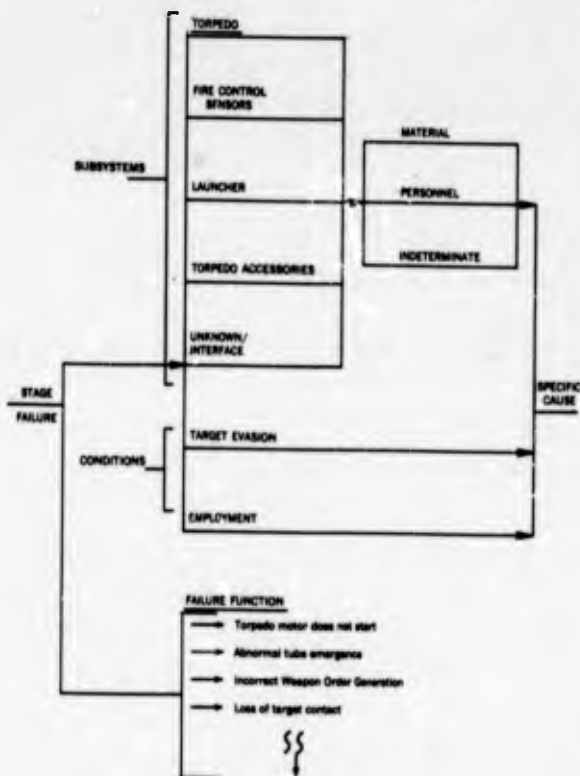


Figure 4

failure identification is categorized as shown in figure 4.

Each unsuccessful event is identified with the major subsystem or firing condition ascertained to be the primary cause of failure.

Independent of subsystem failure, assignment is made to a particular failure function category, i.e., within a predefined listing of independent major system functions that must occur for successful completion of the mission.

This permits failure identification by two distinct, supplementary procedures.

Depending upon the availability and accuracy of the information obtained on the firing event, failures are further classified to designate the material or people effect, and the specific failure cause. This failure apportionment technique has proven to be the best practical method for identifying deficiencies and weighing their impact on the overall effectiveness of the system.

DATA PROCESSING

All data associated with the reported firings: the event data, the performance (or

scoring) data, and the failure apportionment data, are stored and processed by automatic data processing equipment.

These data are then subjected to periodic and demand analysis to meet the basic purpose and intent of the Program.

PROGRAM PURPOSE

Programs of this type are merely academic exercises if there is not a basic need for, and use made of, the results.

The basic intent of this Program is to provide:

- A continuous assessment of the performance effectiveness of current underwater weapon systems, and
- Positive identification of deficiencies and their impact on the weapon system effectiveness.

WEAPON SYSTEM EFFECTIVENESS FACTOR PROFILE CHART
TORPEDO MK7 MOD71

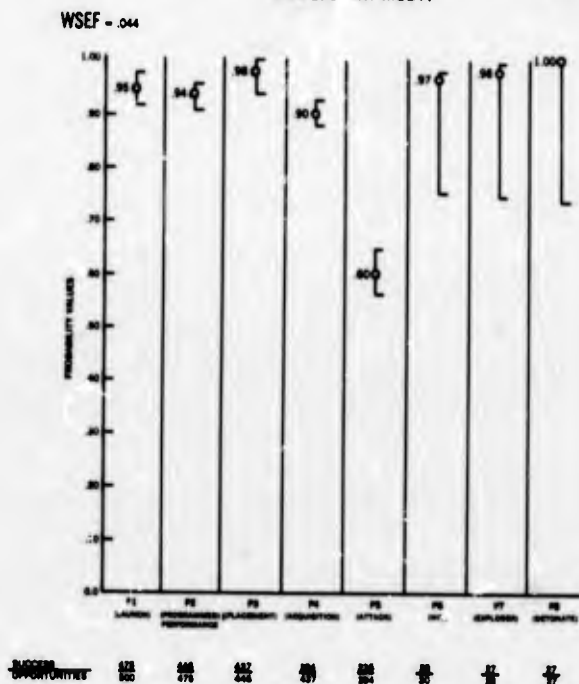


Figure 5

A typical output of this Program is a WSEF profile, figure 5, which provides:

- A current indication of the effectiveness of this system for the conditions under which the reported firings were conducted ("44").
- A measure of the performance of the weapon system in each stage of its mission profile.

- Rapid identification of the factors contributing to an unsatisfactory WSEF to point out areas where resolution of deficiencies would be most beneficial. In this case, P₆, Attack Stage, is clearly shown to be an area of concern, and by supplementing this Profile Chart with the failure apportionment data, a direct relationship can be shown between a particular deficiency and the overall effectiveness of the system.

In this manner, material and operational managers are equipped with tools for effective execution of their responsibilities for underwater weapon systems.

As previously stated, the Program is responsive to, and provides technical analyses and information for, various operational and technical levels of management.

Again, it must be emphasized that programs of this type are justified only if they provide concrete benefits.

They provide a necessary tool for day-to-day management in all facets of underwater weapon systems programs. Some specific examples of management decisions in which results of this Program were used during the decision making process are the following:

- Decision to remove a particular weapon capability from a certain class of ships, and emphasize the use of alternate weapon systems. This decision was based on the observed lack of effectiveness of this weapon when used by this type of ship.
- Determination of the need for, and the incorporation of, an improved switching device for transmitting weapon orders to the torpedo. Performance indicated that improper transmission of weapon orders was significantly degrading the effectiveness of the system.
- Establishment of improved effectiveness benefits that are achieved when a particular torpedo is employed in multiple units rather than as a single unit,

- Use of torpedo performance information under actual conditions to establish valid design specification reliability requirements for development of a mine vehicle.

These are only some of the many uses to which this Program has been put. These are presented to show that it is an operational and responsive Program which is an integral part of the continuing management of underwater weapon systems.

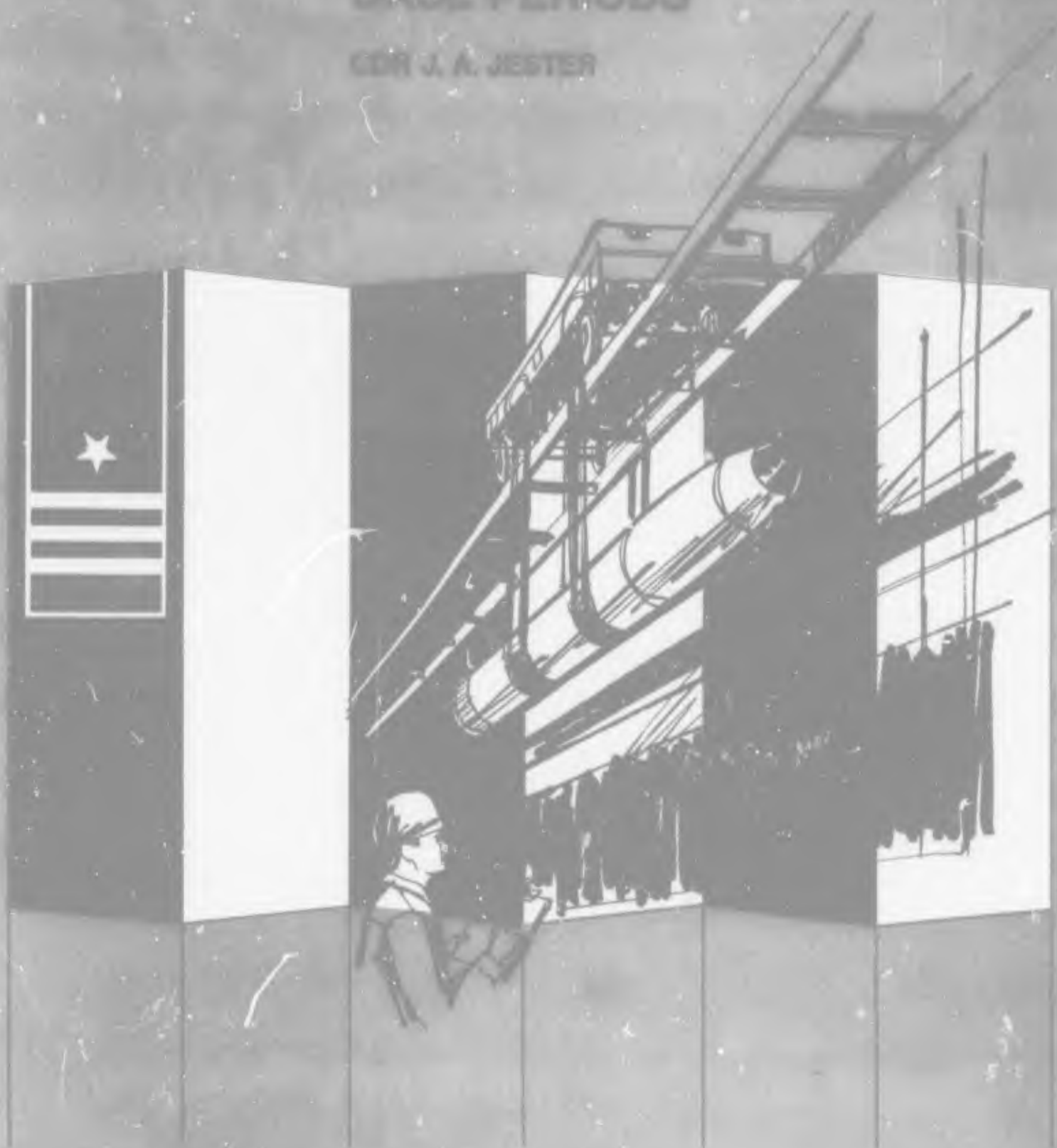
SUMMARY

In summary, this paper has described:

- A continuing Program for assessment of the effectiveness of our underwater weapon systems based on data accumulated during Fleet operations using these systems,
 - Measurement of performance made in terms of a Weapon Systems Effectiveness Factor (WSEF) which is obtained by use of a functional model. Providing for positive identification of factors in relation to their contribution to the effectiveness of that portion of the overall weapon system mission which we are measuring, and
 - A technique that provides a real life measurement of the performance effectiveness of underwater weapon systems. It has become an integral tool of day-to-day management by maintaining or improving the readiness of these systems.
- and incorporation of this concept in Fleet tactical procedures.
- Determination that incorporation of a recommended major redesign in one of our existing weapons would not materially improve the effectiveness of the system, and, therefore, could not be justified on a cost effectiveness basis. The effectiveness of the system was not particularly sensitive to deficiencies in the particular functional area the proposed redesign was intended for.

PRODUCTION OF
QUALITY AMMUNITION
DURING ACCELERATING
MANUFACTURE AND
BROADENING PRODUCTION
BASE PERIODS

CDR J. A. JESTER



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The subject of this paper covers the production of quality ammunition during accelerating manufacture and broadening production base periods.

The Commander, Naval Ordnance Systems Command, a Systems Commander under the Chief of Naval Material, is responsible for the technical management of ammunition. Technical management is defined as management and direction of all effort concerned with advanced and engineering development, procurement, production, technical evaluation and basic in-service engineering support functions associated with navy ammunition. Commander, Naval Ordnance Systems Command has delegated procurement authority to the Ships Parts Control Center (SPCC), Mechanicsburg, Pennsylvania. SPCC is a field activity under the administrative management control of Commander, Naval Supply Systems Command who is also a Systems Commander under the Chief of Naval Material. Additionally, SPCC has the responsibility for inventory management of navy ammunition. Inventory management is defined as "that phase of military logistics which controls the input, availability and disposal of material in the Naval Establishment."

Thus, Commander, Naval Ordnance Systems Command designs the item, computes the end round item requirements, budgets for procurement and subsequent maintenance, and directs Ships Parts Control Center to procure the item and perform the inventory management functions until the item is expended to end use or disposed of.

For the sake of precision in this discussion, it is necessary to define what we mean by "navy ammunition." Navy ammunition includes small arms ammunition, from .22 to .50 caliber; 20mm and 40mm machine gun ammunition; 3"/50, 3"/70, 5"/38, 5"/54, 6"/47, 8"/55 and 16"/50 ship gun ammunition; and surface rockets. Of these ammunitions the 5"/38 caliber is quantitatively most popular.

It is germane to the subject to explain the physical configuration of our ammunition. As an example, 5"/38 caliber ship gun ammunition will be discussed. Gun ammunition of 5"/38 caliber is semifixed (the projectile and propelling charge are separate entities). Other types are: fixed ammunition, such as the .30 caliber (the projectile and cartridge form one unit); and bag ammunition, such as that used in the 16"/50 on the USS New Jersey (the charge is bagged in silk and is separate from the projectile). As shown in figure 1, the 5"/38 charge is made up of five major components: the cartridge case; the primer (which initiates the propellant); the propellant itself; a spacer, and a mouth closure plug to seal in the propellant.

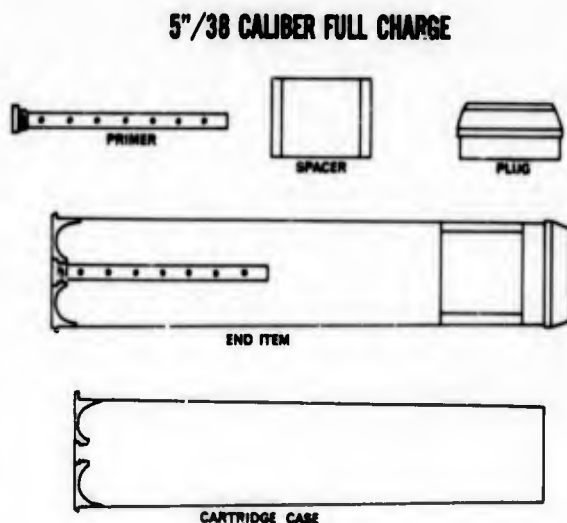


Figure 1

The Navy procures these and similar components from commercial sources. The final assembly and explosive loading of all Navy gun ammunition is accomplished by Navy in-house activities, such as Naval ammunition

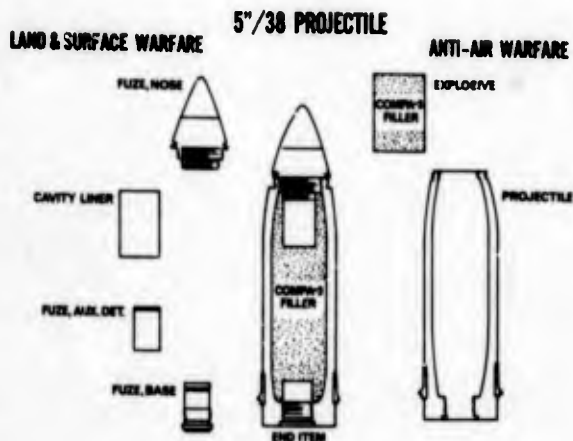


Figure 2

depots. Examining the other half of the round, figure 2 shows the projectile which consists of the following components: a nose fuze; a cavity liner (which separates the fuze from the explosive to allow fuze changes in safety); an auxiliary detonating fuze, a base detonating fuze, and a projectile body and explosive filler. Like the charge, all components are procured from commercial sources and the end round assembly and explosive loading is accomplished at Navy in-house activities.

To present some idea of the magnitude of ammunition management, the ammunition family consists of approximately 5,000 different components assembled and loaded into approximately 1,200 different end rounds. For example, the 5"/38 caliber round can be assembled into a combination of 174 different types of end rounds.

To provide some measure of the magnitude of usage and production, figure 3 shows trends since mid-1965 is in order. From July 1965 until the end of April 1966, when the new Naval Ordnance Systems Command was organized, usage approximately doubled. On a straight line function, it could be forecast that usage would have approximately tripled by the end of 1967. Thus, considering administrative and production lead time, production requirements could be generated. What actually has happened is shown in figure 4. Instead of usage tripling by the end of 1967, it increased approximately seven-fold.

During the same periods, production was rapidly accelerating, and the production base expanded to keep pace with increased expenditures. In June 1965, there were twelve contracts for the production of ammunition components with seven contractors. Today, there are 230 contracts and 27 contractors producing ammunition components.

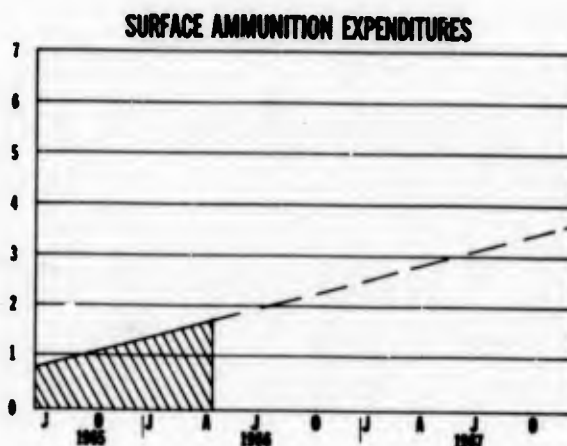


Figure 3

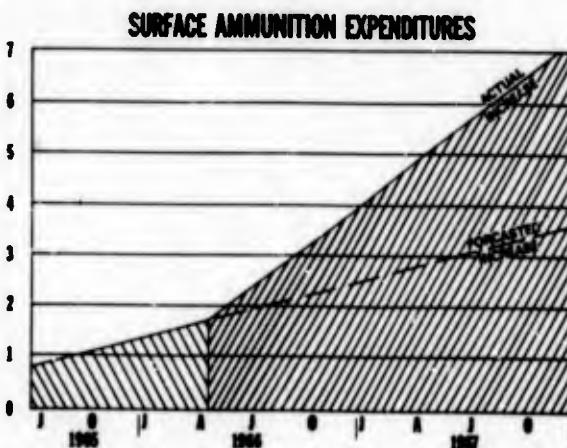


Figure 4

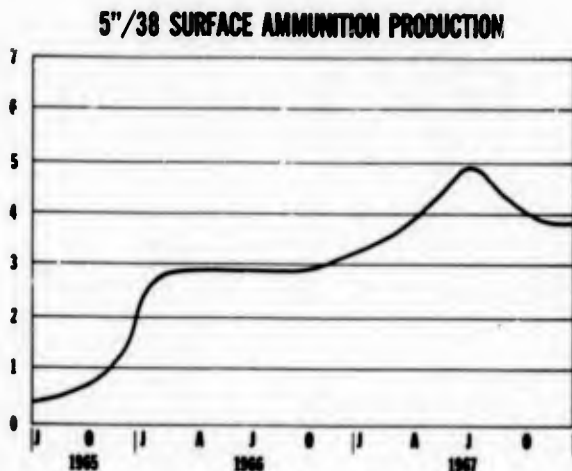


Figure 5

Examining the acceleration in production in the last six months of 1965, figure 5 shows production of that selected item, 5"/38 ammunition, was increased almost six-fold. In 1966, production was leveled off, having met the monthly goal until October 1966; in July 1967, the goal was again increased and exceeded.

Having defined Navy ammunition, and its primary management responsibilities plus the methods for assuring the production of a quality product will now be discussed. Since production acceleration is usually immediate, certain preparatory management actions must have previously taken place. Thus, the discussion progresses from pre-acceleration/production phase effort to actual acceleration and expanded production phase effort.

In the pre-acceleration/production phase, preparations are made for acceleration and expansion by orderly planning and sound engineering and management practices.

First, sound research and development efforts is utilized. This effort is divided into various phases:

Phase I — Basic Research. In this phase, theoretical analysis, exploration, and experimentation without defined goals take place. The aim of this basic research is to demonstrate the feasibility of scientific or engineering development.

Phase II — Exploratory Development. In this phase, various technical approaches are examined, utilizing the media of the Proposed Technical Approach (PTA) document

which defines definitive goals and approaches.

Phase III — Advanced Development. In this phase, the best technical approach is expanded to fruition.

Phase IV — Engineering Development. In this phase, developed state-of-the-art is applied to a particular ammunition end item application. Here, prototype evaluation is conducted and design disclosure documentation is formulated.

Phase V — Operational Evaluation. In this phase, a test of the developed ammunition is conducted under service, or simulated service conditions, to determine as accurately as possible its operational characteristics, its performance, and its utility in military operations. This evaluation is conducted with items which are faithful representatives of those which will result from pilot production.

Phase VI — Release for Procurement. In this phase, the design is officially released for procurement. The release is accompanied by the official release of drawings, specifications, and other documents required for procurement and production. At this point, quality assurance requirements are formally incorporated in the documentation.

Phase VII — Approval for Service Use. In this phase, the item is approved for service use by the Chief of Naval Operations. The approval reflects successful design, operational characteristics, and function. The approval further freezes the operational characteristics and function of the item approved.

Secondly, effective documentation is maintained suitable for immediate procurement and production of all ammunition items in the arsenal. This design disclosure documentation includes:

- Index or list of all drawings and associated media required to successfully produce an ammunition item.

- Drawings required to manufacture the item.

- Specifications and standards for the physical requirements such as materials, finishes, inspection for acceptance and rejection of the product.

● Quality Assurance provisions/classification of defects. (This document provides a classification of defects which may occur in the product, and the criteria for inspection by attributes.

● Technical Manuals including weapon characteristics, instructions for use, and user maintenance.

Thirdly, quality of future production is assured, in part, by quality monitoring of previously manufactured in-service stocks. This monitoring takes place by a quality evaluation program, a periodic quality surveillance of in-store assets, and user performance reporting of ammunition actually fixed.

The quality evaluation program provides for coordinated periodic surveillance of all ammunition by Navy quality evaluation laboratories. Representative samples of identifiable strata of in-stock assets are selected and tested on a periodic basis. The tests are designed to determine quality trends, verify design and shelf life, and determine requirements for renovation and overhaul. Tests are conducted within clearly defined test specifications and requirements in a laboratory atmosphere.

Reports of operational use of ammunition by Naval operating forces provide us with the second part of our input to the quality evaluation program. These reports detail the type and quality of ammunition fired and its performance.

Based on all data accumulated, the coordinating Navy quality evaluation laboratories publish summary reports which include appropriate test results, conclusions, recommendations, and estimates of the reliability of the item tested. Reliability estimates are based on total surveillance information including the applicable firing reports.

The Naval Ordnance Systems Command reviews the submitted reports and directs appropriate service reclassification of assets, renovation and rework, and future design changes to enhance reliability and shelf life.

Lastly, in the pre-acceleration/production phase, we maintain a capability for orderly rapid expansion of the production base by

means of standby government facilities and equipment.

Our standby facilities are in two forms: government owned/government operated, and government owned/contractor operated. In the former category, we maintain a standby capability for end item loading and assembly in all of our Naval ammunition depots. Although the depot is an active activity prior to the expansion phase, the specific load and assembly capability may be in standby. For example, NAD St. Juliens Creek, Virginia, has recently begun the loading and assembly of gun ammunition after a decade in standby. In the case of government owned/contractor operated facilities, sophisticated, costly, and difficult to acquire facilities and equipment are maintained in a standby status. In all cases, these facilities have been production proven. For example, a cartridge case manufacturing facility is maintained at Riverbank, California, which Norris Industries is contracted to operate. Additionally, sophisticated fuze manufacturing facilities are maintained at Rochester, New York, under contract with Eastman Kodak Company.

Finally the Navy has established and maintains certain specialized equipment packages (fixtures and gages) in government custody for future selected manufacturer's use.

To most effectively carry out the functions just described, there exists an ammunition management and engineering team.

The ammunition manager, located at Headquarters, Naval Ordnance Systems Command is responsible for all management and engineering facets of the weapon including: advanced and engineering development, technical evaluation, approval for service use, release to production, procurement, production, production quality assurance, in service engineering, and asset quality surveillance and evaluation.

To assist the ammunition system manager, and to make maximum use of field commands and personnel versed in sophisticated arts and skills, certain management and engineering functions — have been delegated. This management engineering team,

under the ammunition manager's guidance, performs its functions during the life cycle of the weapon.

In the pre-acceleration production phase, the primary contributors to the maintenance of future quality production are:

The design disclosure agent whose functions are:

- Translating design concepts into detailed design from which reliable, economical, and operationally effective ammunition can be reproduced.
- Modifying existing ammunition design where such modifications affect coordination, life, interchangeability functions, or safety.
- Continuous monitoring of existing ammunition design in the light of state-of-the-ammunition-art with a view toward functional improvement, performance reliability, and safety.

The design disclosure documentation agent whose functions are:

- Maintaining custody and maintenance of master design disclosure documentation consisting of drawing, specifications, standards, ordnance data and quality assurance requirements.
- Correcting the documentation as directed by the design agent.
- Issuing design change documentation to all interested parties.
- Providing up to date design disclosure documentation to the ammunition procurement agent, (SPCC) Mechanicsburg, Pennsylvania.

The technical manual agent whose functions are:

- Managing and improving the use of operation and maintenance manuals.
- Coordinating technical content with the design agent and in-service engineering agent.

The in-service engineering agent whose functions are:

- Providing centralized in-service engineering support to the user to ensure that the ammunition in service is suitable.
- Working with the user in the investigation and correction of malfunctions

and deficiencies which arise during service use.

The quality assurance agent whose functions in the pre-production phase are:

- Reviewing the development and design to ensure preparation and inclusion of essential quality documentation in specifications and standards.
- Developing and maintaining documented quality assurance plans, inspection procedures, classification of defects, and product verification inspection.

The quality evaluation agent whose functions are:

- Developing and applying quality evaluation methods, procedures, and equipment for special surveillance of ammunition assets, performance evaluation, and reliability of ammunition assets.
- Collecting, collating and disseminating quality evaluation information and recommendations to all interested parties.

The following will cover the method of maintaining quality of ammunition during actual acceleration and expansion of the production base.

With prior planning and preparedness actions achieved the next step is to execute and act, reduce administrative lead time and devote maximum effort to quality accelerated production. Standby facilities and equipments are activated as necessary. Streamlined contracting procedures (under exception 16 to the armed services procurement regulations) are utilized, and a contractor is tentatively selected.

First, a pre-award survey is conducted to ensure that the nominee is financially solvent; that he has proper production facilities, equipment, personnel, and the expertise to produce the product under a sound quality assurance program.

Having qualified the nominee, a contract is awarded. The contract demands compliance with the quality program or inspection system requirements of MIL-Q-9859, MIL-I-45208, or similar requirements. Compliance

is assured through the services of the Defense Contract Administration Service (DCAS). At contract award, the quality assurance agent, previously described, provides DCAS with class A mandatory inspection requirements. These are for DCAS inspections and are in addition to contractor inspection requirements.

After contract award, a conference is normally held with all interested parties to ensure that the contractor is fully cognizant of all requirements, and to provide any assistance required in the pre-production phase.

To further ensure quality, the contractor is required to produce a pre-production sample/lot of the product representing the articles to be produced. This sample is tested for quality, adherence to specification and drawings, and function. After acceptance of the pre-production sample, the contractor is released to production, with the provision that any significant changes in processes or material would mean requalification.

Maintaining quality control during manufacture is accomplished in several ways. Product identification is assured through the use of a lot control system. Each individual lot is required to pass lot acceptance tests. A representative sample of the lot is randomly selected by the government inspector in accordance with MIL-STD-105D, or other specified sampling plans and tables for inspection by attributes. The sample is tested in accordance with the established test procedure for that product to ensure adequate safety and proper function. Failure of the sample tested is grounds for lot rejection.

In addition to the lot sample tests, the Navy loading and assembly depot sees that all components assembled in end item rounds meet design specifications and have not been damaged in transit. Incoming material is examined in accordance with special sampling techniques. Material found to be discrepant will not be utilized.

Having ascertained that components are suitable for assembly, the end round is assembled and loaded. All assembly and loading is accomplished in accordance with strict assembly and loading specification, Standard Operating Procedures, (SOPS) which ensure

uniform assembly and loading as well as strict adherence to safety requirements. These specifications assist in maintaining uniformity and quality of the end product assembled by different activities.

Material identification of assembled end rounds is assured by a lot control system. The lot control system identifies the material, assembly and loading activity, lot number and year of manufacture. Lot numbering is on a calendar year basis.

Although the majority of the various types of ammunition are not acceptance tested, certain more sophisticated types are tested. All illuminating projectiles, which have pyrotechnic candles and parachute assemblies, and marking projectiles, which have white phosphorus canister loads, are lot acceptance functionally tested by means of randomly selected samples.

Again, as in the pre-acceleration/production phase, the ammunition management and engineering team provides the skills to implement quality control during the acceleration and production expansion phase. The weapons manager, design disclosure agent, and quality assurance agent ensure that quality ammunition is delivered to the fleet by closely scrutinizing component manufacturer performance, quality control, control of design changes, and by monitoring the Naval Ammunition Depots' assembly, loading operation, and general performance.

In summary, the proof of satisfactory quality is functional performance of the material in question. The Naval Ordnance Systems Command is proud of the performance record of its ammunition. Examining the performance effectiveness of the various 5"/38 caliber ammunition components manufactured as early as 1952, the following percentages of operability is found:

5"/38 Projectile	
Nose Fuze	99.4%
Auxiliary Detonating Fuze	98.1%
Projectile Body	99.6%
Base Detonating Fuze	99.8%
5"/38 Cartridge	
Cartridge Case	99.3%
Primer	99.9%
Mouth Closure Plug	100%

Thus it may be assumed that total end round performance effectiveness approximates 96%.

In conclusion, the problem of providing sufficient quantities of quality ammunition to the fighting fleet is not unique to our time, for in 1588, the Lord High Admiral of England sent the following message to the Secre-

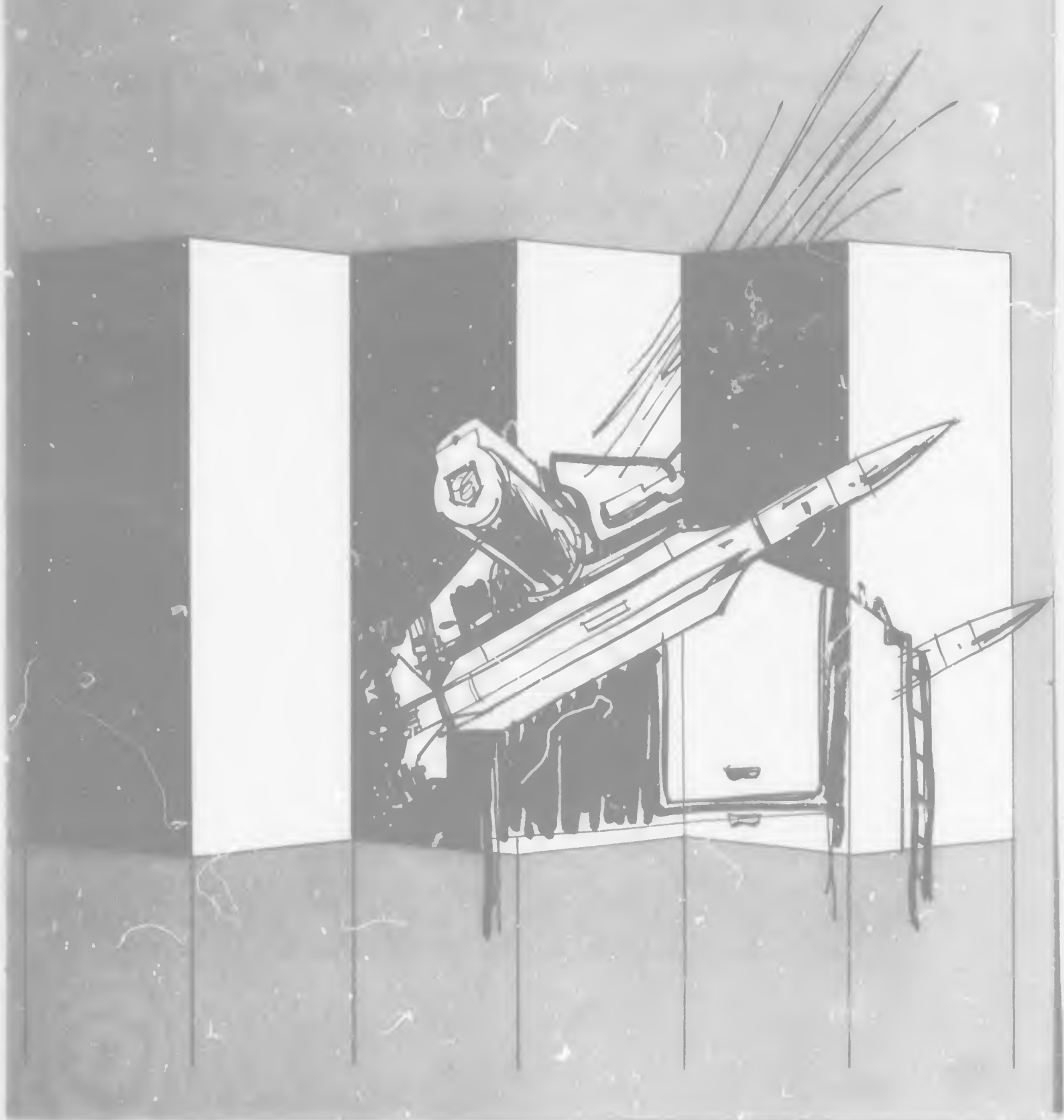
tary of State:

"Sir, for the love of God and our country, let us have with some speed, some great shot sent to us of all bigness for this service will continue long; and some powder with it."

Although we haven't received such a message we believe we have profited from past history and experience.

SURFACE LAUNCHED GUIDED MISSILE NO-TEST PROGRAM

MR. J. F. JACOBS



GENERAL

TARTAR missiles are surface-launched guided missiles fired by certain destroyers and cruisers. On board ship, they are stored on end in temperature controlled circular magazines. Directly above the magazines, and exposed to the elements, are the missile launchers which are either dual or single arm, depending on the class of the ship.

SHIPBOARD NO-TEST PROGRAM

The TARTAR Shipboard No-test Program is officially listed as the Improved TARTAR Missiles Technical Evaluation Project (BUWEPS SMS Test 1-64). This program was proposed in 1962 by the Fleet Missile Systems Analysis and Evaluation Group (FMSAEG) after an extended period of experience with missile test results. The study disclosed the possibility that testing aboard the combatant ships was wearing out the missiles. In addition, testing on board exposed missiles to variations in temperature and salt spray. It was proposed that missiles could remain on Naval vessels without further shipboard testing, in a high state of readiness for relatively long periods of time if certain improvements were to be made at the depots during assembly and test procedure.

The TARTAR Shipboard No-test Program, sponsored by the Bureau of Naval Weapons, was started in October 1963 with the endorsement of the Chief of Naval Operations and under the technical direction of FMSAEG.

Prior to the beginning of this program, missiles containing warheads were tested only on board ship. Now the missiles in the program were to be issued completely assembled and ready to be fired. This is commonly referred to as the "Wooden Round" concept. Certain additional facilities were required at the depots so that the proper safety precautions could be taken during the tests of completely assembled missiles.

The successful application of this concept

required missile assembly inspection in accordance with the Quality Assurance Provisions (QAP). For the first time, quality assurance measures were introduced into the missile area. This work was done by the Naval Weapons Station (NWS), Concord, where all the missiles for Phase I of the program were processed, and identified as missiles certified for BUWEPS SMS Test 1-64.

Qualifications for missile certification are as follows:

- All processing and issuance must be in accordance with the requirements of the TARTAR No-test Program.

- The processing depot must be qualified through a quality assurance audit.

- Each major missile assembly and testing operation must be verified by a QA representative.

Phase I

Phase I of the program was primarily a comparison of the operational readiness of shipboard-tested and untested missiles. Approximately half of the Improved TARTAR (IT) missiles aboard each ship were tested periodically during the ship's deployment period.

Four guided missile ships were used in Phase I. They were: USS COLUMBUS (CG-12), USS TOWERS (DDG-9), USS BUCHANAN (DDG-14), and USS BERKELEY (DDG-15).

The objectives of Phase I were:

1. To determine the feasibility of maintaining IT missiles in a flight-ready condition aboard ship without further maintenance and testing.

2. To test the hypothesis: shipboard no-test missiles are as good as, or better than, test missiles.

3. To evaluate the concept of testing completely assembled missiles prior to fleet issue.

With the outstanding cooperation of the personnel aboard COLUMBUS, TOWERS, BUCHANAN, BERKELEY, NWS CONCORD, and many other Naval activities, the

first phase was completed. From the results of Phase I, it was determined that:

1. The hypothesis: shipboard no-test missiles are as good as, or better than, test missiles, could not be rejected.

2. Design and workmanship problems could be uncovered and resolved; for example — (A) A different method of applying epoxy to one of the circuit boards eliminated stress on a component lead that was causing an intermittent open circuit. (B) Reduction in the filament current of a particular tube type eliminated its failure.

3. Periodic shipboard visual inspection of missiles can reveal many potential problems such as hydraulic leakage.

4. The concept of testing completely assembled missiles at the depot is practicable and desirable.

5. Undue exposure of shipboard stored missiles to the elements can be avoided.

Phase II

Based on the success of Phase I, the implementation of Phase II was approved. Phase II was the evaluation of the results of fired certified missiles, both shipboard no-test and test.

NWS CONCORD, having been qualified during Phase I, began issuing Phase II certified missiles in May 1964. Subsequently, NWS YORKTOWN, CHARLESTON, and SEAL BEACH were qualified, enabling most of the TARTAR guided missile ships to participate in Phase II.

The objectives of Phase II were:

1. To test the hypothesis: shipboard no-test missile firing results are as good as, or better than, those of the test missiles.

2. To evaluate the effects of improved and standardized depot operating procedures.

3. To obtain data for future logistics planning.

A statistical sequential test plan was used to compare the firing results of the no-test and test categories. The upper and lower limits for the comparisons were based on the results of IT missiles fired during the calendar year 1963.

FINAL REPORT

The final report for The TARTAR Shipboard No-test Program was released in June 1966. The conclusions reached were:

1. There is no statistically significant dif-

ference between the operational readiness of shipboard no-test and test IT missiles. The data included the firing results of over 200 missiles.

2. As a result of the Shipboard No-test Program, and standardization of depot operating procedures developed during the program, the Fleet receives better missiles than were previously available.

3. The workload of the ship's personnel is significantly reduced.

Recommendations in the final report were:

1. All shipboard testing of IT missiles should be suspended.

2. Shipboard requirements for IT missile test equipment should be deleted.

3. The certification period for IT missiles would be 24 months.

RESULTING ACTIONS

The following actions were initiated as a result of the TARTAR Shipboard No-test Program:

1. NAVORD Instruction 08821.1, issued 3 February 1967, stated that TARTAR missiles will not be checked aboard ship.

2. On 21 February 1967, NAVORD Project Manager, Surface Missile Systems, requested Chief of Naval Operations to delete the requirement for the AN/DSM 55 on board TARTAR test equipment.

3. On 8 March 1967, Chief of Naval Operations cancelled the requirement for the test sets aboard TARTAR ships.

Additional Advantages Gained:

1. Reduction in technical training requirements for shipboard personnel.

2. Reduction in number of personnel requiring AN/DSM-55 training (NWS only).

3. Cancellation of AN/DSM-55 Refurbishment Program.

4. Elimination of logistic support for the shipboard test equipment.

5. Considerable savings in the TERRIER Guided Missile Test Set Refurbishment Program because of test equipment similarity. TARTAR test equipment components and repair parts would be available for repair of TERRIER test equipment.

6. Reduction in logistic missile support—none required by the ships.

The TARTAR Shipboard No-test Program is a big success both militarily and logistically.

AN ANALYSIS OF QUANTITATIVE MAINTAINABILITY CHARACTERISTICS OF A WEAPONS SYSTEM TRAINER

MR. M. P. GERRITY



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Systems Effectiveness is a composite evaluation of hardware from many different viewpoints. This paper will discuss some of the methods and techniques available to improve the availability component of systems effectiveness from the maintenance engineer's viewpoint. The area of interest is therefore in the maintainability characteristics of the hardware.

For a long time, qualitative features have been designed into Navy equipment to improve maintainability: modular construction, roll-out shelves, and fasteners with quick-disconnect features, are some common examples. This qualitative approach alone, however, discloses nothing other than the fact

that the maintenance man's tasks have been facilitated. It is not known how much—and how effectively because a “yardstick” is not available to measure progress. This can be done, however, by putting in the qualitative design features, and putting numbers on them in accordance with MIL-HDBK-472 techniques. Next, a test would be made to see whether the estimated values are valid. When they are, they can be reused with confidence. When they prove invalid, then we will know where to improve upon our efforts in the future. In essence, through quantitative maintainability analysis, we can pinpoint how and where to progressively improve equipment design.

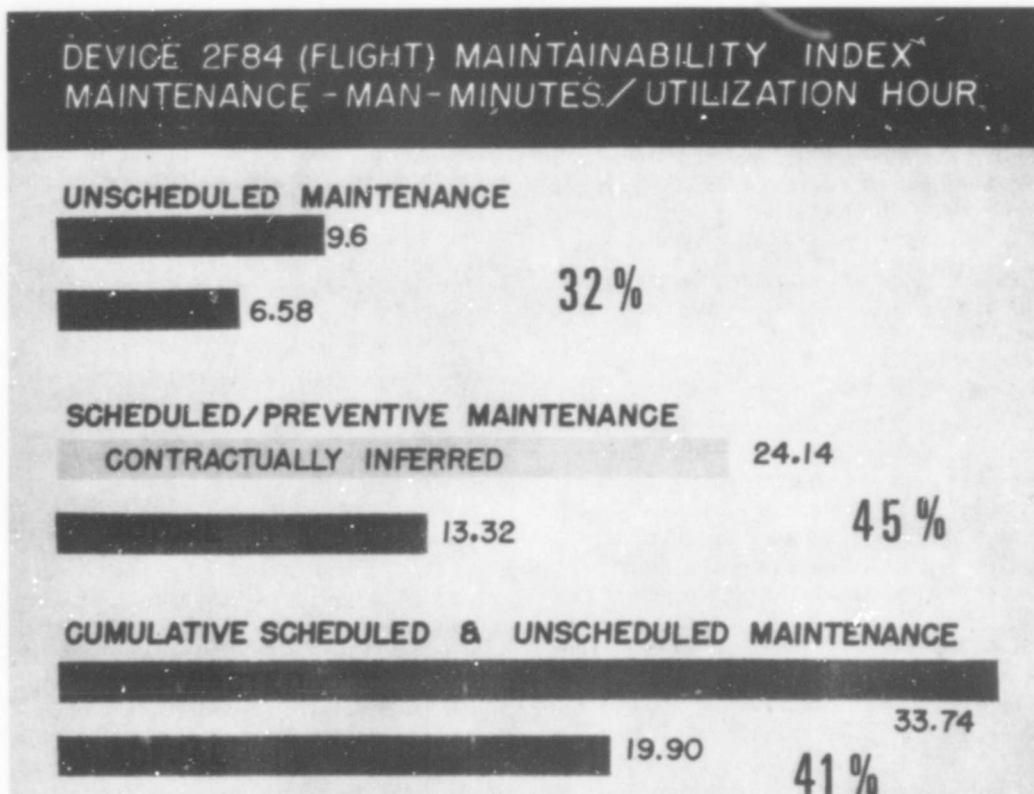


Figure 1

Equipment availability can be improved through quantitative maintainability analysis. The illustrative data used is from the first Training Device Maintainability Demonstration test, completed nine months ago. It ran for 61 consecutively scheduled utilization days, using the normal utilization environment with no simulated failures. Navy TRADEVMEN (TDs) performed all of the maintenance. Two NAVTRADEVCON and two contractor representatives witnessed the test and recorded the data. Contractually, a maximum fixed number of Maintenance Man Minutes (MMM) was specified to keep the trainer operational for each hour it was utilized. MMM is the product of the number of TDs performing a task, and the clock minutes required to perform it. Two TDs performing a task, 15 minutes long, is 2×15 or 30 MMM. The contractual results are shown in figure 1.

(1) The Unscheduled Maintenance limit shown at the top, was 9.6 Maintenance Man minutes per Utilization Hour (MMM/UH). The actual required effort was only 6.58; an improvement of 32 percent.

(2) The other contracted value, shown at the bottom, was for the combined scheduled and unscheduled effort not to exceed 33.74 MMM/UH. The actual effort required was 19.9; an improvement of 41 percent.

(3) By the two contracted values, it was inferred that scheduled maintenance alone would be 24.14 MMM/UH. The actual results here were 13.32 MMM, an improvement of 45 percent under the inferred limit.

This quantitative performance parameter, however, only discloses the man-effort required to keep the equipment operational on an overall basis. This data alone does not tell how to specifically improve upon this effort, but, the wealth of data collected, during the demonstration, does permit performance of a more in-depth analysis of the device maintainability beyond that required by the contract. Parenthetically, this extended approach is the type employed as the basis for demonstrations in accordance with MIL-STD-471.

First, the Scheduled Preventive Maintenance effort: the data was separated into

the daily checks and other Preventive Maintenance (PM) efforts. The histogram of the daily check distribution by quarter-hour intervals is shown in figure 2. Both the actual clock time, and the maintainability index expressed here in Maintenance Man Hours (MMH), are equally distributed about the half-hr. point. From this, it is known that the average daily check is a half hour long, requiring one TD to perform it.

The other PM efforts are shown in figure 3. Numerically, the 50 percent middle-point in the elapsed clock distribution is again half an hour, or actually 33 minutes. The Maintainability Index mid-point occurs at three-quarters of a manhour; this indicates the use of $1\frac{1}{2}$ TDs in the average PM task.

Next, arithmetically averaging all the tasks, a mean value was calculated of 63 clock minutes and 100 MMM. This indicates the usage of $1\frac{2}{3}$ TDs in a PM task. Finally, an average of all the discrete tasks shown over the test period, yields an activity rate of one PM action for each 11 hours of utilization. These three pieces of information, plus the daily check, permit description of the average PM scheduled effort as follows:

A half hour daily check, using one TD, followed by an overall average of one hour PM required the availability of two TDs for each eleven hours of utilization. However, the actual PM task times stray from this average extensively as is shown in figure 3. Further evaluation of the PM data highlighted the fact that there are actually two types of PM tasks. The first type is the predetermined scheduled tasks such as cleaning and lubricating. This type of task effort can be easily controlled by hardware selection in the equipment design.

The second type of PM task is actually a non-critical corrective maintenance type action. These tasks are generated by the early detection of deteriorating equipment performance, while the equipment is still within acceptable operating tolerances. Examples of such tasks are recalibrations, and tune-ups which are done as time permits to avoid interruption of satisfactory operation. This second type of PM task constitutes 66 percent of the total PM effort, and generates a log-normal task time distribution.

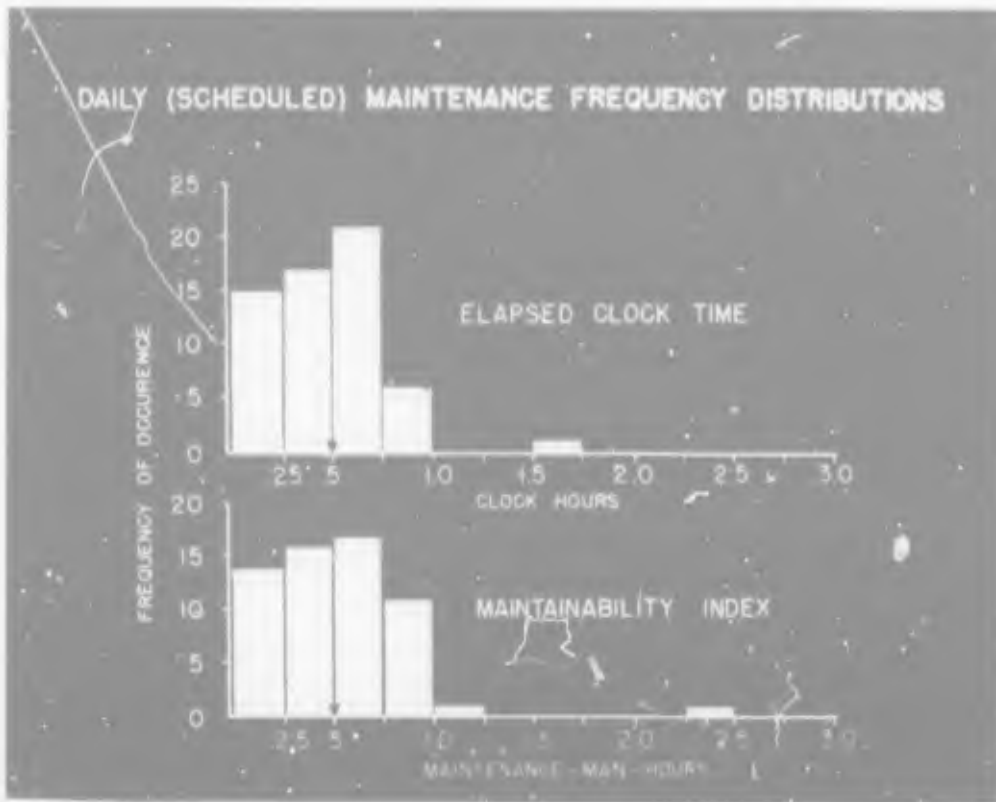
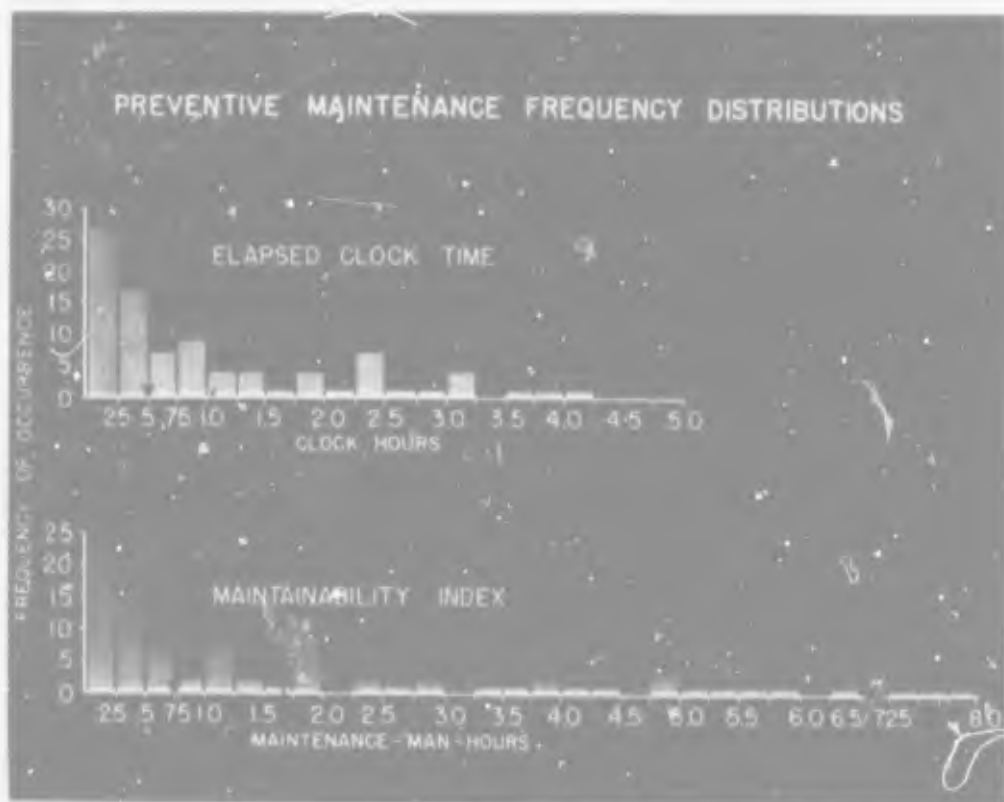


Figure 2

Figure 3



This explains the wide dispersion of task times, and also indicates that PM should be considered as two distinct components; the periodically scheduled tasks, and the randomly generated tasks caused by equipment stability characteristics. PM, therefore, reduces equipment availability because of two design factors: specific selections, and the operating stability of the equipment. The design of equipment for maximum availability and/or minimum preventive maintenance must not only include the judicious selection of components to "design-out" the scheduled maintenance tasks, but must also place a great emphasis on the operating stability of the equipment. The lack of the second type of PM will inevitably transfer the task to a corrective maintenance effort as acceptable operating tolerances are exceeded.

Next, the unscheduled corrective maintenance effort was analyzed. Thirty-eight in-

dependent corrective maintenance actions were recorded in the three-month test period. Data was again arranged in ascending order by 15-min. intervals and is shown in figure 4.

Once again, the middle 50 percent point was a half hr. elapsed clock time requiring 1½ TDs to perform the task. Further review of the test data yielded a Mean Time Between Repairs (MTBR) of 24.4 hours, which is effectively the field MTBF. From this, the average corrective maintenance effort can be described as follows: one action each 24 utilization hours, normally requiring the availability of 2 TDs for 30 minutes to correct the problem.

A further analysis of the corrective maintenance elapsed clock time data, by its three component parts, followed. Note the form of the elapsed clock time distribution; it is continuous to 1½ hrs. with subsequent discrete

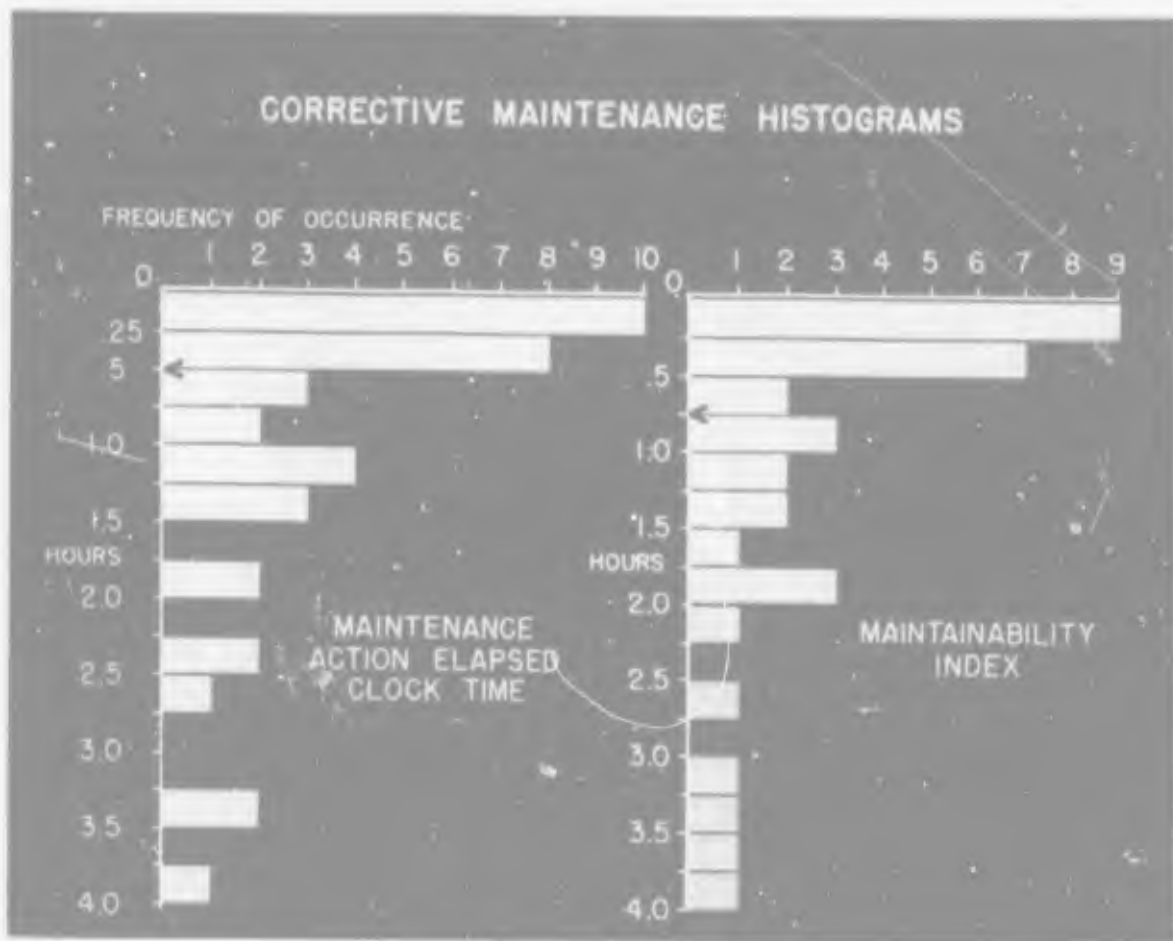


Figure 4

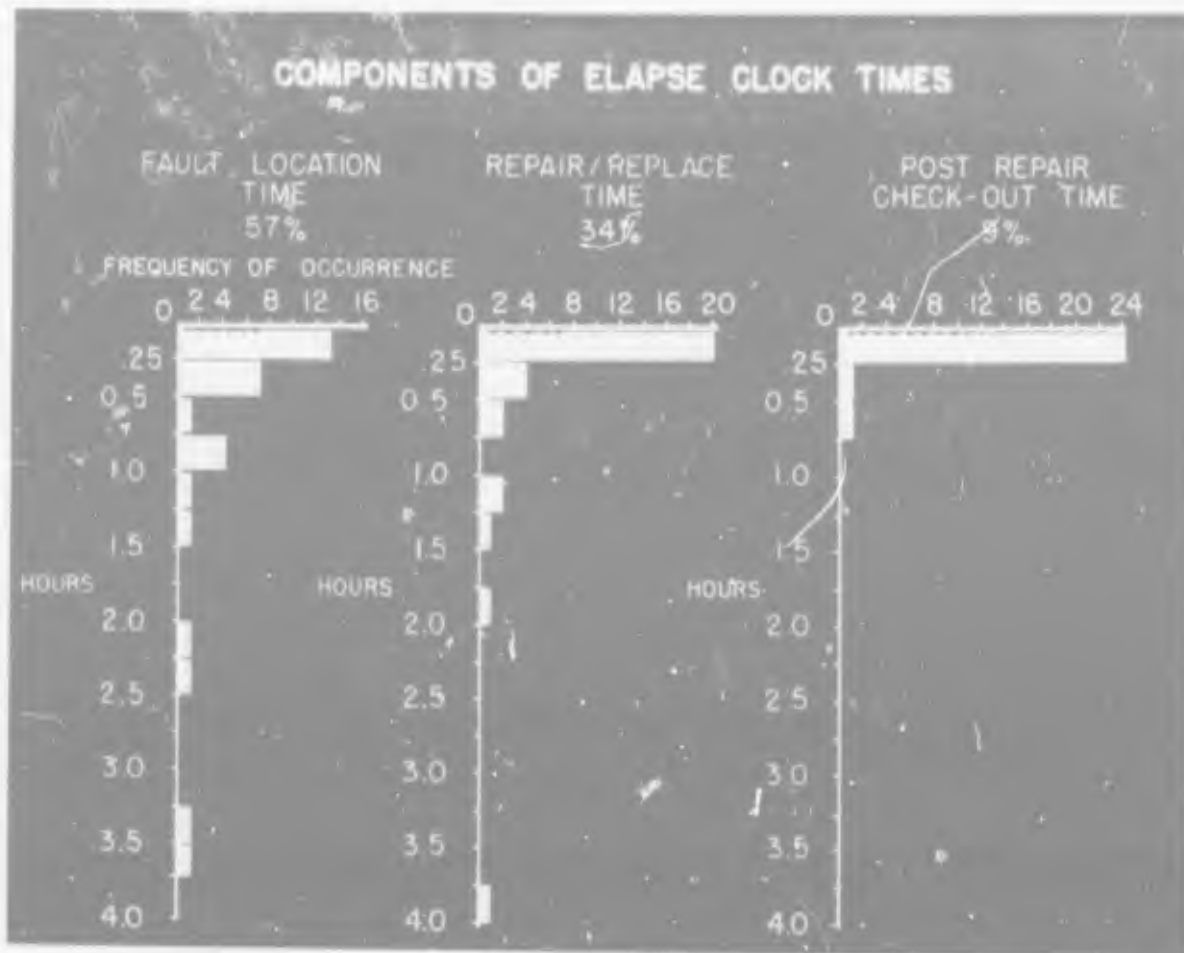
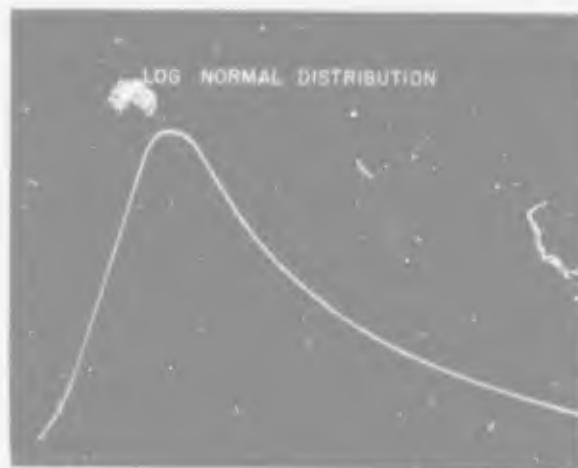


Figure 5

actions to 4 hrs. Figure 5 shows the breakdown of this elapsed clock time by its three components: fault location, repair, and check-out time. Note that the fault location histogram shown at the left closely resembles the overall elapsed clock time histogram. This indicates its importance. 57 percent of the average corrective maintenance action time was spent in locating the fault; 34 percent in effecting the repair, and 9 percent in post repair checkout. This makes a very strong point for automatic fault detection and fault locating equipment in the design of our more sophisticated systems. Inclusion of this type of equipment could immediately cut Corrective Maintenance (CM) time by 50 percent. Additionally, the three plots in figure 5 show that the fault location component constitutes a much higher percentage of the total time for the longer CM tasks than the overall 57 percent average indicates. Therefore, automatic fault detection and locating equipment

would improve the equipment availability by markedly reducing the longer CM task times.

The histograms so far have shown the bulk of data grouped in a low time interval, with less frequent occurrences spreading out over



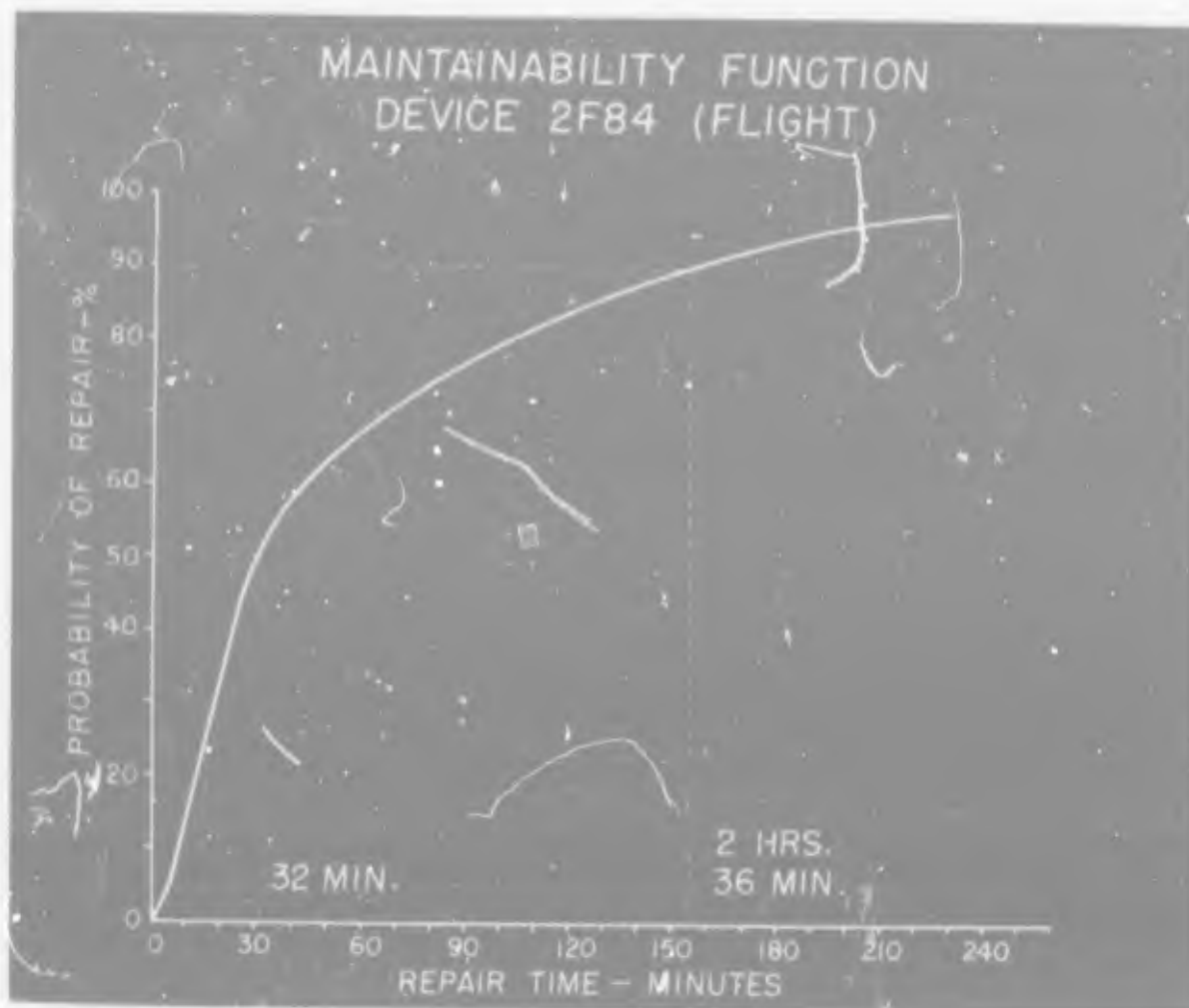


Figure 7

longer time intervals. This is a characteristic distribution of electronic and electromechanical equipment repair known as "The Log - Normal Distribution." Figure 6 shows its characteristic curve. Since the raw data exhibited this distribution, it readily lends itself to a final analysis which is by far the most significant step toward isolating the areas which require an improvement in maintainability efforts.

Taking the sample of CM repairs actually completed, a cumulative probability of accomplishing a repair within, or less than, a given time was plotted. This is the maintainability function shown in figure 7. This curve can be interpreted in two ways: The first is when any fault is detected, there is a 50 percent probability that the repair can be accomplished in 32 minutes or less, and a 90 percent

probability of repair in 2½ hours or less. The second is: of any 100 probable failures, 50 will be repaired in 32 minutes or less, and 90 will be repaired in 2½ hours or less. We are now placing a quantitative value on the down times we can expect to experience. This curve is valid for any percentage, however, its accuracy is subject to the engineer's judgment as to which curve best "fits" the limited number of plotted points, and it tells nothing about the accuracy of the sample data being used for the predictions. To achieve a greater degree of accuracy and confidence, it is necessary to plot original data points on Log-Normal Probability graph paper as shown in figure 8. The paper is preprinted with a log distribution on the abscissa and percent of Normal Probability distributed on the ordinate axis. The points plotted on this preprinted distribution paper should form a

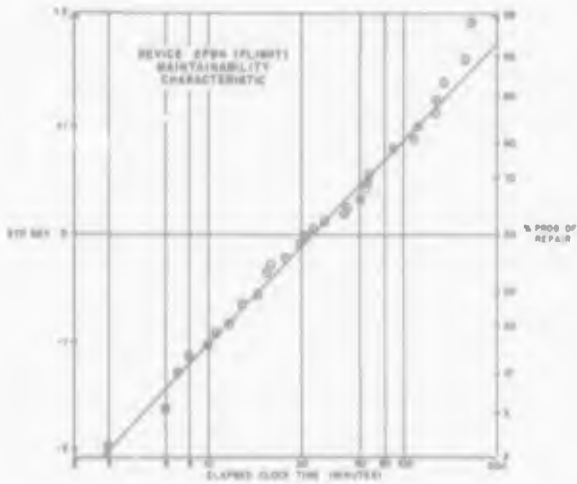


Figure 8

straight line to indicate that the test data has a unity correlation with the log-normal characteristic curve describing electronic equipment repairs. Here the reliability of the data sample is "put to the test." In arbitrarily taking a limited sample from any-

thing, there is always the possibility of selecting pieces of information which may be the actual "oddball" happenings rather than the run-of-the-mill happenings in any particular situation. In the present case, if the plot of the raw data clearly defines a straight line, we know we have collected a representative sample. If not, the data is not totally representative, and the accuracy of any further interpretations is not to be taken too literally. Fortunately, the data samples do sharply indicate a straight line plot as shown in the figure.

At this point, we have a valid sample of the maintainability of the device. Accurate prediction can be attempted of what will occur concerning this equipment's maintenance as justified by the natural law of the Normal Distribution. This straight line plot is called the maintainability characteristic.

Figure 9 illustrates the broad range of knowledge obtained about this equipment.

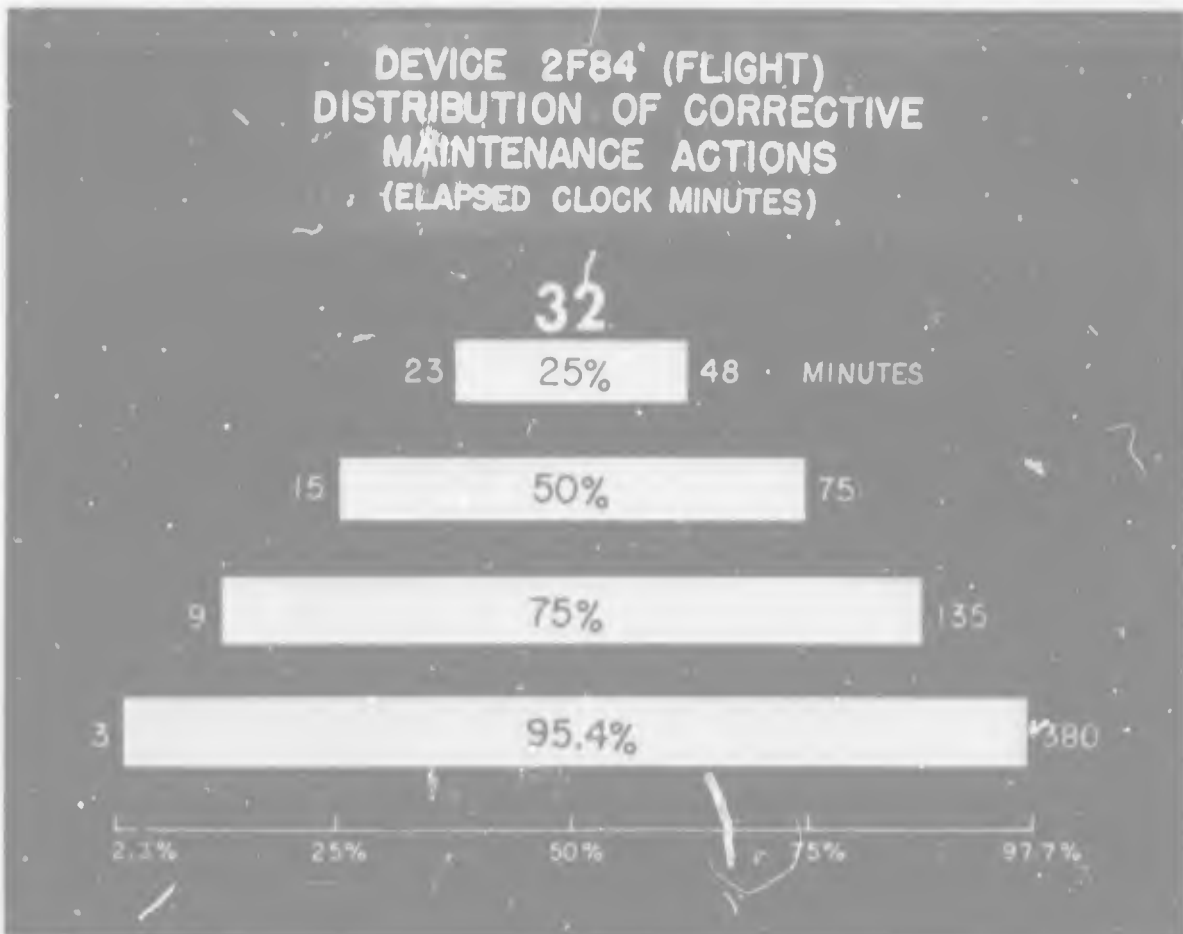


Figure 9

This, again, is a "duo-gram" which can be read in two ways: first; 32 minutes is used as the geometric mean repair time. Under this average point, we can predict that 25 percent of all CM actions will take no less than 23 minutes but no longer than 48 minutes to accomplish a repair. 50 percent of the CM actions (of which we have already defined the center 25 percent) will take no less than 15 minutes and no more than 75 minutes to accomplish a repair. We can similarly predict any desired percentage that approaches but never reaches 100 percent. The second method of interpretation is shown across the bottom line. 25 percent of all CM actions will require 15 minutes or less to accomplish a repair. 50 percent will require 32 minutes or less to accomplish a repair. 97.7 percent of the failures as shown here will be repairable in approximately 6¼ hours or less.

The door is now open to the accurate determination of downtime patterns, and such related items as the appropriate utilization schedule. As noted previously, one failure will be averaged, for each 24.4 hours of operation. Twenty five percent of the failures will not affect continuity because they will be corrected in 15 minutes or less—the tolerance time before losing a training period. The second 25 percent will require from 15 to 32 minutes to effect a repair and a one-hour training period will be lost due to each failure. Continuing in this analysis, it is found that cumulatively about four percent of the training periods will be lost due to corrective maintenance over any reasonable period of time.

The TD workload can also be more accurately analyzed and personnel scheduled accordingly. And most significantly, we can go back into the equipment with time studies to tag repair areas with time-to-repair designations. From this information it can be determined where improvements should be made for maximum equipment utilization. The most rewarding areas in the present case will be repairs made within 15 and 32 minutes. Reducing these times to 15 minutes or less will result in an additional hour of training for each improvement of approximately 17 minutes. By comparison, 75-minute jobs would require a decrease of 60 minutes in

order to realize that same additional hour of training, and would probably cost a lot more to achieve. Obviously repairs of less than 15 minutes require no improvement based on our criteria. The salient point here is that in any family of equipment, whether it is composed of training devices, UHF receivers, or motor generator sets, the basic components and building blocks for a particular type of equipment are essentially the same. They are used again and again in various combinations, with minor modifications, to achieve individual results. If a maintenance profile is established for a few different units in any particular equipment classification, and that profile is equated to the actual use environment for the equipment, we have a powerful tool for reviewing future designs of equipment in that family through Maintenance Engineering Analysis Records (MEAR). Knowing quantitatively what we actually have, and what we really need, we will know where the equipment design requires improvement.

Equipment availability factors were next calculated from the data. Invariant availability, which only considers corrective maintenance downtime, was 96 percent. Operational availability, which reflects the total usage environment including supply, was 79 percent. Based on the above, availability losses can be attributed as follows:

4 percent to Corrective Maintenance

9 percent to Preventive Maintenance

8 percent to Supply time.

Having these percentages in hand, with additional supporting information similar to that previously discussed, we can identify the relative extent of the problem areas and make cost-effective comparisons among the methods of improving availability by an equal percentage.

From this viewpoint, it can be seen how a minimum maintenance and maximum availability goal can be realized in confident, progressive, quantitative increments.

In summation, quantitative maintainability served primarily to improve systems effectiveness through the availability parameter. However, it can also serve to improve life cycle costs by minimizing the peripheral

support requirements through hardware design. The major advantages of quantitative maintainability analysis are:

- Work load distributions and schedule can be derived to maximize manpower utilization.
- Equipment which conforms to the log-normal distribution has a built-in accuracy check of data samples taken in a demonstration through the plotting of the log-normal maintainability characteristic.
- Based on the confidence determined from the log-normal maintainability characteristic, the corrective maintenance downtime can be predicted. From this information, equipment usage programs can be confidently scheduled.
- Hardware designs warranting improvement can be better identified as to the areas and amount needed to effect an increase in availability. Realistic cost-effectiveness studies can be applied to this improvement because

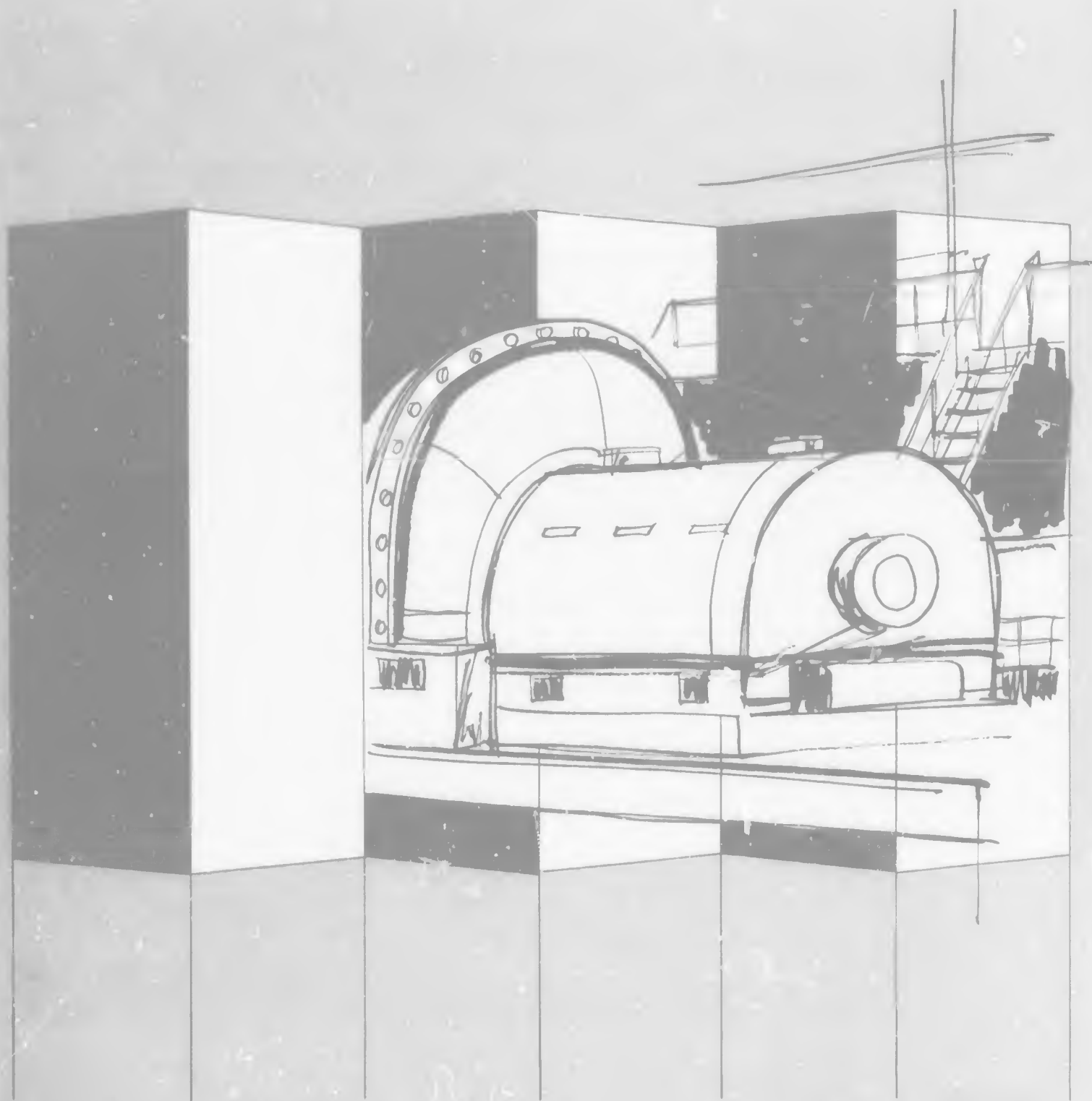
quantitative values are employed in the analysis.

- The different contributing factors to equipment downtime can be quantitatively identified and separated to allow better analysis of the problem and better direction of efforts toward increasing equipment availability.
- The maintenance profile derived from maintainability analysis can decrease problem areas in subsequent procurements through improved specification writing and contractor redesign of the basic building blocks of a particular type of equipment.

The equipment characteristics and analytical techniques discussed in this paper show another avenue toward progressive improvement of equipment availability characteristics by measurable means. Through the application of quantitative maintainability analysis, we can advance more firmly toward that common goal of improving System Performance Effectiveness.

CONDITIONING ELECTRICAL POWER INCREASES SYSTEMS EFFECTIVENESS

MR. G. GIORGI
MR. H. H. KAJIHARA



Electricity has become such a readily available and acceptable source of power that we only become conscious of our dependence on it when it is suddenly not available. Years ago, a disturbance or interruption in the supply of electrical power was at the most an annoyance or inconvenience to most operational systems. However, with the present state of technology, there are many processes and equipment which cannot tolerate discontinuities or degradation in the supply of electrical power. The effectiveness of modern communication and computer complexes in meeting operational requirements is largely dependent on the preciseness and continuity of electrical power available. It is, therefore, imperative for energy systems engineers to realize that these modern electronic complexes can no longer be placed in the category of "just another load" when designing electrical power supply systems.

The problems of how electrical power anomalies affect the operation of critical electronic equipment and what must be done to correct them has been under study by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, for the past four years. During this time, the study investigated the actual input power requirements of sensitive electronic equipment and the interfaces between electric distribution systems and the sensitive equipment. It is noted here that it would be economically impractical to expect the delivery of ideal power from commercial utilities since power disturbances are caused by the exposure of the power transmission networks to a wide variety of natural phenomena and the operation of certain loads by subscribers.

Statistical information and data required to establish precise input power requirements for sensitive electronic equipment has been very difficult to obtain in the past. This is probably due to a mutual lack of understanding of the other fellow's problems by

energy systems engineers, equipment manufacturers, and equipment users. In an attempt to arrive at a solution to this problem, NCEL first launched a program for the development of instrumentation and specialized laboratory test equipment for identification of the acquisition, simulation, and analysis of power system anomalies. With this equipment, input power requirements of critical electronic equipments can be more precisely defined. Once the input parameters are established, power conditioning equipment would then be developed to serve as interfaces between electrical power distribution sources and the critical equipment. In addition, critical electronic equipment and components could be desensitized to short duration disturbances which are the most common on most electric distribution systems.

The major tasks undertaken by NCEL in the electrical power study program include:

- Identification of power system transients,
- Development of power transient suppressors,
- Establishment of transient susceptibility limits of critical electronic equipments,
- Desensitization of electronic equipments to power system transients of short duration.
- Development of power conditioning equipments and components to be used as interfaces between power distribution systems and critical electronic equipment,
- Conduct cost effectiveness analyses on power conditioning requirements,
- Documentation of power supply requirements and specifications for critical electronic equipment.

Several specialized diagnostic test equipments have been developed by NCEL for investigating electrical power problems and



Figure 1

requirements. At the present, the Laboratory is well equipped to develop quantitative information on the effects of power supply anomalies on the operation of critical electronic equipment and components. The major diagnostic test equipment developed to date are described below.

Figure 1 shows a Power Transient Data Acquisition Monitor which is currently undergoing operational testing at NCEL. This Monitor records the waveform of transients whose equivalent frequencies range between dc and 25 kHz, imposed on the base 60 Hz sine wave, and counts pulse voltages of 8 to 5,000 volt magnitude and 2 to 2,000 microsecond duration imposed on the power sine wave. Pulse counts are registered on fourteen counters according to magnitude and duration. A Franklin printer provides a readout of the time of the occurrence of each transient pulse.

The waveform recording portion of the monitor is a magnetic drum-magnetic tape system. Fourteen independent data channels are available on the drum and tape. In principle, the magnetic drum continuously records and erases power waveforms. When a transient occurs, a sensor initiates appropriate action to transcribe the pretransient and transient data from the drum onto the tape. The corresponding time of transient occurrence is also recorded on tape. The data on the tape can be observed on an oscilloscope, oscillograph or fed to a computer.

Figure 2 shows a playback unit which is used to play the tape into a 1620 NCEL computer. A computer program has been written for a Fourier analysis of the distorted waveform. This provides quantitative data for use in design of appropriate transient suppressors.

Upon completion of the laboratory evaluation, the Transient Data Acquisition Monitor will be available for monitoring electrical power distribution systems at military installations wherever power supply problems are encountered.

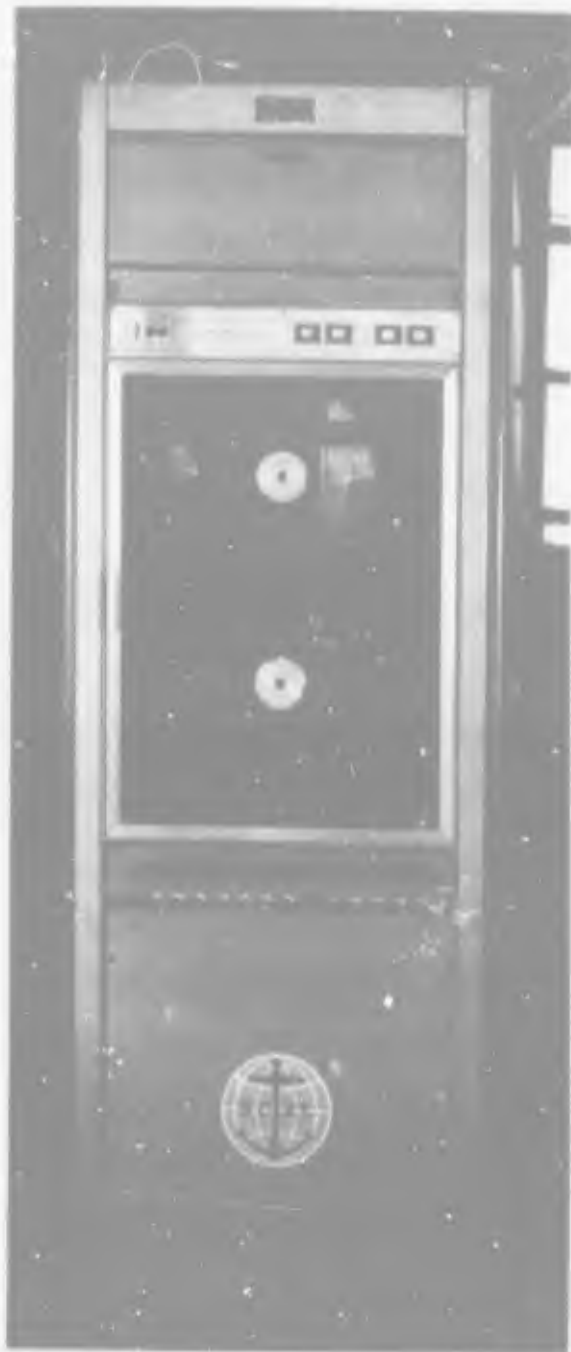


Figure 2

Transient data recorded by the Transient Data Acquisition Monitor will also be used for duplicating the recorded transients on the Power Transient Synthesizer, shown in figure 3. The purpose of the Power Transient Synthesizer is to duplicate the transitory conditions found in the low voltage distribution systems and to provide a power source with controllable output characteristics.

The prototype Synthesizer has been operational since March 1966. The Synthesizer is capable of providing 7.5 kva, three phase, 120/208 volts and 6 kva, single phase, 120 volt, 50/60 Hz sinusoidal and square-wave power containing a family of controlled, repetitive, power parameter variations. These variations include continuous undervoltages and overvoltages, momentary undervoltages and overvoltages lasting for durations of $\frac{1}{2}$ to 20 cycles of 50/60 Hz, complete power outages lasting over the same periods of time, pulse voltages as high as 4,000 volts of 2 to 1,000 microsecond duration which can be superimposed on the base 120 volt, 50/60 Hz sine wave power at phase angles between zero and 360 electrical degrees in 45 degree steps, and frequency-changing voltages up to plus or minus 6 Hz from the base 50/60 Hz.

An advanced model of the Synthesizer, which has improvements and added capabilities over the Mark I model, will become available in June 1968. The added features include superimposition on the fundamental 60 Hz wave shapes of higher frequency, 400 to 2500 Hz voltages, 75 volts maximum, 1 kw, for durations of $\frac{1}{2}$ to 20 cycles of 60 Hz, and a 0-1 kw, 0-270 volt dc output which will contain momentary under- and overvoltage, interruptions and superimposed pulse voltages up to 4 kilovolts.

Pulse tests on electronic equipments with the Synthesizer have shown that the adverse effects of pulse voltages are a function of the phase angle of occurrence as well as voltage magnitudes. It was found that a pulse voltage imposed at, say 45° phase angle, was detrimental to equipment operation whereas a larger pulse voltage could be imposed at 90° at the peak of the sine wave input power



Figure 3

with no operational disruptions. This finding is significant because in specifying the maximum permissible pulse voltage for a given equipment, it is not sufficient to base the pulse voltage limit on component failure considerations alone. Based on such findings, a 0-10 kv pulse generator, shown in figure 4, was developed which can provide 1, 10 and 100 microsecond pulses injected at any phase angle of the input power to test items operating under full load conditions.



Figure 4

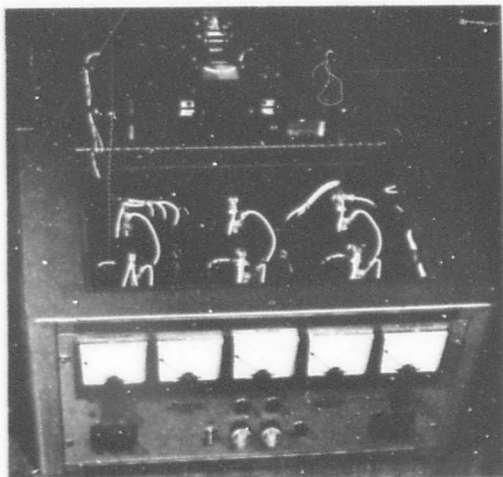


Figure 5

A prototype 15 kva three phase, solid-state, high speed power source transfer switch, shown in figure 5, was developed for those installations having two independent and energized power sources available. This prototype switch senses both the frequency and voltage of the two power sources and automatically transfers from one power source to the other whenever preset limits of frequency or voltage are exceeded. Further studies using this switch will be conducted at NCEL to determine the effects, if any, of high speed switching on power distribution systems and on transient sensitive loads.

The simplest and most economical method of providing electrical energy for power consuming electronic equipment is to use raw utility power directly. However, the quality of raw utility power becomes degraded occasionally because of disturbances caused by man and nature. For improved power quality, power conditioners such as power voltage regulators, motor-generator sets, with and without flywheels, rotary uninterruptible power supply systems and solid-state, uninterruptible power systems are used. The major power conditioners used to date are described below.

M-G sets with a flywheel are conventional motor-generator sets with a rotating mass flywheel whose inertia tends to smooth out

rapid voltage and frequency fluctuations. M-G sets are particularly effective in isolating loads from pulse transients. The commonly used M-G sets range from 30 to 100 kva maximum and can provide to 300 milliseconds of power carry-through while output frequency drops to 59.5 Hz.

The rotary type of uninterruptible power system has been predominantly used to date by all military facilities because it has the longest development history. The power capacity ranges from 30 to 600 kva. The most commonly used sizes are 60 and 200 kva.

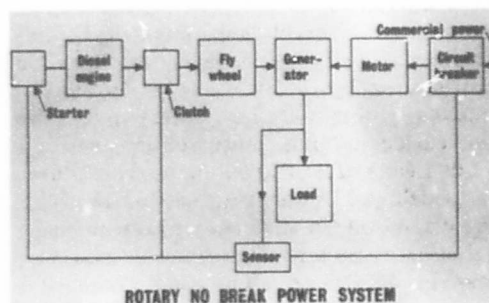


Figure 6

Figure 6 shows a typical rotary uninterruptible power supply system. Commercial power supplies a motor which, in turn, drives a generator. The generator provides power for the load. Upon failure of the normal power source, a standby diesel is brought up to speed and coupled to the generator. During the switchover period, the stored energy in the rotating flywheel continues to drive the generator. Needless to say, massive flywheels are required to sustain the frequency within 0.5 to 1.5 Hz. The disadvantages of rotary uninterruptible power supplies are unreliability due to frequent component failures, the high level of maintenance required, and the need for periodic lubrication and equipment overhaul. Other designs and modifications of this basic rotary uninterruptible power supply are available which have improved performance characteristics.

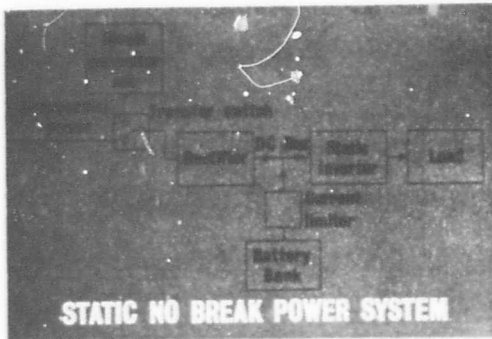


Figure 7

With the development of high power silicon control rectifiers and other solid-state components, the latest method of obtaining continuous electrical power is the use of a solid-state uninterruptible power supply system shown in figure 7. Commercial power is converted to a d-c voltage by power rectifiers. The rectified power is supplied to the static inverter which provides the a-c power output. A battery bank is interposed between the rectifier output and the inverter input. In principle, commercial power supplies the load thru the rectifier and inverter. In this system there are no noticeable voltage or frequency deviations in the output power waveform.

Another method for providing continuity in the supply of electrical power is shown in figure 8. This scheme involves placing a 60 Hz tuned tank circuit between commercial power and the sensitive critical load and is

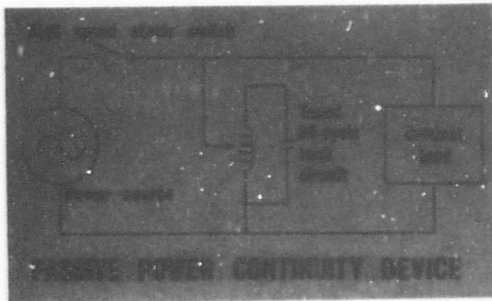


Figure 8

called a Passive Power Continuity Device. A prototype 5 kva single phase, 120 volt Passive Power Continuity Device was developed and tested at NCEL. This device maintains output voltage to 80 percent rated value with a complete 2 Hz power outage at the input. It is believed that 5 Hz of power carry-through is obtainable by the addition of a magnetic voltage regulator on the output of this Passive Device. The development of a three phase, 60 kva unit is planned for further evaluation of this concept.

In conjunction with determining the harmful effects of electrical transients on equipment operation, NCEL is investigating methods and techniques for desensitizing electronic equipments to power transients. Desensitized equipments will, of course, require less expensive power conditioners. During investigations conducted so far on the transient susceptibility of basic regulated d-c power supplies, it was found that by merely increasing the value of the energy storing capacitor, the performance of these power supplies under momentary power outages can be improved tenfold. This area of research shows promising end results. Therefore, a continuing investigation will be conducted of the transient susceptibility of other basic electronic circuitry such as amplifiers, oscillators, multi-vibrators, unijunction pulse circuits and other building block circuits common to all electronic equipment.

Current input power specifications for military electronic equipments contain no performance requirements covering momentary power interruptions, pulse voltage transients, and other power transients. Little effort has been spent to achieve operational compatibility between available electrical power sources and critical electronic equipments nor have tests been conducted to establish transient susceptibility limits of this equipment. Consequently, the best power conditioners that technology offers are now provided for critical electronic equipments to circumvent operational problems resulting from power supply anomalies. This practice is technically unsound and wasteful since such power conditioners are costly and often not necessarily required.

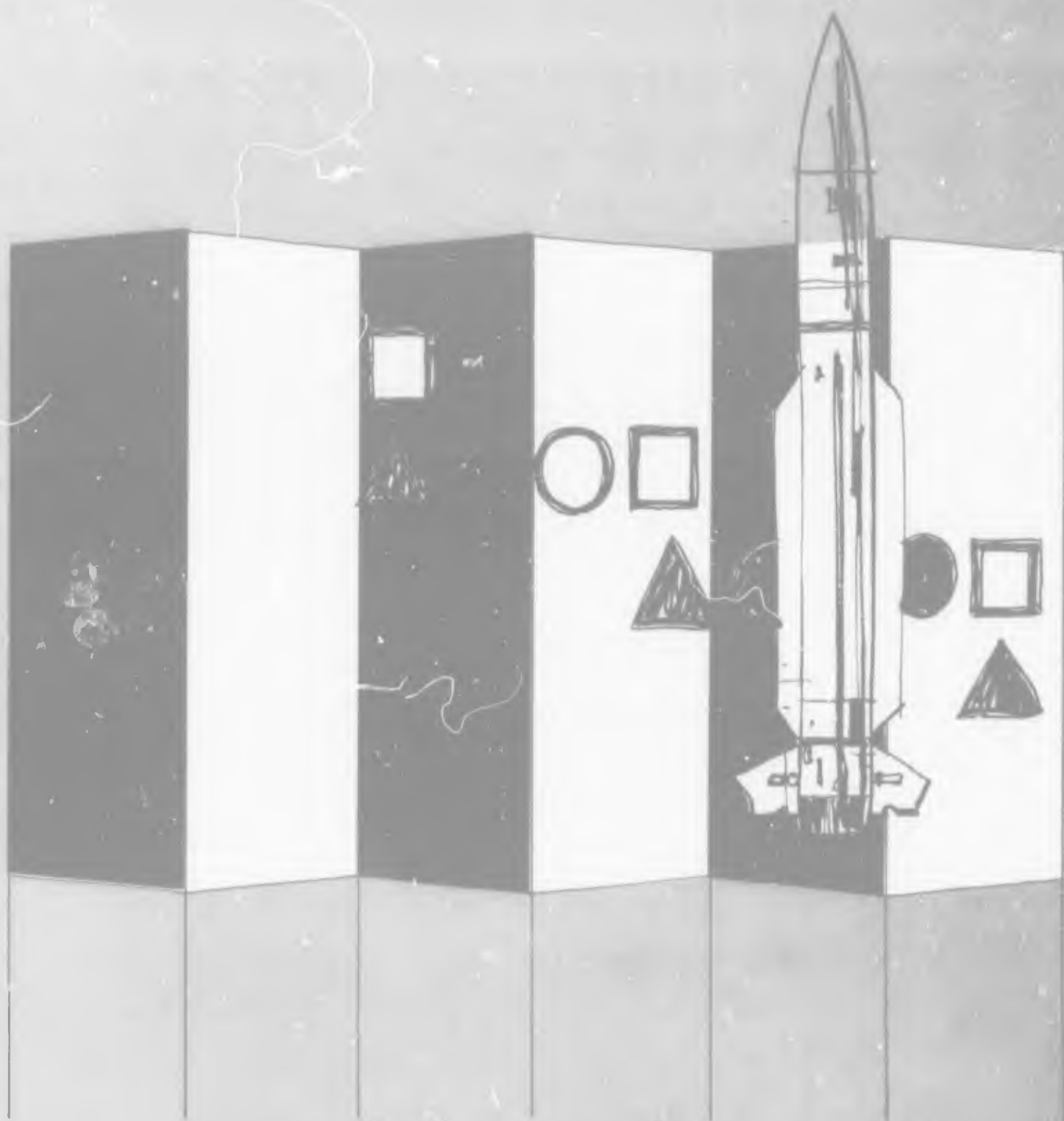
The electrical power research and development program currently in progress at NCEL is expected to reduce, if not eliminate, operational disruptions of highly critical electronic equipment caused by anomalies in the electrical power supply systems. Also, the criteria developed for the use of power conditioning interfaces will be more refined and tailored to the specific type of electronic equipment it is to serve. The goals established for the programs are increased reliability, increased operational effectiveness, and reduced cost of

ownership, all of which will enhance the operational effectiveness of critical electronic equipment used in fleet systems both afloat and on shore.

NCEL is, as discussed earlier, equipped to investigate electrical power problems associated with most modern communication and computer complexes. Inquiries on this subject are indeed welcomed, both because they recommend possible corrective measures and can serve as a continuous source of additional field data for laboratory analysis.

APPLICATION OF DESIGN DISCLOSURE IN ASMS

MR. M. A. DUBINSKY



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INTRODUCTION

This presentation deals with the use of Design Disclosure Format (DDF) in the Advanced Surface Missile System (ASMS) acquisition program. Selection of DDF by the ASMS Program Office followed a critical review of various methods of documentation. Selection criteria were the ability of a documentation method to convey not only the actual intent but also the reasoning behind the system design and to do so with a minimum of data. The DDF is a data presentation which can fulfill these basic criteria, not only for the Navy but also for the contractor within his own plant. It provides a common language communication link among system engineers, design engineers, and technical support personnel such as maintenance, provisioning, handbook, and training experts.

The use of DDF is particularly helpful to the Program Office in the Contract Definition (CD) phase of procurement. Contract Definition provides a competitive atmosphere in which two or more funded contractors define a concept for system hardware and accurately present performance parameters and detailed specifications for the system in the form of a fully documented Engineering Development (ED) contract. The accuracy, comprehensiveness, and presentation of each contractor's documentation are major criteria in source selection for the ED procurement. Hence, the use of the same concise, comprehensive format by all contractors in their presentation of data is of significant assistance to the Source Selection Authority (SSA) in conducting an equitable evaluation of the contractors' proposals.

The ASMS may be the first major Surface Missile System (SMS) program to be carried out on a Total Package Procurement (TPP) basis. Even in the formulative stages of contract definition the TPP concept focuses contractors' attention upon their full development and production responsibilities. Similarly, the ASMS Program Office, for the first

time in a major SMS program, will attempt to explore the potential benefits of using DDF in the earliest phases.

In keeping with Contract Definition procedures, the ASMS program will utilize DDF by means of the methodology of Systems Engineering Analysis (SEA).

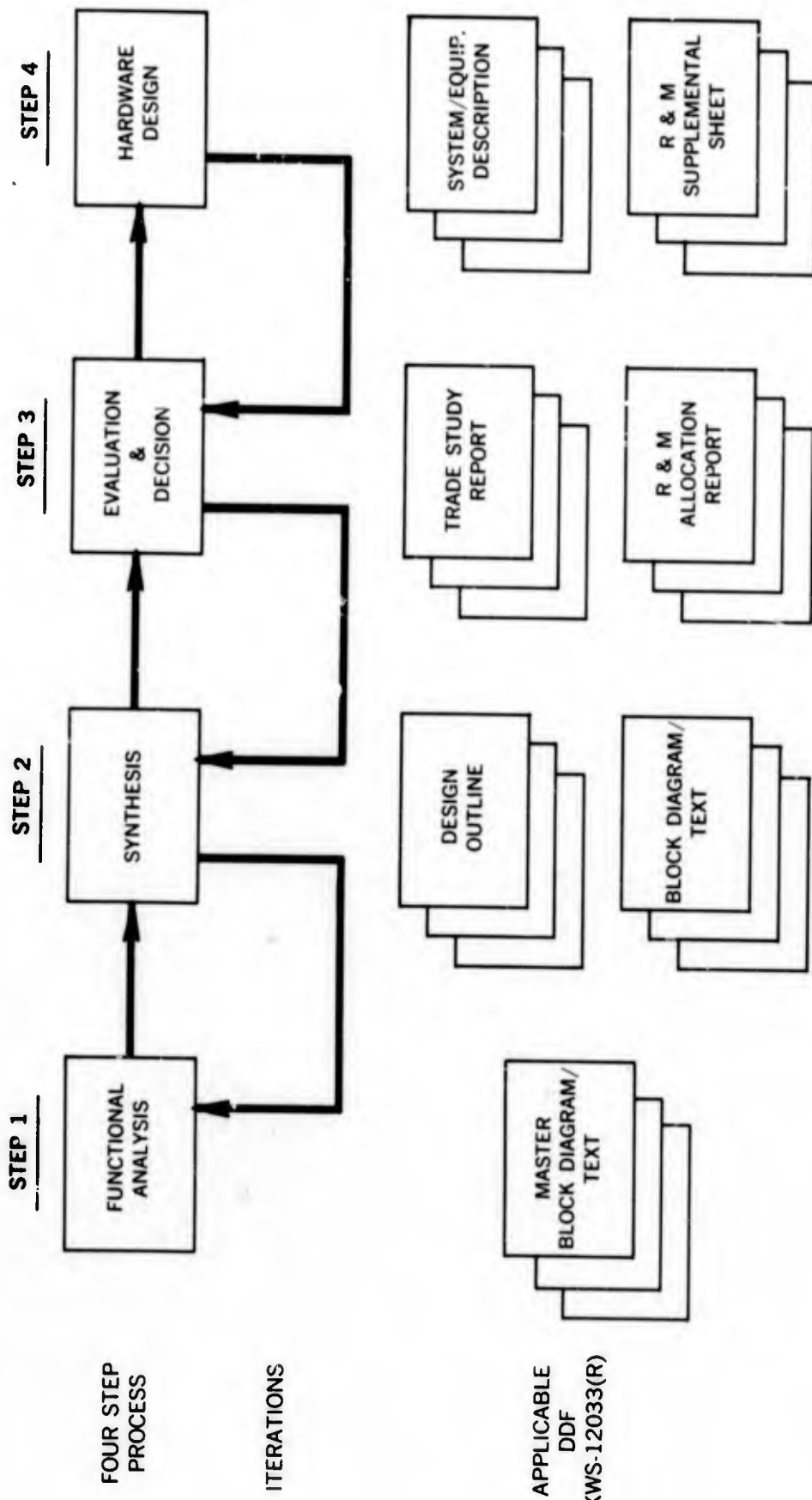
SYSTEMS ENGINEERING ANALYSIS

The SEA process is designed to optimize the system design in a final configuration which will functionally and physically meet overall Navy requirements, and which will satisfy specific system requirements for performance, reliability and maintainability, standardization, safety, electromagnetic compatibility (EMC), quality assurance (QA), and related disciplines. The SEA process is good humoredly illustrated in figure 1. The quality of the system engineered ingredients and of the recipe itself determine whether or



Figure 1

SYSTEM ENGINEERING ANALYSIS



APPLICABLE
DDF
XWS-12033(R)

Figure 2

ASMS TOP-LEVEL FUNCTIONAL DIAGRAM

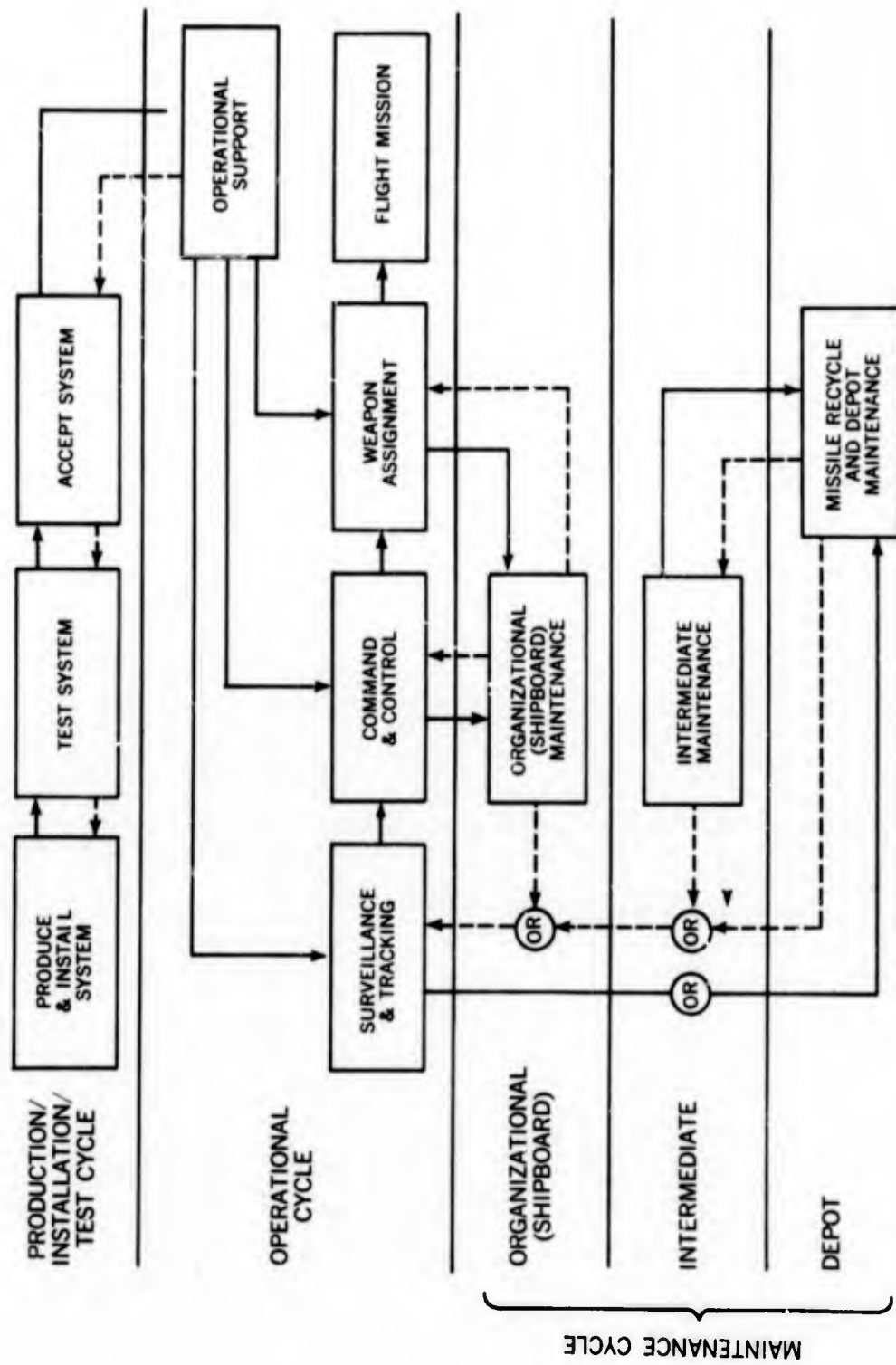


Figure 3

not the process produces prime ground beef or scrapple. System engineering expertise provides the ingredients, DDF is the desired recipe, and SEA is the process which produces a palatable combination.

As graphically illustrated in figure 2, SEA is a four-step process. The process begins with a functional analysis which is followed by a synthesis of function and requirement. This synthesis provides the basis for evaluation and decision from which evolves the configuration description. The SEA process is an iterative one, in which the results of downstream tradeoffs are fed back into the functional analysis and synthesis processes for redefinition and reconsideration of overall effects. Feedback paths are also indicated in figure 2. Each step of the SEA process generates its own requirements for format and content of the necessary communications within the process. The DDF will satisfy these several requirements. It should be emphasized, however, that the result of DDF is a common language, not some mechanically configured format which stresses tolerances in lettering and marginal spacing. Since the DDF is in effect the language of SEA, its application to ASMS may best be described by a description of the SEA process itself.

THE MASTER BLOCK DIAGRAM/TEXT

The starting point for SEA will be a functional description of the ASMS. A top-level functional drawing, such as that illustrated in figure 3, will be expanded into successively more detailed levels of indenture. Its expansion

will be documented by a DDF Master (or Intermediate) Block Diagram/Text as indicated in figure 4. Fundamentally, such diagrams are functional flow block diagrams; however, the functions are described by text printed directly on the functional blocks.

As the SEA process continues into its synthesis step, functions are grouped into hardware-oriented configurations. This grouping is accomplished by enclosing related functions on individual DDF Master Block Diagrams with dotted or dashed lines and by coding functional groups between diagrams.

THE DESIGN OUTLINE

Synthesized functions can be expanded into a Design Outline (DO), as indicated in figure 5. The DO presentation is unique to DDF. By methodically applying a systematic symbology, interdependencies among functions can be identified. Such interdependencies include prerequisite happenings and timing sequences and occurrences. Operational times (e.g., human reaction and decision-making times), maintainability/repair times, and reliability failure rate estimates can also be indicated for each function. For ASMS, the ability of the DO to show time interdependencies is of particular value in overall ship integration. ASMS must interface with Electronic Warfare (EW), Anti-Submarine Warfare (ASW), and Gunfire Control Systems (GFCS) and Command and Decision (C&D) complexes. Time interdependencies among these shipboard systems must be reflected not only in electronic interconnections,

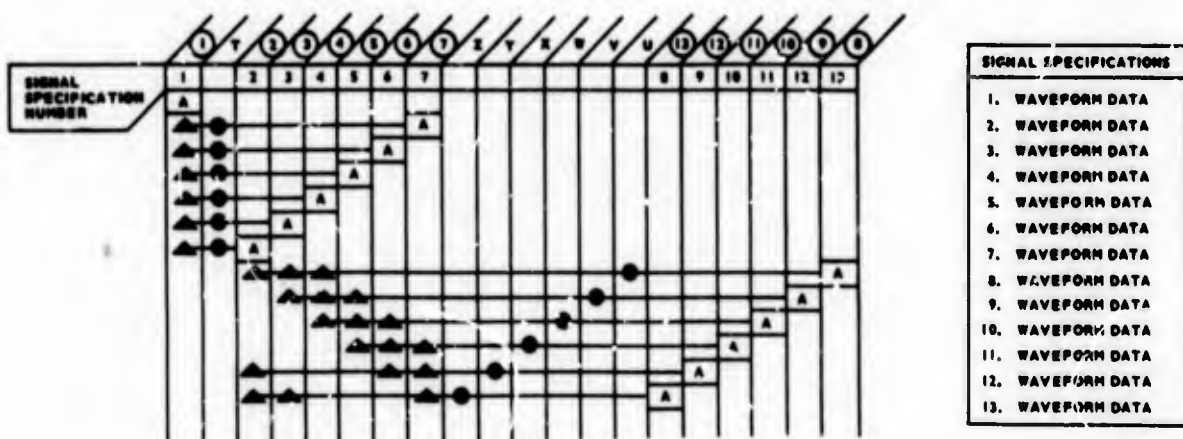
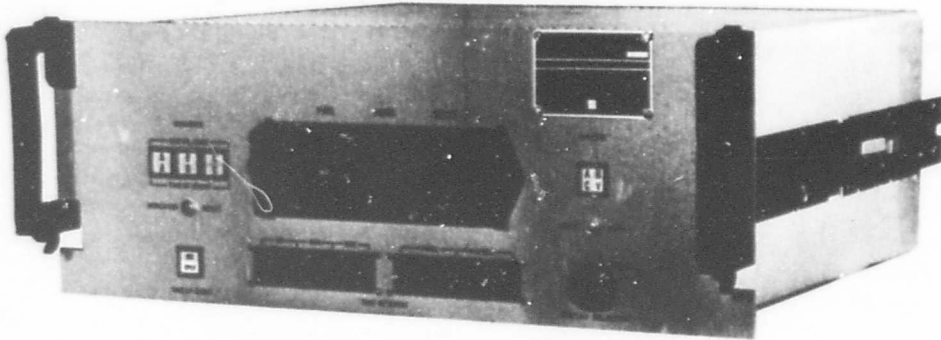


Figure 5



OVERALL DESCRIPTION:

THE TIME SIGNAL GENERATOR IS A DIGITAL CLOCK AND TIME CODE GENERATOR INTENDED FOR USE AS A CENTRALIZED TIMING EQUIPMENT FOR SHORE OR SHIPBOARD INSTALLATIONS. THE TIME SIGNAL GENERATOR UTILIZES REDUNDANCY OF THREE INDEPENDENT DIGITAL CLOCKS TOGETHER WITH A MAJORITY VOTE TECHNIQUE TO PROVIDE HIGHLY ACCURATE AND STABLE TIME INFORMATION.

OUTPUTS INCLUDE:

1. A VISUAL DISPLAY OF HOURS, MINUTES, AND SECONDS IN THE 24 HOUR SYSTEM.
2. A TIME OF EVENT CONTROL PULSE CAPABLE OF BEING PROGRAMMED TO THE MICROSECOND OF ANY 24 HOUR PERIOD.
3. 12 DECADE INCREMENTED TIMING PULSES RANGING FROM ONE PULSE PER MICROSECOND TO ONE PULSE PER DAY.
4. DIGITAL AND ANALOG TIME CODES.
5. TIME MARKER PULSE TRAINS.

TWO MODES OF OPERATION ARE PROVIDED: (1) MAJORITY VOTE OR CHANNEL COMPARISON; (2) SELECTED CHANNEL. IN THE MAJORITY MODE, ALL EQUIPMENT OUTPUTS ARE GENERATED AS THE RESULT OF A MAJORITY VOTE DECISION BASED UPON THE COMPARISON OF INDIVIDUAL OUTPUTS FROM THE THREE INDEPENDENT DIGITAL CLOCK CHANNELS. THE SECOND MODE OF OPERATION (SELECTED CHANNEL) IS PROVIDED TO ENABLE THE TIME OF EVENT CONTROL PULSES, TIME OF DAY DISPLAY, AND DIGITAL TIME CODE OUTPUTS TO BE CONTINUED WITHOUT BENEFIT OF MAJORITY VOTE, DURING THE TIME REQUIRED FOR TROUBLESHOOTING OR REPAIR OF A CHANNEL WHICH IS IN DISAGREEMENT WITH THE OTHERS.

THE TIME SIGNAL GENERATOR IS CAPABLE OF DRIVING 25 REMOTE DIGITAL DISPLAY INDICATORS.

PERSONNEL REQUIREMENTS		
QTY	RATE	SKILL REQ.

TEST EQUIPMENT SUPPLIED		
QUANTITY PER EQUIPMENT	NAME	DESIGNATION

PHYSICAL CHARACTERISTICS				
OVERALL DIMENSIONS			VOLUME	WEIGHT
HEIGHT	WIDTH	DEPTH		

TEST EQUIPMENT REQUIRED BUT NOT SUPPLIED		
QUANTITY PER EQUIPMENT	NAME	DESIGNATION

Figure 6A

PERFORMANCE CHARACTERISTICS	
DESIGNATED NAME	CHARACTERISTICS
1. OUTPUTS DIGITAL TIME CODE FORMAT CODING BIT RATE RESOLUTION OUTPUT IMPEDANCE SIGNAL LEVEL OUTPUT RATES	32 BIT SERIAL (LSB FIRST) BCD TIME OF DAY PULSE WIDTH MODULATED (BINARY ONE = $6\mu\text{s}$; BINARY ZERO = $2\mu\text{s}$) 100KPPS UNITS OF MILLISECONDS HIGH LEVEL 250 OHMS; LOW LEVEL 100 OHMS ZERO TO +6V; OPEN CIRCUIT RISE AND FALL TIME LESS THAN $0.1\mu\text{s}$ 1 MILLISECOND; 1 SECOND
2. INPUTS MODULE POWER DISPLAY POWER	+22 TO +30V (+26V NOMINAL) AT 4 AMPS +22 TO +30V (+26V NOMINAL) AT 0.2 AMPS

RELIABILITY CHARACTERISTICS
1. MEAN-TIME-BETWEEN-FAILURES $\frac{\text{EQUIPMENT}}{\text{MTBF}_{\text{EQUIP}}} = 5,224 \text{ HRS}$

2. PART RELIABILITY HIGH RELIABILITY DIODE-TRANSISTOR MICROLOGIC INTEGRATED CIRCUITS USED THROUGHOUT EQUIPMENT.

MAINTAINABILITY CHARACTERISTICS
1. MEANT-TIME-TO-REPAIR $\frac{\text{EQUIPMENT}}{\text{MTTR}_{\text{EQUIP}}} = 30.1 \text{ MIN}$

2. MODULARIZATION FUNCTIONAL MODULAR CONSTRUCTION HAS BEEN USED THROUGHOUT EQUIPMENT. CONSTRUCTION IS SUCH THAT REDUNDANT FUNCTIONAL MODULES MAY BE REMOVED (FOR TROUBLESHOOTING OR REPAIR) AND REPLACED WITHOUT INHIBITING THE GENERATION OF THE VISUAL DECIMAL DISPLAY OR THE TIME OF EVENT PULSE.
3. DIAGNOSIS INDICATORS PLACED SUCH THAT DIAGNOSIS CAN BE PERFORMED USING NO EXTERNAL TEST EQUIPMENT AND THE FAULT ISOLATED TO A MAXIMUM OF THREE CARDS.
4. REPAIR AVERAGE TIME TO REMOVE AND REPLACE A CARD IS FIVE MINUTES.

Figure 6B

but also in operational procedures and requirements. The DO's provide the information necessary to develop these interface requirements, procedures, and the operational requirements. The DO's can also be used to analyze shipboard handling, test, and other support equipment requirements to determine applicability of depot and/or intermediate maintenance equipment.

THE INTERMEDIATE BLOCK DIAGRAM/TEXT

Once the functional analyses and synthesis steps have been completed and the DO's have been drawn up, the SEA process enters its evaluation and decision step. In this step, alternatives are identified and tradeoff studies are made to determine hardware characteristics which will most effectively satisfy system functional requirements. Throughout the evaluation and decision process, the Intermediate Block Diagram/Text and DO's are expanded and refined to reflect the effects of tradeoff decisions. The results of each tradeoff study are documented in a final report.

Once the system hardware concept has been determined, the SEA process provides for the writing of a detailed hardware description. Documentation in this step includes the System Equipment Descriptions, Reliability-Maintainability Supplemental Data Sheets, and the further refinement of Master and Intermediate Block Diagrams/Texts and DO's.

THE SYSTEM EQUIPMENT DESCRIPTION

System Equipment Descriptions, such as the one illustrated in figure 6, will have a significant role in the ASMS system engineering process. They establish, for the Program Office, a handbook-like summary of deliverable items which can be used in the development of the Project Management Plan (PMP). For agencies and activities supporting the Program Office, the System Equipment Descriptions can be expanded for use during ED to define the replaceable parts level, and to form the basic foundation for Maintenance Engineering Analysis Report (MEAR) information required by the Integrated Logistics Support (ILS) plan for maintenance. The System Equipment Description provides visibility

for both program management and support engineering personnel. This visibility is based upon design decisions made early in the SEA process and therefore meets the "establishment of documentation media" requirements of NAVMATINST 4000.20.

THE RELIABILITY-MAINTAINABILITY SUPPLEMENTAL DATA SHEET

Both the System Equipment Description and Reliability-Maintainability Supplemental Data Sheet (figure 7) are used by the ASMS Program Manager within his ILS program to coordinate the requirements for provisioning, maintenance, test, and calibration. As far as possible, the summary data required by these sheets will be supplied by the ASMS contractor in his own format, providing that, during CD, such format is determined by the Navy to be acceptable.

DIFFICULTIES IN USING DDF

The primary difficulty in the use of DDF is expected to be encountered in the areas of overlap and/or conflict with existing NAVMAT and NAVORD data forms (e.g., provisioning data and PMS/SMS 4616). For example, during ED, handbooks and technical manuals developed by the contractor must be designed to meet the PMS/SMS requirements of WS 4616. The PMS/SMS requirements of WS 4616 apply to engineering drawings which present design details including fabrication documentation, schematic wiring diagrams, assembly and subassembly layout drawings, and single-function flow diagrams. These requirements are not covered by the DDF, per se. However, the basic language to be used in such handbooks and technical manuals will be established in DDF during the early phases of SEA. Hence, DDF provides a foundation of consistent terminology and an overall system description for the technical writer providing guidance and background for him. Data originating in DDF will also support the System Integrated Maintenance Manuals (SIMM's) method of handbook preparation as per MIL-M-24100. During CD, ASMS contractors must evaluate the requirements of WS 4616 to determine where the technical manuals can be made more effective by the SIMM's data presentation approach.

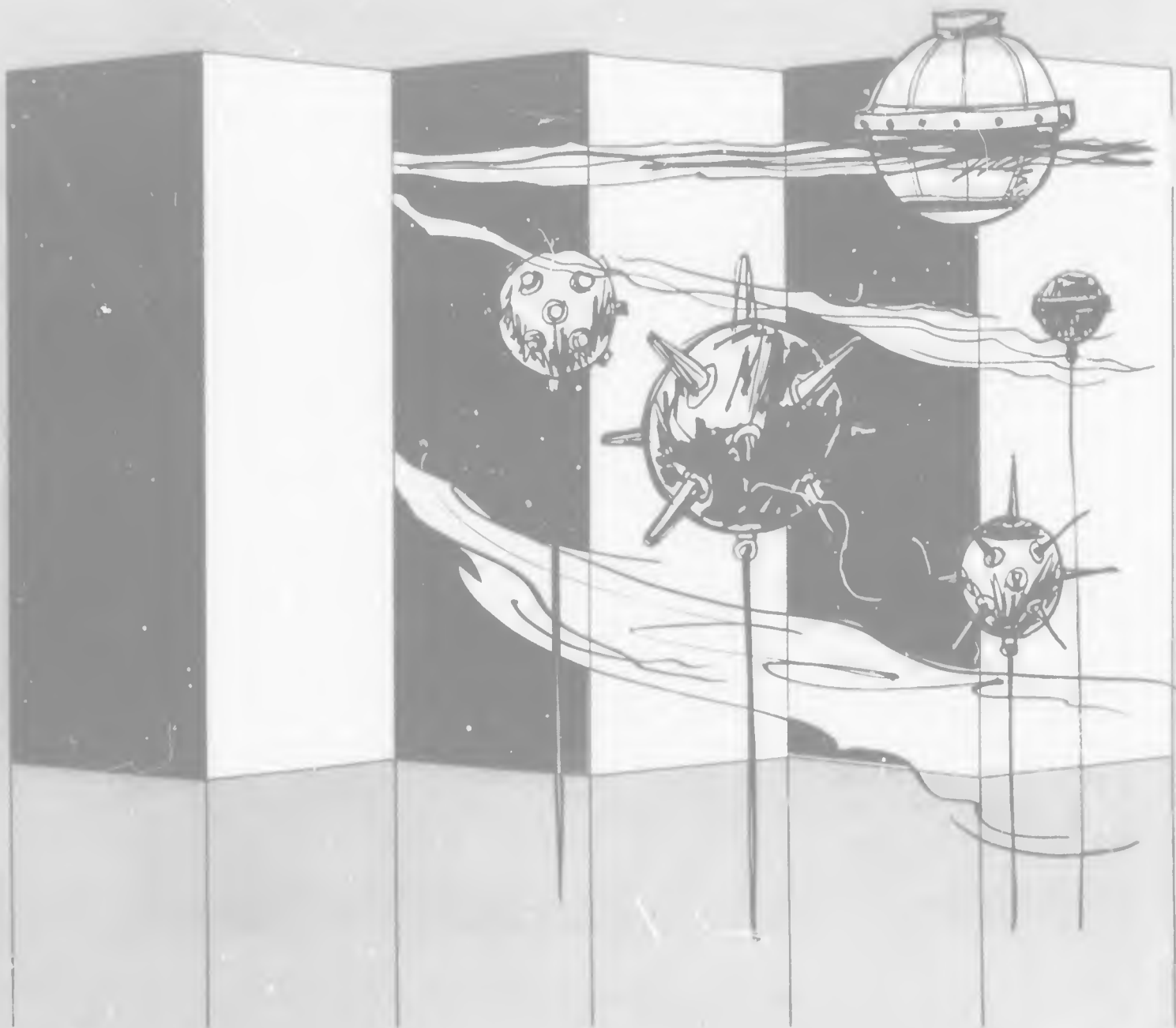
SUMMARY

It must be emphasized that ASMS is being designed for high availability and effectiveness. Hence, the Program Office has investigated all media which may be expected to be of significant value in accomplishing these goals. Three basic approaches were considered: current contractor formats, the Air Force contract series AF-375 documentation, and DDF. Informal contractor formats did not appear to provide adequate data for the Program Office to compare proposals for the SSA. Use of the AF-375 format requires the

adoption of the entire Air Force contracting system which would thereby require changes to virtually every aspect of the current program approach. The System Engineering Analysis process and a Design Disclosure Format offer compatible methodologies for the derivation of a standard system language by means of which the required system effectiveness and concomitant availability requirements can be achieved. Contract Definition affords the ASMS Program Office the opportunity to establish this language early in the development process and thereby to take maximum advantage of such standardization and systematic procedure.

APPLICATION OF RELIABILITY ASSESSMENT PROGRAM TO MINE WARFARE

MR. J. VON SAS
MR. C. DUKE



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INTRODUCTION

The cost of a contractually specified reliability requirement is of critical concern to the Navy project manager. If he does not have reasonable assurance that the weapon reliability requirement is achievable, the manager is faced with unexpectedly high quotations from competing contractors, possible unacceptable over-runs if the contractor's reliability plans are unrealistic, or a final product that falls below the reliability needed by the Fleet. It is important, therefore, that the project manager have some estimate of the reliability potential of a proposed design, or know the potential problem areas, before he accepts the specified reliability and plans his procurement budget. In this discussion, one method of assessing a proposed design's reliability potential is presented. For security reasons, all equipment identifications are coded and the values simulated, but the problem is taken from an actual program.

THE PROBLEM

The XL-3 is a new type of weapon capable of being launched at sea; it comprises an aft mobile section subsystem and a forward section subsystem. Most of the components used in the weapon have already been used in other weapons. The mobile subsystem is similar to Type-A1 and Type-A2 weapons, although the guidance equipment is a gyro type similar to that used in the Type-A3 weapon. The components in the forward section subsystem are similar to those used in the Type-B1 and Type-B2 weapons.

The problem confronting the Naval Ordnance Systems Command's Mine Warfare Division arose from a change in the XL-3 reliability requirements specified in the Technical Development Plan (TDP). The TDP specified a minimum acceptable reliability at the lower 80-percent confidence level as a contract reliability goal. Approval of the TDP by the Chief of Naval Operations, however, was contingent on increasing the minimum

acceptable reliability and the contract goal by four percent.

Management at NOSC's Mine Warfare Division recognized the need for an appraisal of the XL-3's reliability potential so that the effect of the more stringent reliability requirements could be assessed and appropriate actions taken. The effects on projected costs and schedules were of particular concern.

Since the planned configuration consisted primarily of similar components in current use in several operational weapon systems, the mission-reliability experience of these operational systems could be used to estimate the achievable mission reliability of the XL-3. The XL-3 configuration was theoretically synthesized with components from these operational weapons, and its reliability was computed from operational data on these components. The following steps were taken:

Configuration Synthesis

- A configuration analysis was performed to identify the operational components.
- The mission requirements of the XL-3 components were compared with those of the associated operational components.

Data Collection and Screening

- Sources of available operational data were identified.
- The reliability data from the identified sources were extracted and organized.
- These data were reviewed and screened to extract those that were applicable to the XL-3 mission and to the synthesized hardware configuration.

Data Analysis

- Statistical tests were applied to determine the relationship of failure occurrence to time.
- Confidence intervals for the derived reliability values were computed.

CONFIGURATION SYNTHESIS

To synthesize the XL-3 configuration, the major components in the forward and mobile

section subsystems were identified and each was then associated with a similar component in an operational weapon. The forward section components were essentially the same as those used in the Type-B weapons:

- Arming Device
- Timer
- Detector
- Firing Mechanism
- Control Box
- Counter
- Cable Assembly
- Power Supply

The mobile section consisted of the following subsystems, selected from several Type-A weapon designs:

- Propulsion
- Power Supply
- Guidance and Control

DATA COLLECTION AND SCREENING

Most of the forward section data were obtained from annual reports of Naval Engineering Facilities for the fiscal years 1956 through 1966. These reports covered test programs conducted to determine trends in serviceability, training, logistics problems, and reliability of the weapons. The tests simulated the conditions that would be encountered in a mission; service materials were used; and the tests were conducted by the Fleet personnel who would participate in actual tactical operations.

Test data were collected on eleven similar Type-B weapons, including the Type-B1 and Type-B2, and were screened for validity. Since the objective of the study was to assess the reliability of the XL-3 operational hardware only, tests were not considered valid if any of the following occurred:

- The weapon failed because of human error.
- The weapon failed because of delivery-system malfunction.
- The weapon was lost.

The test data summarized in table 1 were used for a general evaluation of a number of weapons similar to the Type-B1 and Type-B2 associated with the XL-3 design. This evaluation provided assurance that the Type-B1 and Type-B2 test results were generally of the same level as similar weapons and not extremes caused by a limited sample size.

The data on the mobile section subsystems pertinent to the XL-3 design were obtained from quarterly reports on Fleet activities for the years 1965 and 1966. The reports provided information on the type of weapon used, the performance level of each weapon system, the significant causes of failures, and the types of recurring failures. Additional data were obtained from tests performed by the Naval Ordnance Laboratory on contractor prototype Range and Accuracy Vehicles (RAV) and from FARADA (Failure Rate Data Handbook).

Test Data From Existing Designs Related To XL-3 Forward Section				
Type of Weapon	Total Valid Tests	Number of Successes	Number of Failures	Point Estimate of Probability of Success
B 1	206	171	35	0.83
B 2	135	121	14	0.90
B 3	211	177	34	0.84
B 4	167	122	45	0.73
B 5	82	81	1	0.99
B 6	572	507	65	0.89
B 7	105	86	19	0.82
B 8	580	527	53	0.91
B 9	92	87	5	0.95
B 10	134	122	12	0.91
B 11	41	38	3	0.93

Table 1

The criteria for screening out invalid data on the mobile section subsystems were the same as for the forward section, with the following additions:

- The weapon failed because of malfunctioning components that were not related in any way to the XL-3's design.
- The weapon failed because of unintentional changes in control settings, and the cause could not be identified definitely.

The mobile section data are summarized in table 2. Data on other, similar weapons were also tabulated to assure that the data for the mobile section were not extremes because of limited sample sizes. The probabilities of success of these other weapons were 0.89, 0.87, 0.82, and 0.91.

Test Data From Existing Designs Related To XL-3 Mobile Section				
Type of Weapon	Total Valid Tests	Number of Successes	Number of Failures	Point Estimate of Probability of Success
A 1	905	787	118	0.87
B 2	649	558	91	0.86
C 3	145	133	12	0.92
RAV #1	9	8	1	0.89
RAV #2	17	9	8	0.53
Battery	108	104	4	0.96

Table 2

DATA ANALYSIS

The first step in the data analysis was to determine the distribution of failures of components related to the XL-3's forward section and the distribution of failures of subsystems related to the mobile section. Table 3 lists the distribution of component failures for the Type-A1 and Type-A2 weapons. Since like components used in these two weapons are identical for the purpose of the XL-3's assessment, the combined valid tests (341 tests) were used to compute the component reliabilities.

Unlike the forward section subsystem of the XL-3—for which a composite equipment of like configuration is already in operational

Failure Distribution Of Components Related To XL-3 Forward Section		
Component Type	Distribution of Failures	
	A 1	A 2
• Arming Device	2	1
• Timer	2	1
• Detector	0	0
• Firing Mechanism	5	2
• Control Box	4	1
• Counter	1	1
• Cable Assembly	1	3
• Power Supply	0	0
• Structure	3	0
• Other*	17	5
Total	35	14

* Failures whose causes are unknown or could not be attributed to a particular component.
NOTE: Total number of valid tests = 341 for each component.

Table 3

use—the mobile section was not represented by any existing weapon that offered a configuration similar to that of the XL-3's proposed mobile section subsystem. Consequently, in the analysis of the mobile section data, an appropriate mobile system was first synthesized from the pertinent subsystems of the various weapons considered, and then the corresponding reliability estimate was synthesized. The distribution of these failures is shown in table 4. In assembling this table,

Distribution Of Failures Of Subsystems Related To XL-3								
Mobile-Section Subsystem	Distribution of Failures							Total Number of Valid Tests
	A 1	A 2	A 3	RAV 1	RAV 2	Battery	Totals	
Propulsion	7	13	--	0	0	--	20	1580
Power Supply	--	--	--	-	-	4	4	108
Guidance & Control	--	--	12	1	8	--	21	171
Other*	41	22	--	-	-	--	63	1554

* Failures whose causes are unknown or could not be attributed to a particular component.

Table 4

it was assumed that the subsystems of the weapons observed were independent with regard to reliability. Hence, for example, when failures were recorded against the Guidance and Control equipment of the Range and Accuracy Vehicle (RAV), it was assumed that the propulsion subsystem operated satisfactorily. This tends to bias the reliability prediction optimistically since the propulsion subsystem might have failed later in the test.

Relationship Of Forward-Section Reliability To Test Time

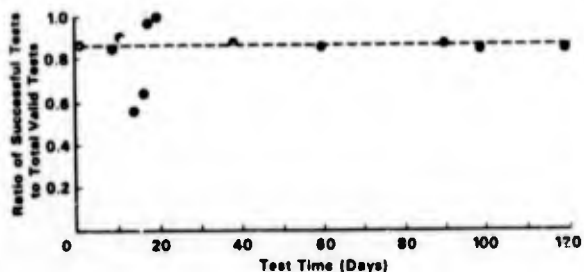


Figure 1

Relationship Of Mobile-Section Reliability To Test Time

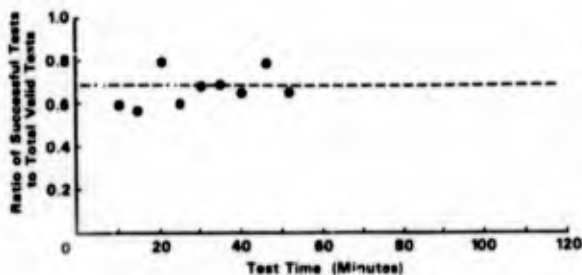


Figure 2

In the second step of the data analysis, for both sections of the XL-3, the data from the representative weapons were analyzed independently to determine the relationship between failures and mission times. A regression analysis of the plots shown in figures 1 and 2 indicated that the forward and mobile

sections' representative weapon reliabilities are independent of test time for the periods represented by the available data. Therefore, it was reasonable to quantify the XL-3's reliability in terms of the ratio of successful attempts to total attempts.

The usual procedure for computing the reliability of a complex weapon system is to determine the product of the system's failure rate (λ) and the mission or operating time (t) and use this value as the negative exponent of e , so that $R = e^{-\lambda t}$. In the assessment of the mission reliability of the XL-3's forward and mobile sections, this relationship would not hold for the mission times under consideration. If such a relationship were used, it would result in a pessimistic value since R decreases as t increases. For the XL-3, the mission reliability, within the constraints of this assessment and the observed data, is a constant.

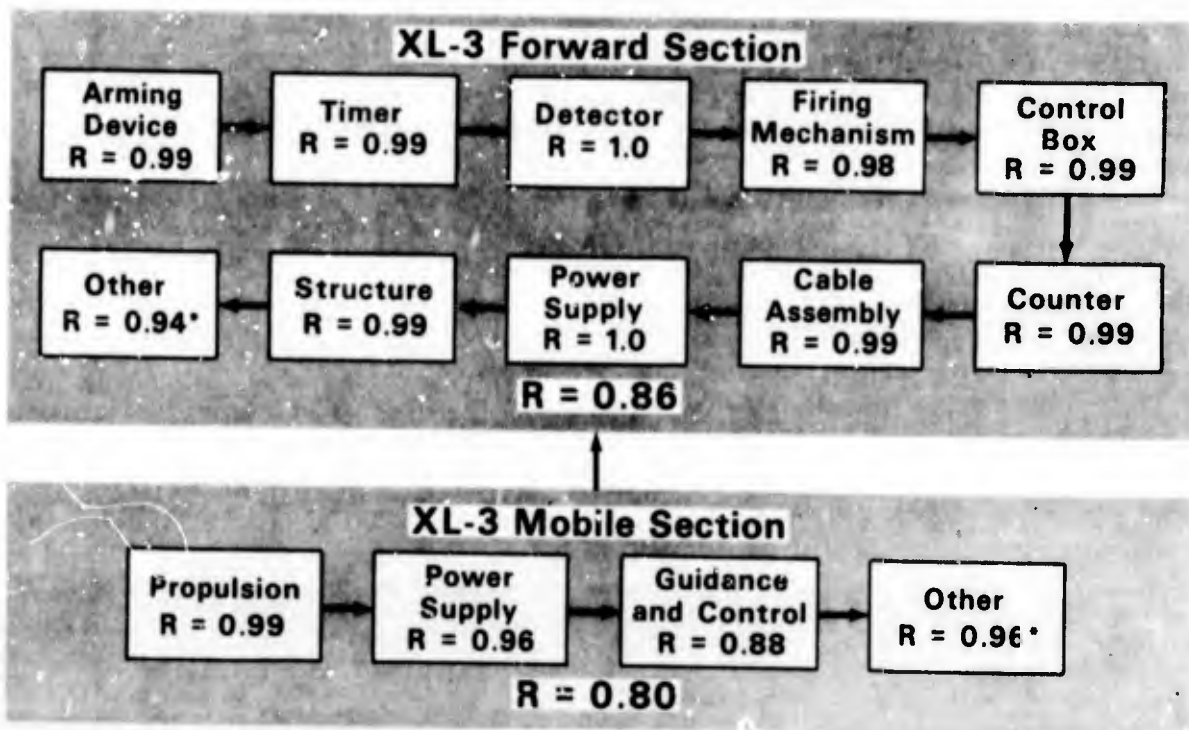
By use of the observed data from operational weapons representing the forward and mobile sections of the XL-3, reliability point estimates were computed. These values are presented in the reliability block diagram of figure 3.

XL-3 RELIABILITY ASSESSMENT

An NCSC requirement for the study was that confidence limits about the reliability point estimates be determined. Since the data sample sizes used to calculate the reliability estimates for two representative sections were different, a special technique developed by A. Mandansky* was used to compute upper and lower confidence limits about the reliability point estimate for the system. This approach uses a chi-square approximation based on the proposition that $-2 \log \lambda$ is distributed approximately as chi-square when λ is a likelihood ratio statistic.

*A. Mandansky, Approximate Confidence Limits for the Reliability of Series and Parallel Systems, RM-2552, The Rand Corporation, 4 April 1960.

Reliability Block Diagram Of The XL-3 Weapon



*Accounts for unassignable component reliability.

Figure 3

The confidence region for the reliability (R) of the system is:

$$\prod_{j=1}^m (X_j - \lambda_1^*) / (n_j - \lambda_1^*) \geq R = \frac{X}{n} \geq$$

$$\prod_{j=1}^m (X_j - \lambda_2^*) / (n_j - \lambda_2^*)$$

where

λ_1^*, λ_2^* ($\lambda_1^* < \lambda_2^*$) are the values of λ that satisfy the equation

$$\sum_{j=1}^m X_j \ln(1 - \lambda/x_j) - \sum_{j=1}^m n_j (1 - \lambda/n_j) = \frac{\chi^2(1)}{2}$$

where $\chi^2(1)$ is the upper 100% point of the χ^2 distribution with 1 degree of freedom. In the above equations, the X_j 's are the number

of successes of the representative subsystems of the XL-3, and the n_j 's are the number of valid trials.

The mathematical procedure described above and the product of the reliability estimates for the representative forward and mobile sections provide reliability values for the XL-3 weapon as shown in table 5.

Predicted Reliability For XL-3 Weapon System		
Probability of Success	Confidence Limits	
	Lower 80%	Upper 95%
0.69	0.65	0.72

Table 5

The lower confidence level was computed to permit a direct comparison of the results of this assessment with the requirements specified in the TDP. The upper 95% confidence level was computed to indicate the probability that the conceptual designs would meet the requirements. In the actual comparison, it became apparent that the proposed configuration was not likely to meet the reliability requirements set forth in the TDP.

The advantage of performing such a comparison early in a given program, particularly before development funds are committed, is that it gives the project manager a good basis for accepting the requirements as achievable or seeking additional development funds.

RELIABILITY CONSIDERATIONS FOR MULTIPLE-WEAPON EMPLOYMENT

One of the questions that arises in a weap-

on system analysis is the relationship of individual weapon reliability to the number of weapons in a group that will fail during a given mission time. For example, assume a weapon reliability of 80 percent and the requirement that, in a weapon grouping of 100, twenty or fewer failures occur during the mission with a probability of at least 99.5 percent.

Although the binomial distribution applies here, it is assumed for the sake of graphic presentation that the sample is large and the probability of failure is small. In this case the binomial distribution is approximated by Poisson's distribution.

In the Poisson Cumulative Probabilities graph, figure 4, the ordinate gives the probability of r or fewer failures and the abscissa gives a value $m = np$, where n is the group size and p is the probability of failure.

For the problem hypothesized, observe that

Poisson Cumulative Probabilities

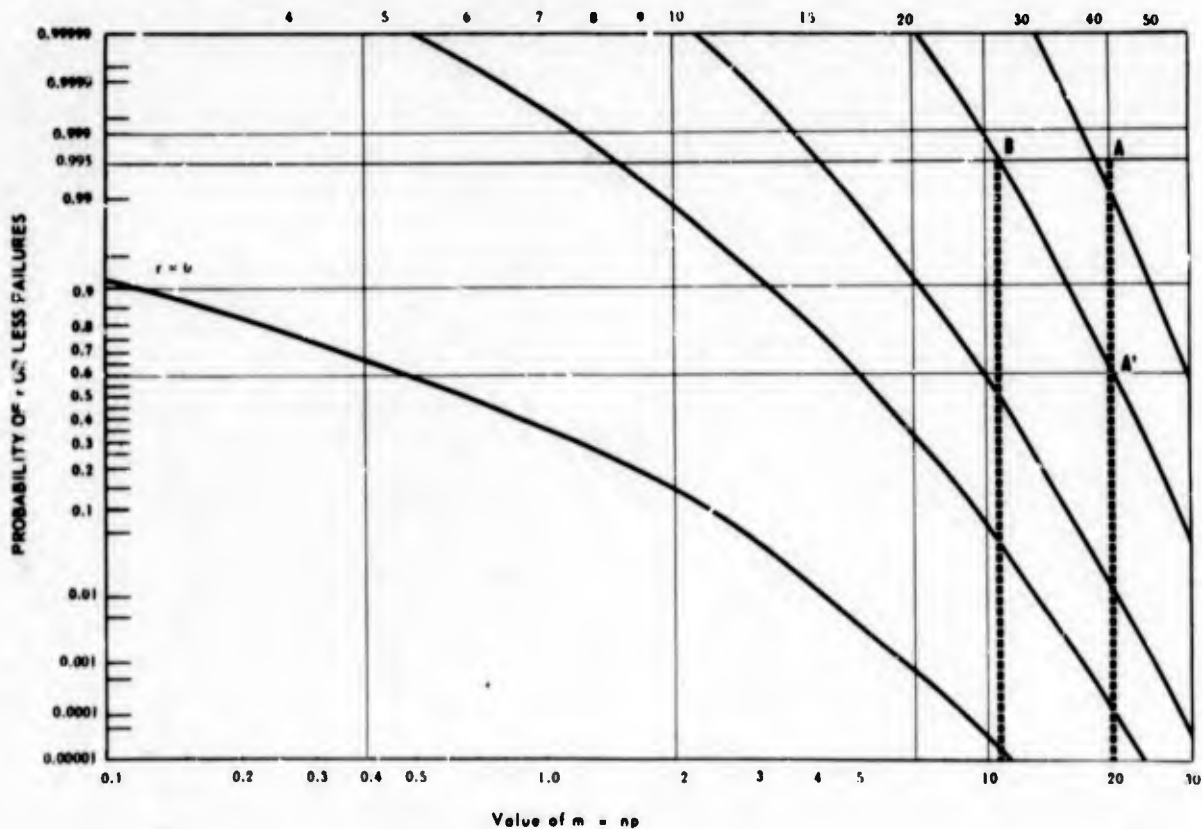


Figure 4

$m = 20$. Point A' shows that there is a 60 percent probability that 20 or fewer failures will occur. If the binomial were used, the probability would be 55 percent.

Point A shows that there is a 99.5 percent probability that 32 or fewer failures will occur (binomial = 31). If a reliability of 89 percent were attained, then m would equal 11 and point B would indicate a 99.5 percent probability of 20 or fewer failures occurring (binomial = 21). This shows graphically that if it is desired, 99.5 percent probability of 20 or fewer failures, an individual weapon reliability of 89 percent is required. Therefore, the 80-percent weapon reliability previously stated is not consistent with the group reliability requirement.

SUMMARY

This discussion has described a procedure whereby a reliability assessment can be made early in a system's life cycle when the following conditions are present:

- The quantity of test data on the proposed design is so limited that a valid assessment is not possible.

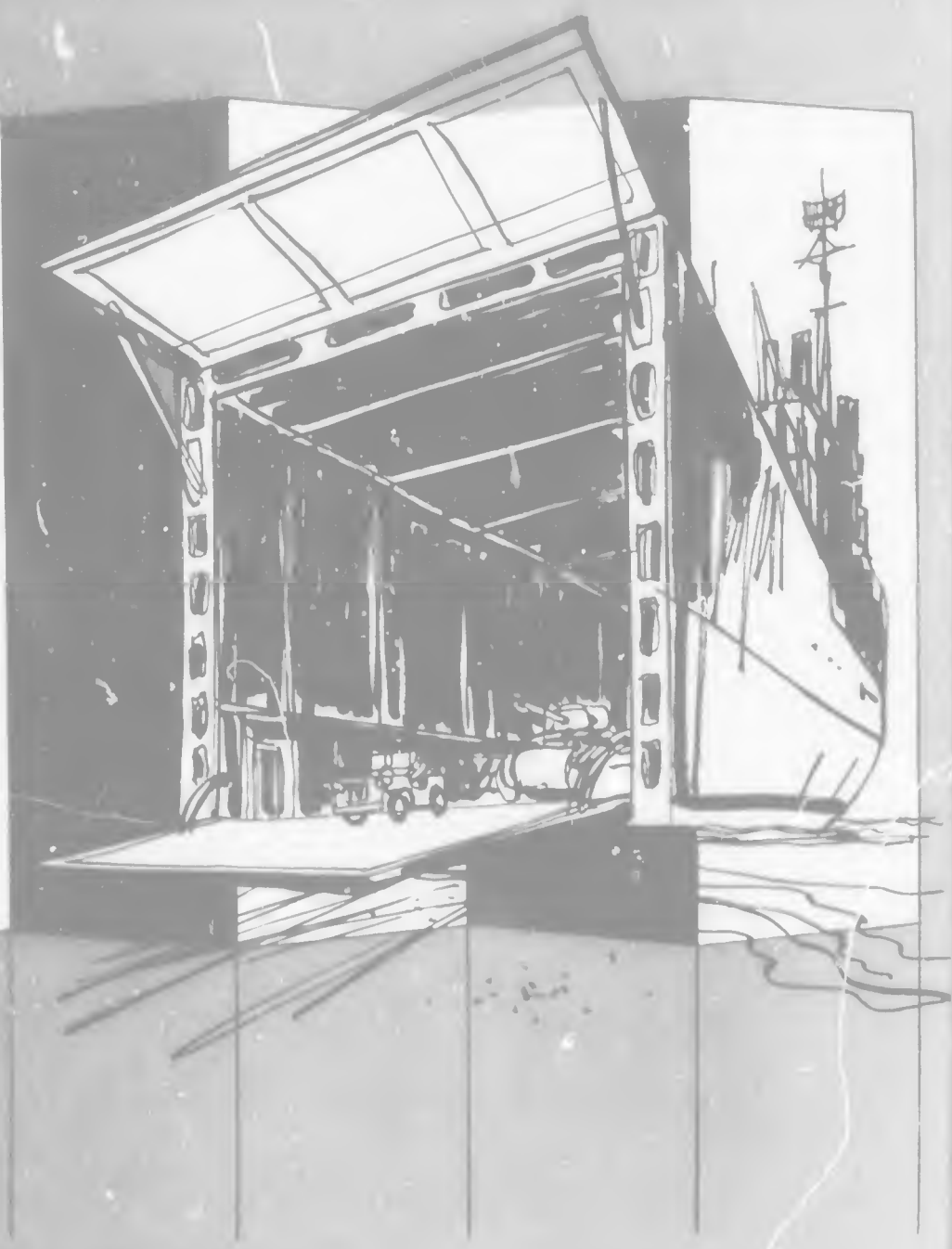
- The proposed design (or portions of it) is similar to developed designs.
- The operating environments and mission requirements of the proposed design are reasonably similar to those of the developed designs.
- Operational reliability data are obtainable for the developed designs.

The discussion has shown that statistical methods are available for combining data from several different sample sizes to develop confidence levels about the point estimates of the combined results. The method used in this study is considered one of the more efficient confidence-interval estimators. There are, however, others that might be easier to compute and that could produce acceptable results.

Finally, the discussion has presented considerations for determining the reliability requirement for an individual weapon when the planning requirement is based on a fixed group of these weapons having a specified reliability. In this case, the individual weapon's reliability must be significantly greater than the group's specified reliability.

NAVY PROGRAM FOR ADVANCED DEVELOPMENT OF LANDING CRAFT

MR. J. L. SCHULER



This paper outlines the genesis of a program which is expected to have a major impact on the effectiveness of Naval Amphibious Operations of the future. This program is fully documented in a classified Technical Development Plan, but will be unclassified here. Only a few major points will be covered. The first will be the program goal and how it evolved. The second will be the program schedule, showing how the Systems Analysis (Operations Research/Computer Simulation) preceded the hardware definition of the system. The third point will be to summarize some of the lessons learned which will be of value in follow-on and similar programs. Finally, these remarks will be tied into the "Systems Performance Effectiveness" issues.

PROGRAM GOAL

The original program goal was stated in January 1965. The goal was to develop a new Landing Craft Vehicle Personnel (LCVP). The LCVP is a 36-foot boat developed in World War II to carry a Jeep or forty people. In the intervening years, many varieties of LCVP have been built. They have been built with steel, wooden and plastic hulls and with or without armor. The LCVP(K) is a Hydrokeel version, and the LCVP(T) is a twin engine version. The LCVP(H) designation has been used for at least three hydrofoil versions.

In view of this long history, a natural question arose when this goal was stated: "When so many versions have been tried, why haven't any been chosen?" Exploring this question uncovered several interesting facts. For example, requirements were also to be issued covering the larger LCM-6 and LCM-8 landing craft. Clearly known deficiencies needed to be cured and these deficiencies were not confined to the LCVP. A catalogue of deficiencies was assembled. In the course of this effort, it was discovered that these craft were used to perform a wide variety of functions. The search and re-

search continued. No one could be found who could clearly relate specific landing craft performance characteristics to "Military Effectiveness."

Armed with these observations, a study was initiated to relate craft performance with the operational effectiveness of amphibious assault operations. The first result of this study was complete frustration. It seemed to be impossible to relate the performance of a single craft to any definable measure of military effectiveness. The study was broadened to address the complete set of craft required to perform an assault operation. Then the pieces began to fall into place. Meaningful effectiveness measures could be defined. One measure was the total time required to put a defined payload on the beach. Another was the speed of response to an unplanned offloading requirement.

By December of 1965, the studies had progressed far enough to submit a PTA (Proposed Technical Approach). This document proposed a broad approach including the analysis of several hundred possible craft concepts of several sizes, speeds and types. The analysis would include operations research, studies, computer simulation and a substantial design effort as well as collection of data and experience on prior designs and existing craft. It was also proposed that the requirements be restated in this broader context. On 29 February 1968, this broader requirement was promulgated in the form of an ADO. The new requirement includes development of an improved set of craft, plus shipboard handling gear and beach handling equipment. It also addressed a wide variety of related problems including refueling and maintenance. It seeks to tie the whole thing together with studies of operational and technical subsystems.

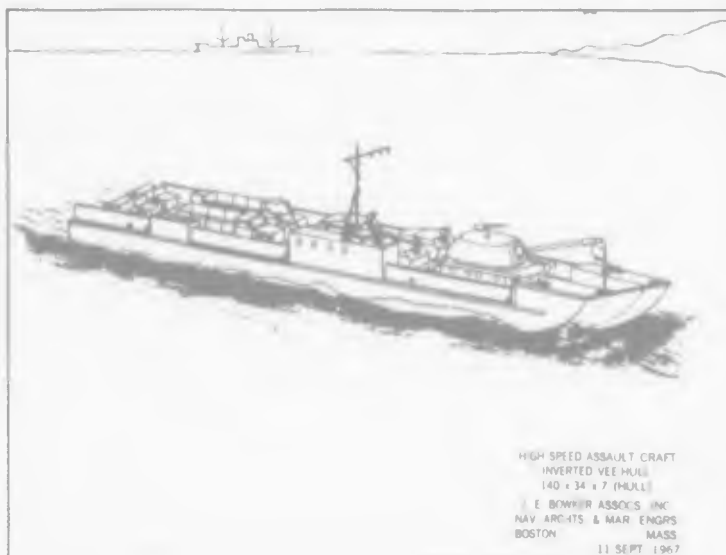
This represents a step up from component to system development. The details of the plan were submitted in a Technical Development Plan on 11 March 1968. The plan was



AVIATION SUPPORT CRAFT
 140' x 34' x 7' (HULL)
 BOSTON, MASS.
 11 SEPT 1967



AMPHIBIOUS LANDING CRAFT
 140' x 34' x 7' (HULL)
 BOSTON, MASS.
 11 SEPT 1967



HIGH SPEED ASSAULT CRAFT
 INVERTED VEE HULL
 140' x 34' x 7' (HULL)
 E. BOWEN ASSOC'S INC
 NAV ARCHT & MAR ENGRS
 BOSTON MASS
 11 SEPT 1967

Figure 1

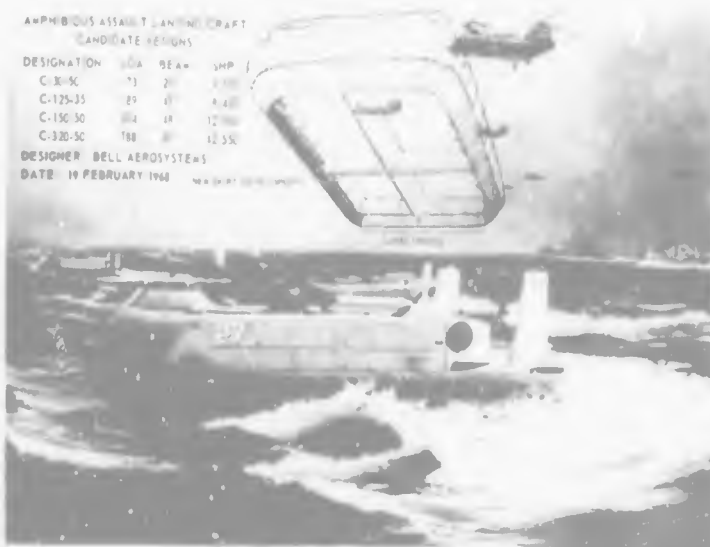
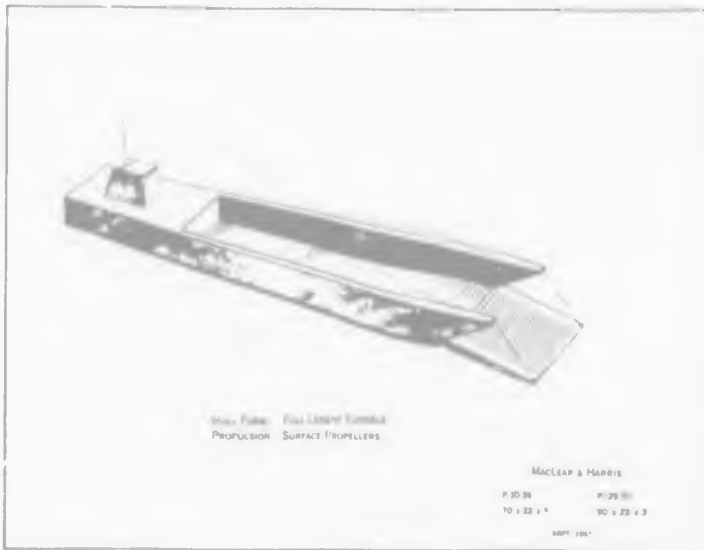


Figure 1

approved on 5 April 1968. Thus, the program has evolved from a few boat improvements to a broad system to improve amphibious assault. Some of the new craft concepts are shown in figure 1.

SCHEDULE

The program schedule is shown, in a very simplified fashion, in figure 2. Note that the systems analysis started before, and will conclude after, the hardware development. In the early years, this is an attempt to define a baseline and measure craft concepts and other hardware possibilities against the baseline. This permits measurement of subsystem improvements in terms of improved system effectiveness.

As the program proceeds, hardware is developed, the configuration becomes firm, tests are made, trials are conducted, and data replaces estimates. The final validation will proceed to accept these data from specific trials and expand them into a broad range

of tactical and strategic situations. By this kind of planning, we find the Systems Effectiveness Analysis preceding the Advanced Development and then reappearing to cement Advanced Development to Engineering Development.

LESSONS LEARNED

The first basic lesson is to view the flow from Exploration through Advanced Development to Engineering Development as a PROCESS. It needs to be managed as a changing thing. If you know the answer before you start, it's not R&D. The plan must be able to grow as greater knowledge becomes available. Even today, after three years of effort, System Effectiveness has not been definitized. The goal is to have the yardstick ready when measurements and decisions need to be made.

The second lesson is derived from the first. It is to make decisions in a timely fashion.

Amphibious Assault Landing Craft
Advanced Development Program

Functions	FY 66	FY 67	FY 68	FY 69	FY 70	FY 71	FY 72	FY 73	
Manage Program	Planning, Guiding, and Monitoring						Conform	SOR	CDF
Provide People	Preliminary Planning and Evaluation			Final Plans		Crew Training			
Analyze System	Planning	Baseline Simulation	Syst. Comprsn. Craft Hndlg		Validation of Simulation				
Design Craft	Planning	Preliminary Designs							
Develop Subsystems	Analysis and Studies of Handling Gear			Design - Build - Test					
Develop Craft			Pro-cure	Design - Build - Test					
Conduct Trials			Prel. Plans	Final Plans	Trials				

Figure 2

Good decisions can only be made when the facts are available. There is a great temptation in an Advanced Development project to decide first and then study. This tendency must be fought. A good plan will produce the required information in a timely manner. This will avoid starts, stops and abrupt re-directions.

A third lesson is that a single firm plan must be prepared. It must also be flexible. It must include reassessment points and re-definition activities. The handiest way to do this is to plan to go through each major decision cycle at least twice. The first decision is tentative. Later, when more information is available, the final decision is made.

For example, it was originally planned that the Stanford Research Institute (SRI) perform all of the Systems Analysis and Computer Simulation work. It was later learned that the NWL, Dahlgren had a great capability available. Their STS-2 Computer Simulation is a unique asset to the Navy. We discovered how to use it and now SRI and NWL are working together in a fashion which is better than either could have done alone.

Another example is the Craft Preliminary Designs. Eleven contractors are preparing thirty one designs and will be added to existing craft (both operational and experi-

mental) to provide about 50 firm craft concepts for the analysis. The analysis will guide in selecting a half dozen prime candidates for development and test. In each case, the cycle will contain construction, test, and trials. None of these six craft will duplicate the preliminary designs. Something will be learned about each in the interim. Clearly, also, these experimental craft will not be duplicated as we move out of this Advanced Development into Engineering Development. Engineering Development is an optimization process and precise optimization is not really expected in the test craft.

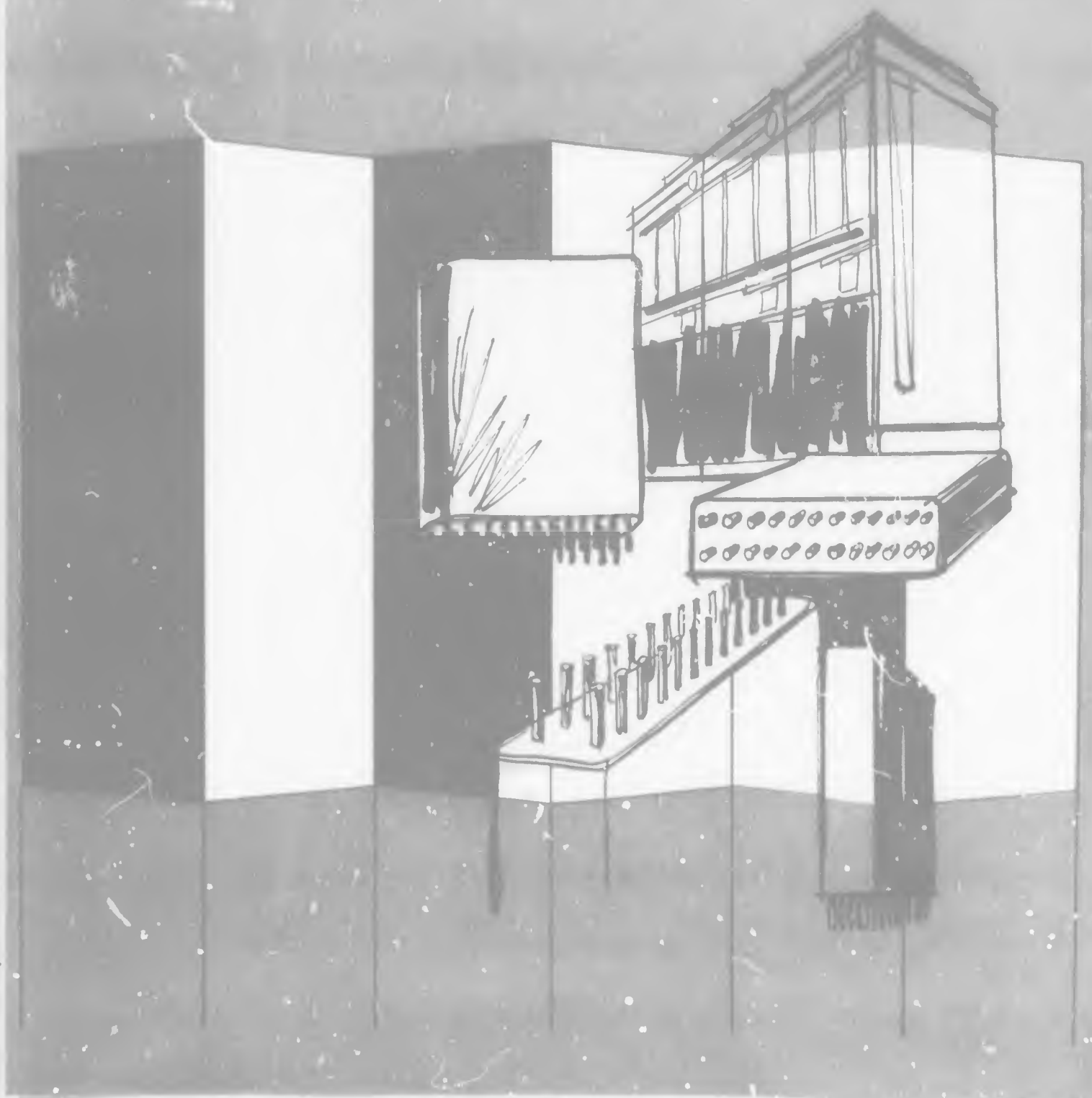
A third example is in the Tentative Test and Trials Plan. This will provide some valuable guidance to the builders. Of course, after the construction contracts have been awarded, this will have to be redone to suit changes in construction site and other details which will be learned in the meantime.

CONCLUSION

The whole program can be summed up by saying we have tried to keep flexible. This is an Advanced Development. It is known that a substantial improvement in effectiveness can be made. In a few years, we will be able to prove the precise magnitude of the improvement. In the meantime our confidence is growing and our pencils are getting sharper.

STANDARDIZATION OF ELECTRONICS COMPONENTS/ EQUIPMENTS

MR. F. M. BERG



In 1966, the Chief of Naval Material initiated a standardization program directed by NAVMAT INSTRUCTION 4120.97, entitled "Standardization of Components/Equipments (C/E) Required for Fleet or Ashore Support." This instruction resulted from a number of studies by the Vice Chief of Naval Operations in 1965 to describe and analyze Navy logistics support and recommend remedial action for problems identified. The proliferation of equipments and components in the hull, electrical and machinery areas of the Navy had reached such proportions that a formal program was necessary to make known the progress in hardware standardization. The Chief of Naval Material added the electronics area to the program.

Lack of C/E standardization has resulted in excessive components and equipments with limited application and many with poor performance histories. Those with poor reliability are degrading the readiness of the fleet. Their use complicates logistic support, leads to excessive costs, excessive spare parts, and a mushrooming of training requirements.

The NAVMAT Component/Equipment Standardization Program applies to all elements of the Naval Material Command covering all hardware, and covers all phases of system development, acquisition, and maintenance. It encompasses all systems, subsystems, equipments and components under the cognizance of the NMC, including aviation, ordnance, ship, electronics, construction, and material handling equipment. Stated in the broadest terms, the policy of the program is to:

- Include hardware standardization requirements in concept formulation, contract definition, procurement, production, maintenance, conversion, modernization and alteration.
- Standardize designs - with - inter and intra-system standardization of C/E and parts.

- Reuse (in new design) existing, suitable C/E already supported in depth by the military system.
- Preclude use of limited application and poor performance C/E.
- Exercise configuration control to maintain standardization.
- Use procurement techniques to restrain proliferation.
- Effect item entry control in design selection and provisioning phases of material acquisition.

The attainment of optimum standardization by curbing C/E make and model multiplication, and resultant spare parts proliferation, must be within the bounds of Armed Services Procurement Regulation (ASPR) and all requirements of the Defense Standardization Program. Standardization cannot be mandated arbitrarily. It must result from thoroughly considered trade-offs, generally on the basis of total costs versus effectiveness.

By definition, "Components/Equipments" (C/E), as applied here, are repairable items which either require repair part support or will require it when introduced into Naval operating forces, afloat or ashore. In the electronics area, this program does not apply to repair parts such as capacitors, resistors, transformers, etc., but rather to such equipment as: transmitters, receivers, modems and repairable components. The kinds or types of material to which NAVELEX is applying the policy of the NAVMAT Instruction are those for which it has Command Charter assigned material support responsibilities.

As of February 1968, these materials were:

- Shore (ground) electronics, complete (except Marine Corps tactical).
- Shipboard electronic equipment under system control of the Ship Systems Command: IFF, ECM, Communications, and NAVAIDS.

- SOSUS
- Material support for NAVAIRSYS-COM electronic equipment: NAV-AIDS, Air Traffic Control, Meteorology.
- Space programs; SATCOM and material support of SPASUR.
- Shore based strategic data systems; OPCON centers.
- Data-link systems (external to ships and aircraft).
- Radiac equipment.
- General-purpose electronic test equipment, components, techniques, and services.
- Electronic systems not otherwise assigned.

The standardization of electronics components and equipments is a difficult task. Dynamic changes in the state-of-the-art, the complexity of equipments and systems, the necessity for more advanced, more reliable, more maintainable, smaller and less power-consuming electronic hardware to meet changing military requirements are critical factors in this assignment.

The immediate goals for standardization of NAVEX components and equipments are: first to determine the background and status of NAVEX cognizance material, and secondly, to apply standardization planning and action. **Background** means the identification of a component and/or equipment and its association with one or more military requirements. **Status** means the performance ability of a component and/or equipment to meet one or more military requirements. Terms applicable to shipboard C/F authorized by the Office of the Chief of Naval Operations, known as suitability status classifications, are used to categorize performance ability. These are:

Planned Standard — Equipments under evaluation or consideration. Approval for service use and classification is required prior to installation.

Standard — The most advanced and satisfactory equipment approved for service use. These are preferred for procurement.

Substitute Standard — Equipments approved for service use which do not have as satisfactory military characteristics as standard equipments. When necessary, they may be procured to supplement the supply of standard equipments.

Limited Standard — Equipments approved for service use which do not have as satisfactory military characteristics as standard or substitute standard equipments, but are usable substitutes. Complete major units will not be procured, but component parts, accessories and complementary articles, even though they too may be limited standard equipments, may be procured if necessary and economical, to maintain complete major units in serviceable condition for a reasonable life expectancy.

Obsolescent — Equipments which no longer have satisfactory military characteristics, but which must be continued in service pending availability of improved replacements. Complete units, component parts, accessories, and complementary articles will normally not be procured for maintaining this equipment. Spare parts common to other equipment in the supply establishment may be used, however, for their maintenance.

Obsolete — Classification denoting those equipments which have been declared unsuitable for their original military purpose. Disposal of stocks of obsolete equipment will, in all cases, be expedited.

The previously mentioned goals, i.e., to determine background and status of NAVEX material and secondly, to apply standardization planning and action utilizing these classification terms are implemented by a number of tasks which are included presently in the standardization plan described by NAVEX INST 4120.1. The interplay of these goals, terms, and tasks are shown in figure 1 entitled "Standardization of NAVEX C/E."

Referring to figure 1, notice that potential NAVEX C/E, the need for which is generated by a military requirement, starts at the top and in the center of the figure. Then in succession there is standardization planning, procurement planning, and as the material is procured, the various NAVEX

C/E flow into the rectangle which symbolizes installation in the operating forces, and become stratified according to their suitability status classifications (i.e., their ability to meet the military requirement for which procured). In the desired life cycle history of C/E, material would start as a Planned Standard and migrate to successively lower strata classifications and finally to Obsolete C/E, which is drained off when disposal takes place. The NAVELEX Standardization Plan then surrounds this basic flow and is implemented by the seven tasks identified on the figure.

The program responding to this plan is evolutionary due to the broad range of material and actions involved.

Further tasks will be instituted as the program evolves. Studies under Task 1, entitled "Identification of NAVELEX C/E," have revealed approximately 9000 nomenclatured, or otherwise, identified C/E used or being used

afloat. Similarly, 18,000 NAVELEX C/E were or are applicable to use ashore. Many find application both ashore and afloat. Task 2, entitled "Population Data for NAVELEX C/E," discloses the number of C/E presently installed afloat and ashore. Involved are both the active and reserve fleets, and all activities in the Naval Shore Establishment such as, Naval Communication System Radio Stations, U.S. Fleet Training Centers, Reserve training Centers, and Support Activities. With NAVELEX C/E identified and population counts made, Task 3, entitled "Suitability Assignments for NAVELEX C/E" determines the suitability status classification assignments, i.e., Planned Standard, Standards, etc. Tasks 1, 2, and 3, together, provide the background and status for the second program goal which is to apply standardization planning and action.

Let us observe some results of Tasks 1, 2, and 3 in a study of 52,391 NAVELEX C/E items installed afloat, consisting of radio

STANDARDIZATION OF NAVELEX C/E

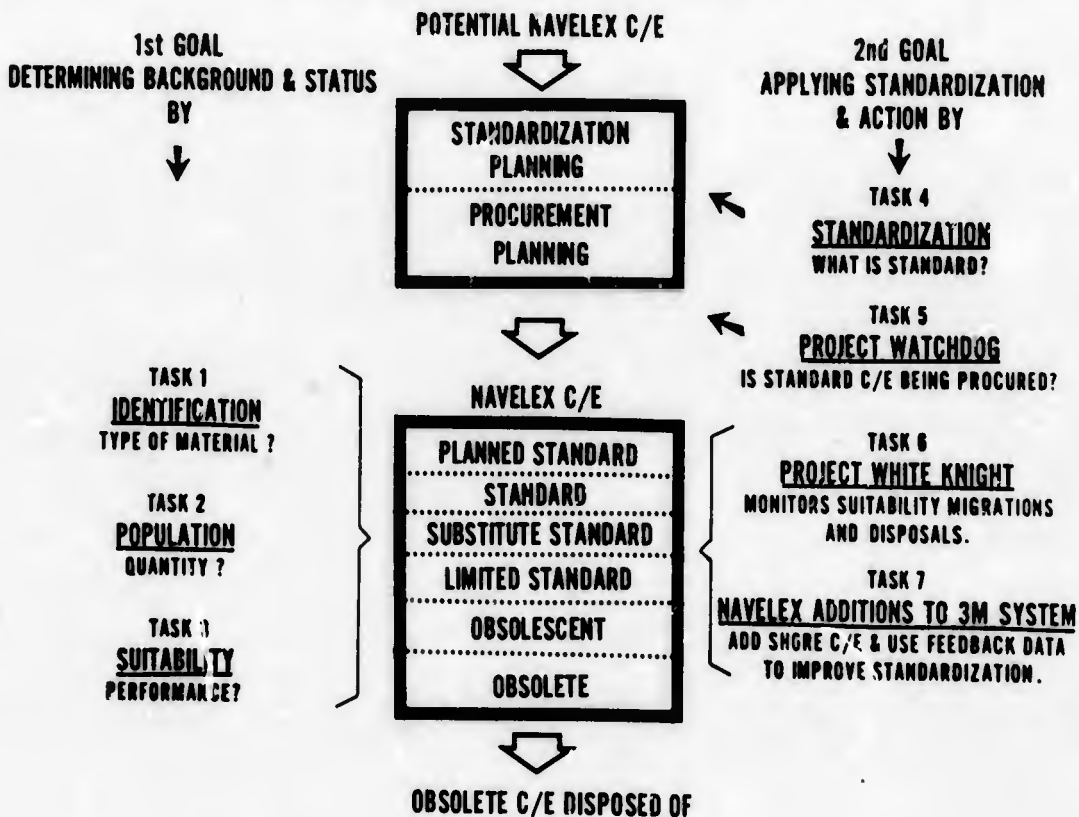


Figure 1

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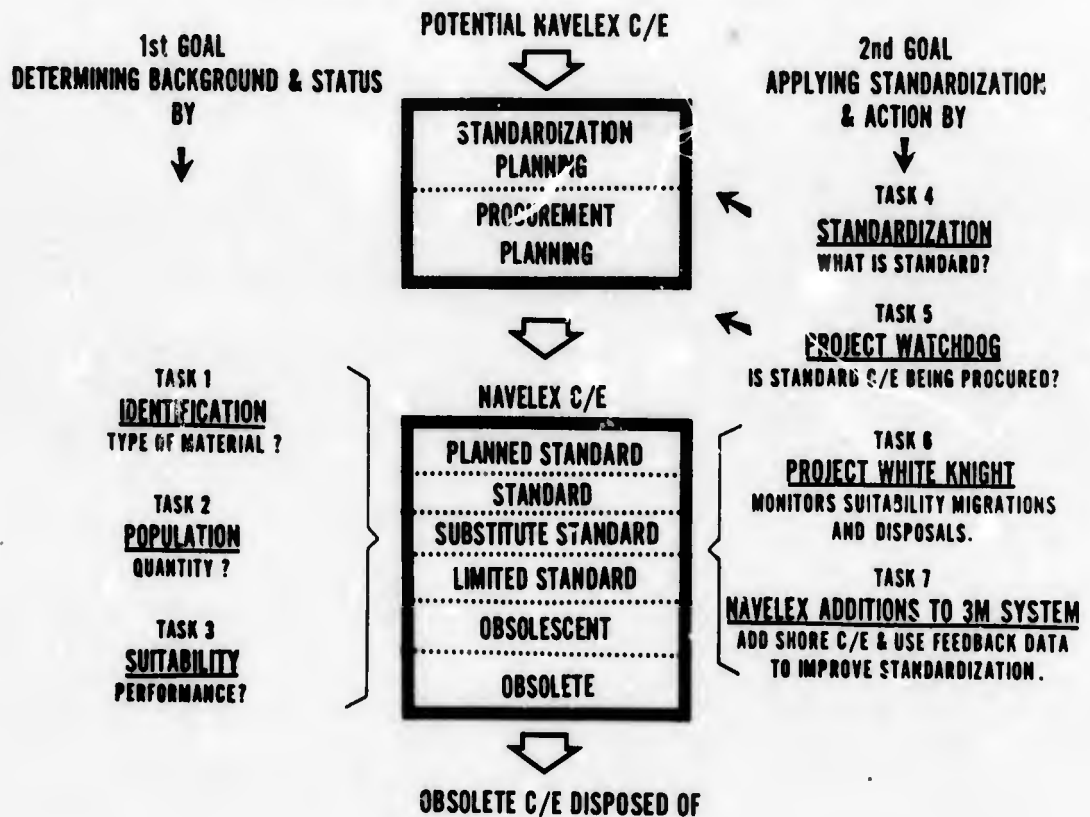


Figure 1

data collection effort applicable to NAVEL-EX C/E.

Task 5, "Project Watch Dog," monitors Procurement Requests (PR's) to determine the extent to which standard NAVELEX C/E is being procured. Appropriate MIL specifications and standards are cited in the PR's. Task 5 provides feed-back to technical and logistic support organizations within NAVELEX for initiating or accelerating standardization programs for NAVELEX C/E. Full implementation of this task is dependent upon the assignment of suitability status classifications to NAVELEX C/E used ashore, and to C/E used afloat that have no assignments. When this occurs, standardization will be more effectively policed.

At this stage of the program, "Project Watch Dog" is making an analysis of C/E procurement. Analyzed were 210 typical PR's under the following categories:

- RDT&E and Software Studies.
- Hardware.
- Services and Miscellaneous Items.

Figure 4 shows the percentage of PR's by

quantity and dollar value related to each of these categories. The purpose of the analysis was to determine the nature of what was being bought. It soon became apparent that the hardware category as described in figure 4, comprising 65% of the 210 PR's and 59% of the total dollar value, was the prime area of interest. It will be observed, by referring to figure 3, that this is the category where the standardization actions are taking place.

Task 6, "Project White Knight," monitors the migration or changes to NAVELEX C/E suitability status classifications, the disposal of those designated obsolete, and the eventual elimination from the supply system of repair parts when no C/E remains. It advises the Electronics Supply Office (ESO), Great Lakes, Illinois, of changes taking place in the suitability status classifications of NAVELEX C/E, as well as changes that may be required for repair parts support of the NAVELEX C/E affected. When obsolete C/E is eliminated from installations, this task informs ESO to cancel the Allowance Parts Lists (APL's) and to declare, as excess, parts peculiar to the C/E involved.

**PROJECT WATCH DOG
ANALYSIS OF 210 PROCUREMENT REQUESTS TO DETERMINE
NAVELEX C/E STANDARDIZATION POTENTIAL**

PR CATEGORY	WHAT'S BEING PROCURED	% OF 210 PR's ANALYZED	% TOTAL DOLLAR VALUE
RDT&E AND SOFTWARE STUDIES	RDT&E IN TECHNOLOGIES INVOLVING VACUUM TUBES AND SOLID STATE, ELECTRO-OPTICS, MICROWAVE, COMMUNICATIONS, SPECIAL SURVEILLANCE, FIELD MEASUREMENTS, ETC. STUDIES INVOLVING COST EFFECTIVENESS, ELECTROMAGNETIC COMPATIBILITY, COMMUNICATIONS, ETC.	17%	31%
HARDWARE	SHORE AND SHIPBOARD ELECTRONICS COMPONENTS/EQUIPMENTS INVOLVING COMMUNICATIONS, IFF, ECM AND NAVAIDS, AIR TRAFFIC CONTROL, METEOROLOGY, RADIAC, GENERAL PURPOSE TEST EQUIPMENTS, ETC.	65%	59%
SERVICES AND MISCELLANEOUS ITEMS	ENGINEERING SERVICES, TRAINING ASSISTANCE, MODIFICATION KITS, ANCILLARY COMPONENTS USED IN INSTALLATION, ETC.	18%	10%

Figure 4

**SUMMARY OF POPULATION DATA (TASK 2) AND SUITABILITY ASSIGNMENTS (TASK 3)
FOR NAVELEX COMMUNICATIONS EQUIPMENT AFLOAT (ACTIVE FLEET)**

# OF SCAT* ASSIGNMENTS ASSOCIATED WITH C/E TYPES	TYPE OF C/E	VARIETY OF NOMENCLATURED TYPES		SUITABILITY CLASSIFICATION AND C/E POPULATION AFLOAT (ACTIVE FLEET)						
		WHEN COUNTED WITH SUFFIXES**	WHEN COUNTED WITHOUT SUFFIXES	PLANNED STANDARD	STANDARD	SUBSTITUTE STANDARD	LIMITED STANDARD	OBSOLESCENT	OBSOLETE	TOTALS
10	RADIO TRANSMITTERS	97	36	0	2,702	1,498	82	6	3,988 (a)	9,255
11	RADIO RECEIVERS	114	42	11	1,273	2,325	4,077	5,884	3,803 (b)	18,953
34	RADIO TRANSCIVERS	80	43	0	3,214	282	3,235	2,827	2,115 (c)	11,663
16	MODEMS	50	16	0	384	0	0	0	0	384
21	TELETYPES	119	87	0	8,185	4,358	1,749	2,381	443	15,116
TOTAL 90		478	284	11	13,758	8,471	8,123	10,878	10,158	52,391
% SUITABILITY CLASSIFICATION DISTRIBUTION OF 52,391 C/E				0.02%	26.26%	16.17%	17.42%	20.77%	19.36%	

NOTES: *SCAT - Sub-Category Requirement i.e. breakdown of functional requirements to be met by certain functional types of equipments and components such as transmitters, receivers, etc.
 ** - Suffix is defined as an alphabetical letter added to the basic nomenclature i.e. AN/WRC-10. The 0 is the suffix.
 (a) - 97.9% or 3873 Transmitters consist of 6 nomenclatured types.
 (b) - 95.8% or 3453 Receivers consist of 5 nomenclatured types.
 (c) - 98.7% or 2088 Transceivers consist of 5 nomenclatured types.

Figure 2

transmitters, receivers, transceivers, modems and teletypes. Figure 2 is a tabulation of these results. Of the total C/E involved, the suitability status classification assignment percentage breakdown for the sample is:

Classification Assignment	% Breakdown for Sample
Planned Standard	0.02%
Standard	26.26%
Substitute Standard	16.17%
Limited Standard	17.42%
Obsolescent	20.77%
Obsolete	19.36%

It is significant that 97.9% of the obsolete transmitters consist of only six nomenclatured types; 95.8% of the obsolete receivers and 98.7% of the obsolete transceivers consist of only five nomenclatured types each. This may be explained by the practice, followed for many years, of consolidating purchases of major shipboard electronic C/E as Government-Furnished Material (GFM). Essentially, such practice has placed a degree

of control on what could have been unbridled proliferation of many types of C/E for given operational requirements. The fact that sizeable numbers of obsolete transmitters, receivers, and transceivers are concentrated in so few nomenclatured types, indicates that consolidating purchases assists in promoting standardization. Invoking the multi-year, instead of the single-year, method of procurement even further serves to limit the proliferation of different type C/E for a requirement. Under ASPR, if the multi-year method of procurement is invoked in a contract, the successful bidder may produce the C/E up to a maximum of five years, rather than one. Thus, when electronics C/E is procured by the multi-year method, particularly where performance type specifications are involved, proliferation is reduced, if no engineering production changes are made. However, to keep a Navy standardized with hardware as dynamic as electronics, for which military requirements are constantly being changed or upgraded, is a very difficult task. Where

C/E has been declared unsuitable for its original military purpose, a desirable and systematic replacement rate of installed obsolete C/E has been thwarted by limited annual funding levels and budgetary priorities.

Task 4, entitled "NAVELEX C/E Standardization," now comes into play. This Task provides visibility for standardization planning and action. Figure 3 illustrates Task 4 standardization accomplishments to date for certain general purpose oscilloscopes, signal generators, electronic counters and a number of shipboard radio transmitters, receivers and transceivers. Additional families of C/E are under study to establish background and status information, as well as the goal of standardization. Documentation from which these studies are derived has influenced the selection of shipboard C/E first. It is anticipated

that standardization studies of C/E for the Naval Shore Establishment will be far more difficult since an applicable suitability status classification system has yet to be devised. NAVELEX has commenced action in regard to this problem by issuance of an instruction which provides a systematic method for dealing with NAVELEX C/E used ashore as well as afloat.

Task 5, entitled "Project Watch Dog," covers NAVELEX C/E procurement. Task 6, entitled "Project White Knight," monitors changes in the suitability status classifications of NAVELEX C/E and provides orderly procedures for withdrawal of support when obsolete C/E is no longer installed. Task 7, entitled "NAVELEX Additions to the 3-M System," provides visibility for the standardized preventive maintenance and maintenance

NAVELEX COMPONENT/EQUIPMENT STANDARDIZATION

1. STANDARDIZATION OF GENERAL PURPOSE TEST EQUIPMENT

EQUIPMENT CATEGORY	FUNCTIONAL REQUIREMENTS	EQUIPMENT TYPES USED	STANDARDIZATION ACTION TO SATISFY FUNCTIONAL REQUIREMENTS AS OF 2/68
OSCILLOSCOPES	19	66	3 TYPES NOW STANDARD
	<u>2</u>	<u>6</u>	3 TYPES PLANNED STANDARD
	21	72	TOTAL - 6 TYPES PLANNED PROCURE FY-69
SIGNAL GENERATORS	7	23	3 TYPES NOW STANDARD
	<u>13</u>	<u>50</u>	3 TYPES UNDER DEVELOPMENT
	20	73	TOTAL - 6 TYPES PLANNED PROCURE FY-70
ELECTRONIC COUNTERS	6	27	TOTAL - 2 TYPES NOW STANDARD

2. STANDARDIZATION OF CERTAIN RADIO TRANSMITTERS, RECEIVERS, AND TRANSCEIVERS

RADIO TRANSMITTERS	5	18	TOTAL - 3 TYPES NOW STANDARD
RADIO RECEIVERS	6	28	TOTAL - 5 TYPES NOW STANDARD
TRANSCEIVERS	3	4	1 NOW STANDARD
	<u>12</u>	<u>11</u>	2 TYPES PLANNED STANDARD
	15	15	TOTAL - 3 TYPES PLANNED PROCURE FY-70

Figure 3

data collection effort applicable to NAVEL-EX C/E.

Task 5, "Project Watch Dog," monitors Procurement Requests (PR's) to determine the extent to which standard NAVEL-EX C/E is being procured. Appropriate MIL specifications and standards are cited in the PR's. Task 5 provides feed-back to technical and logistic support organizations within NAVEL-EX for initiating or accelerating standardization programs for NAVEL-EX C/E. Full implementation of this task is dependent upon the assignment of suitability status classifications to NAVEL-EX C/E used ashore, and to C/E used afloat that have no assignments. When this occurs, standardization will be more effectively policed.

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SERVICES AND MISCELLANEOUS ITEMS	ENGINEERING SERVICES, TRAINING ASSISTANCE, MODIFICATION KITS, ANCILLARY COMPONENTS USED IN INSTALLATION, ETC.	18%	10%

Figure 4

PROJECT WHITE KNIGHT
NAVELEX C/E SUITABILITY STATUS CLASSIFICATIONS CHANGED DURING 1967

C/E DESIGNATIONS

STANDARD	SUBSTITUTE STANDARD	LIMITED STANDARD	OBOLESCE	OBSOLETE	OBSOLETE C/E INSTALLED *	
					AFLOAT	ASHORE
AN/USM-281/296	AN/URM-52A, B	AN/URC-58(V)	R-390/URR	AN/FGC-11	1	36
AN/SPN-40	AN/URM-61A	AN/SDR-2	CV-89/URA-8A	AN/PDR-27NX	34	0
	AN/URM-54A	TT-171/UG	AN/USM-113	AN/PDR-58	5	0
	AN/URM-103	CP-95/PD	PP-364C/PD	AN/PDR-58A	0	0
	AN/URM-140B, C, D			AN/SGC-2	15	4
	AN/USM-49A			AN/UGC-40	283	0
	AN/USM-105A			AN/UCC-41	86	0
	AN/USM-139			AN/URA-8	35	11
	AN/USM-141			CP-95B/PD	0	0
	IM-144A/WOQ			CV-89A/URA-8A	12	6
				TT-298/UG	16	0
				TT-298A/UG	1	0
				TT-299/UG	31	0
				TT-299A/UG	81	0
				TT-299B/UG	648	64
				TDQ	100	36

* PROJECT WHITE KNIGHT REVEALS WHEN INSTALLED QUANTITIES OF OBSOLETE C/E ARE REDUCED TO ZERO. IF SUPPORT IS NO LONGER REQUIRED, ACTION WILL BE INITIATED WITH THE ELECTRONIC SUPPLY OFFICE, GREAT LAKES, ILLINOIS FOR CANCELLATION OF THE AUTHORIZED PARTS LIST (APL's) PROVIDING FOR THE DISPOSAL OF PARTS FROM THE SUPPLY SYSTEM.

Figure 5

A total of 36 suitability status classification changes occurred during 1967. These are shown on figure 5. Sixteen C/E were designated obsolete, as unsuitable for their original military purpose. Disposal of stocks are being expedited. As shown in figure 5, quantities installed afloat and ashore are displayed to the right of each obsolete designated C/E. Prior to this cancellation of the Authorized Parts List (and disposal of parts peculiar for each of the obsolete C/E shown), these quantities must be reduced to zero. "Project White Knight" provides visibility for a number of vital factors involved in the final step of withdrawing interest and disposing of obsolete C/E.

Finally Task 7, "NAVELEX Additions to the 3-M System," provides visibility to the number of ashore-installed NAVELEX C/E planned under the Navy Maintenance and Material Management (3-M) System. This task describes part of NAVELEX's effort in standardizing preventive maintenance and

maintenance-data collection. The system consists of two subsystems. One is the Planned Maintenance Subsystem (PMS) which includes the development of Maintenance Requirements Cards (MRC's) to provide standard scheduled maintenance procedures for each C/E and system. The other is the Maintenance-Data Collection Subsystem (MCDS), which includes the assignment of Equipment Identification Codes (EIC) resulting from an identification breakdown of shore-installed C/E and system identification.

NAVELEX has the responsibility of providing maintenance support for NAVELEX C/E installed ashore. A pilot run is now underway to implement the 3-M System in Shore Facilities. A Planned Maintenance Subsystem specification/purchase description has been completed for the procurement of MRC's with newly acquired NAVELEX C/E.

NAVSHIPS is the Program Manager for the 3-M System afloat. As of early 1968, fifty

percent of all NAVSHIPS/NAVELEX nomenclatured electronic C/E used afloat, and subject to the 3-M Subsystem, have been EIC coded. PMS, applicable to electronics C/E, has been delivered to 94% of the ships in the fleet.

The 3-M System input into the NAVELEX C/E Standardization Program provides an important source of data, enabling decision on appropriate standardization status classification.

The proliferation of C/E used in systems and subsystems applicable to aviation, ordnance, ships, electronics, construction and material-handling equipment is a serious problem. Formal programs have been initiated, by the Chief of Naval Operations and the Chief of Naval Material for the Naval Systems Commands, to develop and increase standardization. C/E standardization increases effectiveness and reduces costs for the Navy's use of its resources.

The NAVELEX plan of operation is two-fold. The first, to determine the background and status of NAVELEX C/E. The second, to apply standardization planning and action. These goals which will hopefully be accomplished by Tasks to channel and make visible

the standardization effort, are a major challenge. NAVELEX accepts the challenge.

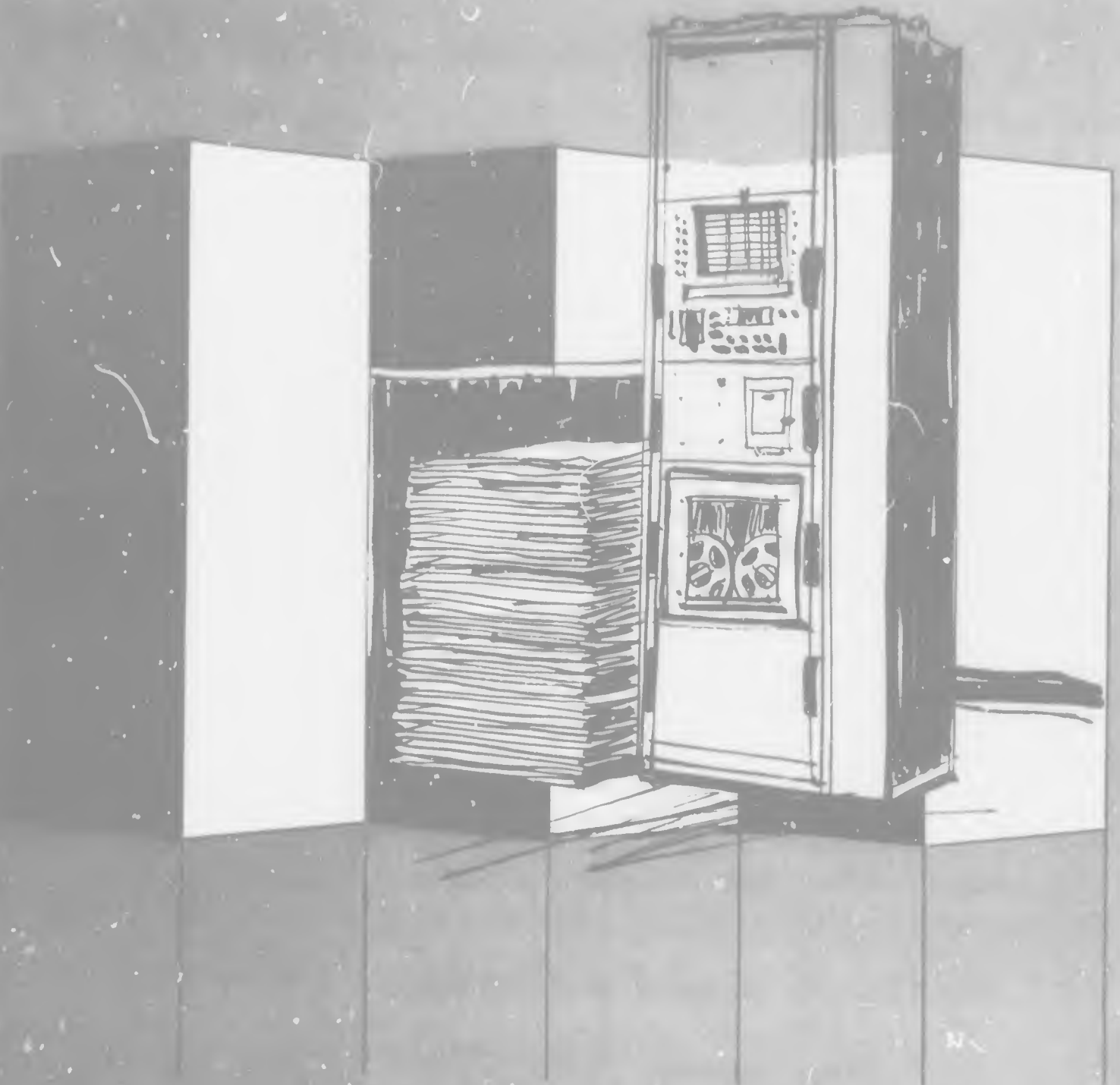
Acknowledgement and appreciation are extended to Messrs. A. J. Gugler, W. L. Heitman, and G. B. Gustafson, Electronics Standards Office, U.S. Naval Electronic Systems Command, for their assistance in the collection and analysis of data used in this paper and for their helpful advice.

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SHIPBOARD CENTRALIZED AUTOMATIC TEST EQUIPMENT/THE SOFTWARE DILEMMA

MR. J. ROSEN
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During the experimental and early development phases of shipboard automatic testing systems, the hardware was given major emphasis. The limited software in these early phases was used to test concepts and provide laboratory demonstrations of hardware feasibility. Software techniques were developed solely for these purposes.

Today, these systems are in development hardware form and are undergoing test and evaluation which will lead to appearance of preproduction hardware in the near future.

It is time to adapt the techniques used to produce one-of-a-kind software, to the large scale production of automatic test systems programs that will be required when these systems are introduced into the Fleet.

This paper presents some of the major problems in producing software for automatic test systems and highlights a few of the production problems encountered and the solutions that were found for the following NAVSHIPS systems.

- **Test Evaluation and Monitoring System (TEAMS)**

This system continuously monitors on-line electronic systems, and isolates faults to a line replaceable unit. The central processor is controlled by a program that is read from a perforated mylar tape.

- **Automatic Test System (ATS)**

This system continuously monitors performance of on-line electronic systems, predicts trends, and isolates faults to a line replaceable unit. The central processor is computer controlled by a program loaded in the computer memory.

- **Assembly Tester (NELAT)**

This system automatically check out discrete line replaceable units, and semi-automatically isolates faults to component parts. The units to be checked are removed from the parent system,

carried to and plugged into the NELAT. The central processor is controlled by a program that is read from a microfilm carrying both control codes and viewable graphics.

GENERAL

The major features of automatic test software discussed later are:

- **English Language Programs (ELP)**

These are the end-to-end monitor, test, and fault isolation procedures described step by step in English language statements.

- **Machine Language Programs (MLP)**

These are the ELP integrated with machine control instructions and then converted into the machine language of an automatic test system.

- **In Service Programs (ISP)**

These are the machine language programs integrated with graphics (NELAT), the computer executive programming (ATS), or the manual fault isolation procedures (TEAMS). The in service programs software produced ready for issue are: for NELAT — microfilm in cartridges; for TEAMS — perforated mylar tape on reels and fault isolation procedural sheets; for ATS — computer magnetic tapes.

- **Validation of in Service Programs**

The validation of ISPs is a total acceptance checkout, with the individual ISP loaded into the automatic test system. The automatic test system is connected to the systems under test and the validation is performed with all systems energized.

- **ISP Change Control**

The problems and proposed solutions for correcting ISP deficiencies or updating ISPs because of field changes and alterations of monitoring systems are contained in this program.

English Language Programs

Automatic testing information, upon which the ISP is based, for the on-line system (TEAMS or ATS) is different from that required by the off-line system (NELAT). This difference arises from the system purpose. TEAMS and ATS monitor systems performance and isolate faults to a line replaceable unit (LRU); whereas NELAT operates upon allegedly faulted LRUs to check out their performance and isolate faults to the defective components parts.

Assembly of the end-to-end checkout program from technical manuals, specifications, test plans, acceptance and buy-off criteria, is not feasible costwise or timewise. For new systems such programs are best developed while the new systems are being tested, designed and produced. For retrofit of existing systems, programs are most efficiently developed by the system contractor.

Therefore, the Navy has prepared two military standards for the test information required and has called the deliverable test information package the "English Language Program (ELP)".

For the on-line test systems the applicable military standard is MIL-STD-1326 (NAVY) 15 January 1968 "Test Points, Test Point Selection and Interface Requirements for Equipments Monitored by Shipboard On-line Automatic Test Equipment.

- Logic for monitoring performance;
- Logic for fault isolation;
- Test point and selection;
- Sensor requirements;
- Performance limit values, stimuli, sensor output signal interpretation, delay and timing consideration; and
- Interface hardware and connection.

For the off-line system (NELAT), the applicable military standard has been prepared, is under review, and will be released in the near future. This military standard is titled, "Test Information Requirements for Modular or Other Replaceable Electronic Assemblies to be Tested by Automatic Test Equipment."

The standard will cover the information requirements for individual assemblies:

- Physical parameters of the assembly and assembly parts layout;
- Passive resistance tests, performance tests, and fault isolation tests to be performed automatically using the connector pins;
- Manual tests or actions required for tests not possible at the connector pins;
- End-to-end test logic;
- Performance limit values, stimuli, loads, delay and timing considerations; and
- Fault isolation logic and part replacement procedures.

It is intended that the ELP will be developed by the hardware contractor, who will deliver a completely integrated end-to-end program in two formats. One format will be the ELP documented in english statements of each procedural step. The second format will be a coded version of the ELP on keypunched cards.

The purpose of the second format is to enable quick conversion of the ELP to machine language of any test system. The code format is under development by the Navy Automated Testing Software Center (NATSC).

Machine Language Program (MLP)

Conversion of an ELP to an MLP is a manpower and time consuming task, and fraught with many opportunities for errors, if performed manually. Therefore, a compiler is being developed for each automatic test system to integrate the ELP coded instructions with pertinent system instructions and produce a card deck or magnetic tape of the MLP for each automatic test system.

In Service Programs (ISP)

ISPs are the finished programs ready for insertion in the automatic test system. However to produce the ISP end item for each system requires a different method.

ATS requires a second compiler to merge the MLP with the ATS computer executive program to produce the ISPs for various

ATS installations. These are complete programs on ready-to-load magnetic tapes.

TEAMS requires a second compiler to produce the ISP. This is recorded on perforated mylar tape. The ISP also has companion manual fault isolation instruction sheets (in English).

NELATS requires special filming equipment to merge the compiler MLP punched cards and graphic photomats. The ISP is on microfilm that is then assembled into film cartridges. The special filming equipment has logic to differentiate among the punched cards that are format instructions, code images for exposure, and what is to be exposed on the film.

VALIDATION OF AUTOMATIC TESTING SOFTWARE

The marriage of a unit under test (UUT) to a test system is performed through software, but consummation of the marriage only occurs when the UUT and the test system are mated successfully.

If the UTT design is compatible with the tester design, and the tester has been loaded with the program, then the moment of truth is at hand. What will happen when the UUT is integrated with the tester?

If the information upon which the tester program is based was correct, if no errors were introduced in preparing the program, if the tester is performing correctly, and if the UUT is the one for which the test program was prepared, then the system should work successfully.

This is validation, but only the start. If the system does not work successfully the validation process must identify the cause, determine the corrective action required, and correct the fault. However, this process can be complicated somewhat by the possible source of the fault; the UTT, the program, the test system, and the numerous variables within each source.

There is a basic difference between on-line and off-line testing which is due to portability or immobility of the UUTs serviced. Validation of on-line test programs is very different from validation of off-line programs.

The UUTs serviced by the on-line testers are large equipments (e.g. a shipboard radar or sonar) that cannot be removed, replaced, and checked out in a shop. The UUTs serviced by an off-line tester are replaceable units (e.g. modular plug-in assemblies) that can be removed, replaced, and checked out in a shop.

On-line testers monitor shipboard systems in place, detect degradations or malfunctions, and isolate the fault to a line replaceable unit. Therefore, validation of the on-line test programs can only be done on a ship having the on-line tester, the systems to be monitored, and the test program.

Since on-line validation must be a shipboard operation the Validating Activity must be a Navy Center closely related to the Fleet. This activity will checkout all new on-line test programs aboard ship and maintain an automatic test data feedback system to ensure continuing validity of these programs.

Off-line test programs, however can be totally validated at the NATSC prior to release of NELAT ISPs.

On-line ISP Validation

Although the original ISP is carefully prepared so that the performance limit values are those established in the contract or ELP, some modification may be required. Ship power variations due to loading and unloading of primary power sources may cause shifts in performance limits. Variant equipment installations could also affect performance limits, as may other unique shipboard environmental influences. The probability of this problem arising will be examined during validation. The solution to the problem is to modify stored performance limits to accommodate such effects.

ISP Change Control

After validation of the original ISP aboard ship, other changes of stored performance limits may be found necessary. Some may be due to a desire to increase sensitivity of detecting performance degradation; some may be due to a belatedly discovered shipboard environmental effect; or simply an exercise of command privilege to accept marginal performance during certain missions. It

is expected that the need for such changes will become apparent as more experience with the automatic test system is obtained, and thorough analysis is made of recorded feedback data by the Validation Activity and NATSC.

Another source of changes, after validation of the original ship ISPs, will be the field changes and alterations of the monitored systems. The validation Activity will determine the effect of field changes and alterations on the interface between the system and the ISP, and pass this information to NATSC. The NATSC will update the affected ISP and provide all ships with the particular ISP with either a complete new ISP for substitution, or material necessary for updating. Updated ISPs will be validated by the Validation Activity in conjunction with the activities installing the field change or alteration, which are normally the forces afloat.

CONFIGURATION MANAGEMENT

Configuration management is vitally important to automatic testing. Before any TEAM or ATS can be used aboard ship it must be loaded with the correct ISP for the ship. In the same sense, a shipboard NELAT isn't going to be of any use unless the NELAT adapters and ISPs are compatible with the ship's equipment and the LRUs of that equipment.

But, the NATSC cannot provision a ship with ISPs unless the equipment baseline is precisely identified and continuously appraised for changes.

The essential configuration management functions to be carried on are:

- Establishment of a precise equipment baseline for each ship (verified by an on-site survey)
- Update baseline when field changes or alterations are made
- Determine which proposed field changes and alterations will affect individual

system-ISP interfaces, the new or modified logic, and the parameters applicable

- Coordinate effectivity date for field change or alteration with NATSC
- Maintain a well organized feedback system and analysis procedure using printout test data tapes to detect ISP deficiencies and verify compatibility of updated ISPs with field changes and alterations.

Since the number of ships is quite large, and maintenance of each ship's equipment baseline configuration and changes to it is mandatory, it is apparent that the Navy Activity doing the Configuration Management function must be closely related to the Fleet. Therefore, this responsibility is given to the Validation Activity.

A sequel to maintenance of the ship's equipment baseline, and its changes, is the use of this information for provisioning off-line (NELAT) ISPs and adapters.

The NELAT Adapters and ISPs for individual systems produced by NATSC will be given to ships according to their systems configuration baseline. Updated ISPs, or modified adapters, for particular systems will be provided to those ships having the pertinent systems listed in their systems configuration baseline.

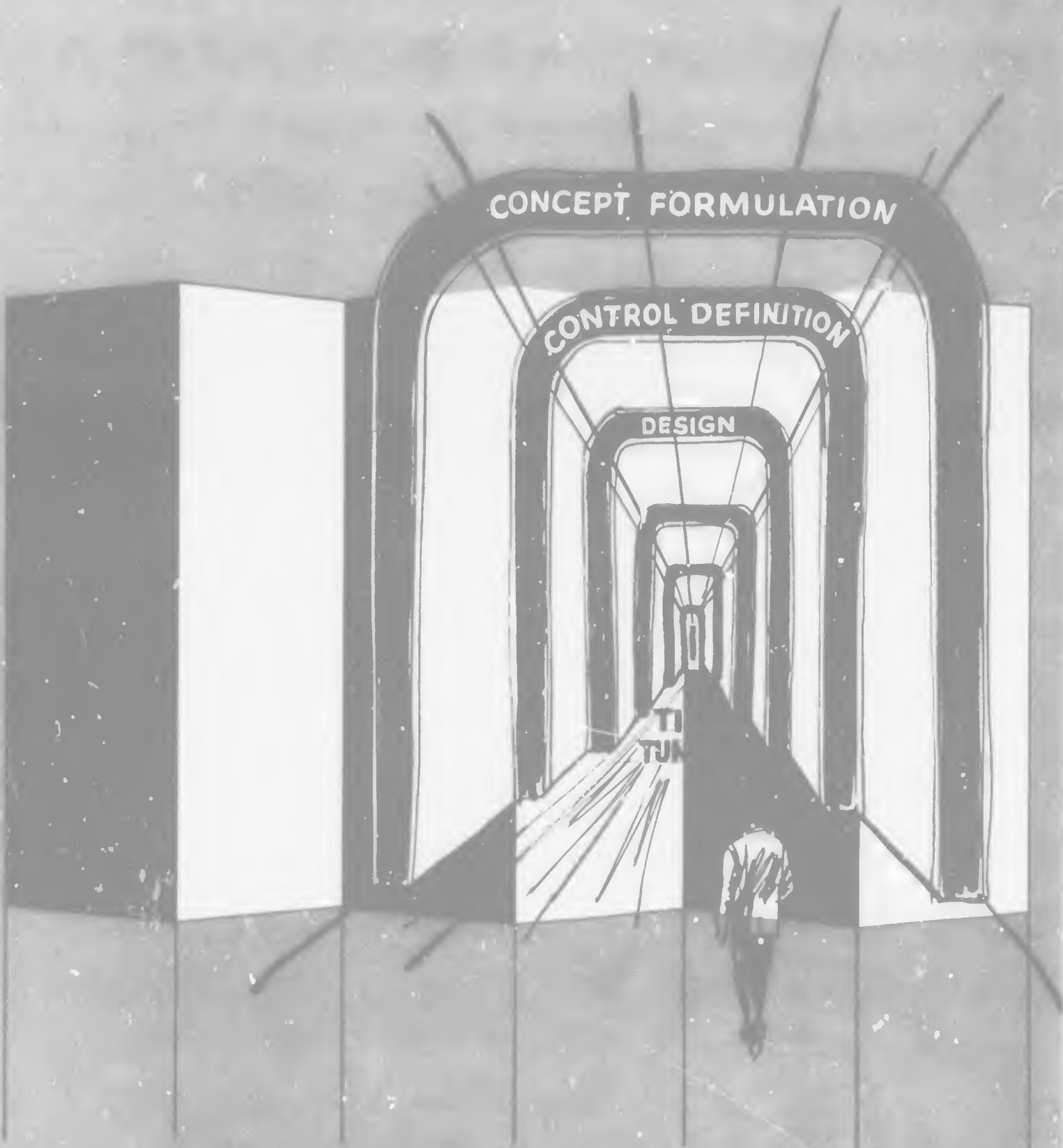
CONCLUSION

The hardware approaches to Navy on-line and off-line automated test systems are basically state-of-the art. The software, however, must cope with various ship classes with different operating systems in various states of modification. This is the dilemma.

The foregoing is a brief approach to solving the problem. The solution is not perfect. However, the built-in adaptive features for validation, on board surveys, and Fleet reporting should provide rapid correction of any deficiencies.

CONCEPT FORMULATION APPROACH FOR TOTAL SHIP SYSTEMS

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INTRODUCTION

Basically the systems engineering approach stresses detailed problem identification (threat and mission definition) and logical approaches to a solution (synthesis and analysis). Although it is recognized that real world data problems and lack of ability to quantify many important factors necessitate incorporating subjective analyses, heavy reliance on model building and analytic procedures have made computers an integral part of the approach. The measures developed are usually unique to particular studies, but in addition to performance parameters, such resource criteria as lead time, manpower levels and skills, development, investment and ownership costs, and, logistic support factors must be included. Performance parameters such as kill probability, detection probability, range errors, etc. are themselves mission time dependent and must therefore include considerations of system reliability, maintainability and availability.

Application of the system engineering discipline to military problems has been termed Cost Effectiveness Analysis by DOD. As a result of its use on most large programs over the past five to six years, many techniques have evolved and a comprehensive data bank has been generated. Despite this scope of application, many aspects of analysis remain an art rather than a science. It is generally agreed that system analysis is only an aid to a decision maker. Complete quantification of system parameters and weighted sets of objective measures do not, and probably never will exist for complex military development.

These techniques, which have had major use in evaluating single weapon systems, have recently been applied to total ship systems such as Fast Deployment Logistics (FDL) and Landing Helicopter Assault (LHA); they are currently being applied to the new construction destroyer program (DX) concept formulation. The requirement

for DOD-wide competitor examination, coupled with the need for optimizing the multi mission nature of ship systems operated both alone and in various task groupings, make the total ship analysis problem extremely complex.

This paper discusses a specific approach to total ship system analysis applicable to a ship systems program.

SYSTEMS APPROACH TO SHIP DEVELOPMENT

Historically, the Navy has brought ship hull classes in split awards to various shipyards with all electronics and weapons systems government furnished and delivered dockside. Recently, in an attempt to achieve economics of scale and provide incentives to shipbuilders to modernize facilities, multi-year awards were made for 17 LST's and 20 DE types. These awards resulted in substantial updating of facilities.

proach continued with the award of contract

This evolution to the total systems approach continued with the award of contract definition studies for the Fast Deployment Logistics Ship (FDLS). Although this program had been stalled, it was quickly followed by concept formulation and contract definition of the Landing Heavy Assault (LHA) ship. The LHA is considerably more complex than FDL but is still classified as a support ship. The features of four existing support vehicles are combined in one ship, and includes the following:

- Amphibious Assault Ship (LPH)
- Amphibious Transport Dock (LPD)
- Dock Landing Ship (LSD)
- Attack Cargo Ship (AKA)

By virtue of its ability to carry helicopters in addition to landing craft, men, and equipment, the LHA will be able to land elements of a Marine force by vertical assault, or over the beach with initial combat readiness not previously available by a single ship system. This factor is indicative of the new challenge

to the system engineer, namely; the direct relationship between the procurement level (design control) and the system end use (mission requirements). This relationship allows higher order parameters to be considered.

The final step in the development of a total systems approach for Navy ship acquisition involves application of system engineering principles to total package multi-year procurement of warships. The multi-mission character of many warships, coupled with their need to interact with other forces, makes this step probably the most difficult challenge ever for the proponents of the "systems approach." This task is further complicated by the fact that a ship's useful life may exceed that of its weapons systems by as much as 4 to 1 requiring that the ownership cost/performance models include refit and overhaul cycles, and account for advanced development projects.

The Navy undesignated destroyer and mis-

sile destroyer vehicles program (DX), currently in contract definition, by the Ships System Command, is the first attempt at the total system approach for a Warship. The program objective is destroyer acquisition in the 1970 - 1980 time frame. The new ships' design will replace classes currently designated DE, DD, DDG and DLG. Recent congressional decisions on * nuclear propulsion for major fleet escorts suggests a separation of DX and DXG, with systems effort and total package procurement most likely to occur first for the DX requirements. Simply stated, the DX requirements are shown in figure 1 as performance requirements and economic requirements leading to mission responsiveness vs. total ownership costs.


* This is a complex issue which is not germane to the point of this paper and will therefore not be discussed in detail. The problem, however, is treated in excellent detail in hearings before various congressional committees (Spring 1967).

PERFORMANCE OBJECTIVES

- APPLY SYSTEM ENGINEERING PRINCIPLES TO DESIGN/DEVELOPMENT/PRODUCTION/DEPLOYMENT OF TOTAL SHIP SYSTEM TO OPTIMIZE SYSTEM FOR PROJECTED THREATS (3200.9)
- PROVIDE ADAPTABILITY TO REFIT ADVANCED WARFARE SYSTEMS . (ERA-ASMS-APDMS-175MM-LANCE) VS. PROJECTED THREATS OVER SHIP LIFE
- CONSIDER MULTI-MISSION NATURE OF SHIP SYSTEMS

ECONOMIC OBJECTIVES

- ACHIEVE ECONOMIES OF SCALE VIA MULTI-YEAR PROCUREMENT (CAPITAL INVESTMENT)
- REDUCE ILS BURDEN VIA TOTAL SYSTEM APPROACH (4:00.35) (DOCUMENTATION, FACILITIES, PEOPLE, SUPPORT EQPT)
- REDUCE OPERATOR AND MAINTENANCE REQUIREMENTS THROUGH STANDARDIZATION, MATERIALS SELECTION, AUTOMATION TECHNIQUES AND DESIGN INTEGRATION



MISSION RESPONSIVENESS
VS. OWNERSHIP COSTS

Typical Ship Requirements

Figure 1

Having established that a new avenue has been opened to us, the question becomes: how far can we go with the tools at hand, and what developments are required to effectively plan and implement total ship programs? The impact of total ship programs on industry is summarized simply as one of more responsibility. The process of concept formulation and contract definition for ship systems is by no means well defined. The Ship Concept Design Division of the Naval Ship Engineering Center (which has the prime responsibility for ship concept formulation) has planned a long range resource development program to run concurrently with specific ship concept formulations. Key Naval engineers hope that the cross fertilization of resource development with actual direct program experience will result in an evolutionary growth of capability in this area. Translation of familiar system terms such as: threat and mission analysis, requirements, DOD-wide competitor examination, synthesis of alternate ship designs (accounting for multi-missions), selection and design optimization of preferred system, and development of system acquisition plans (including management, procurement, and integrated logistic support), have all proved to be complex assignments.

PROCEDURE FOR PERFORMING TOTAL SHIP SYSTEM ANALYSIS

The analysis technique described herein is a procedure for performing the analyses required for ship concept formulation. Although many techniques exist within the over-all system engineering discipline for problem definition, model building, model evaluation etc., the complexity of the total ship problem (multi-mission nature of ship system), and the vast organizational structure of the DOD/Navy complex, requires that a procedure be developed which is uniquely suited to total ship concept formulation.

To date, most attempts to perform total system analysis within the Navy required simplification of the problem before synthesis and evaluation activities were performed. Either a single mission was selected as "worst case," or various missions were weighted and combined using figure of merit

techniques. In recognition of the complex decision structure and its close interface with analysis, we have also seen many changes within the DOD/Navy organization which resulted in complete vertical structures for specific programs, such as: Polaris/Poseidon, reorganization of the Bureaus (as Commands under the CNM), and change from bilateral user (CNO), producer Navies (CNM) to a direct line CNO-CNM structure. Simplifying assumptions for problem solution, organizational change for maximum resource utilization and useful approaches to the over-all process of weapon system development are required. The sequential analysis approach does not attempt to discredit either, but rather omits its consideration to the maximum extent possible. It is envisioned that a procedure for total ship concept formulation will not be developed via an isolated technique study, but will evolve from experience with real world studies such as those now going on in LHA, MCS, LFS, and DX/DXG. It is hoped that procedures and techniques developed by researchers along the way will serve to speed up that process.

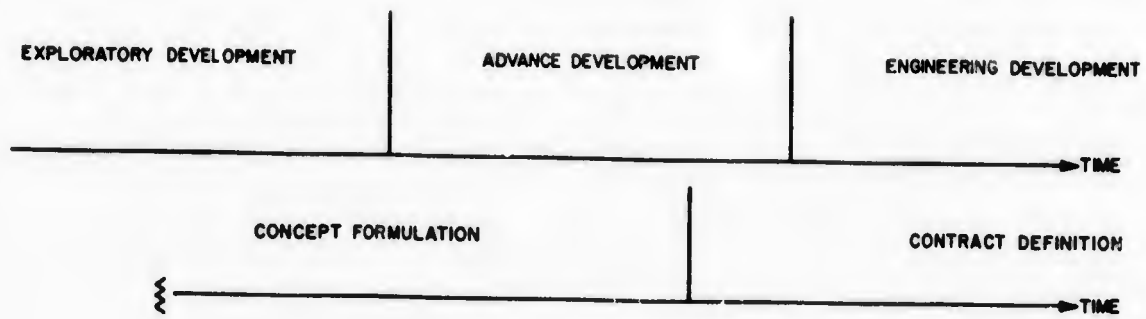
BASIC PRECEPTS

Two fundamental ideas embodied in this are:

(a) **System Use Functions or Missions Are Not Weighted But "Ordered."**

Analysis is done for each mission sequentially. Requirements and constraints become definitized via the sequential analysis. Constraints generated by the first analysis become limiting requirements on the next in turn etc., until a fully constrained design is finally generated. A more detailed description of this approach with a suggested format or order of progress is described in later sections of this paper.

(b) **Presentation of Information Outputs Tailored to the Decisions Makers' Needs.** Development of measures which allow quantitative analysis and preserve physical meaning of analysis outputs are key requirements if one is going to provide information to a decision maker (really a large series of decision makers with different responsibilities). The information outputs of the models



RELATIONS OF DEVELOPMENT AND CONCEPT FORMULATION ACTIVITIES

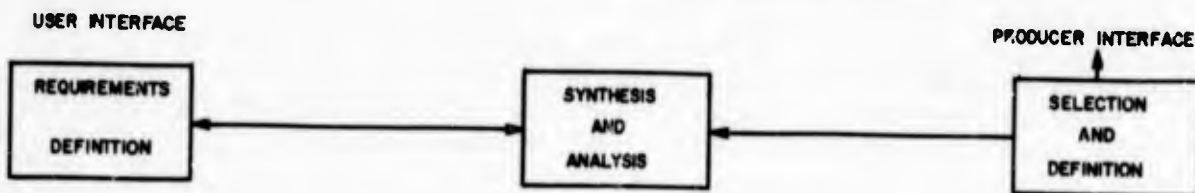
Figure 2

used are not combined beyond the point where real world meaning is lost. All information is retained in useful form after each sequential analysis so that a complete information base is preserved throughout the concept formulation. Existing techniques and models present numerical answers to the manager, and his decision then becomes one of accepting the technique. In this procedure, an attempt is made to force model outputs in the direction of more management visibility of problem variables, and the manager's decisions, therefore, are considered an integral part of the technique. Organizational interfaces then become inherent aspects of the final procedure. In order to achieve this end, the measures selected must combine system variables into higher order parameters. For example, Sonar parameters can be shown in terms of beam pattern plots. Reliability and maintainability parameters can be shown in terms of probability of success curves for variable mission time, initial conditions, etc. In general, the use of plot outputs will receive highest priority in this technique since a broader presentation of

information can be developed in graphic form.

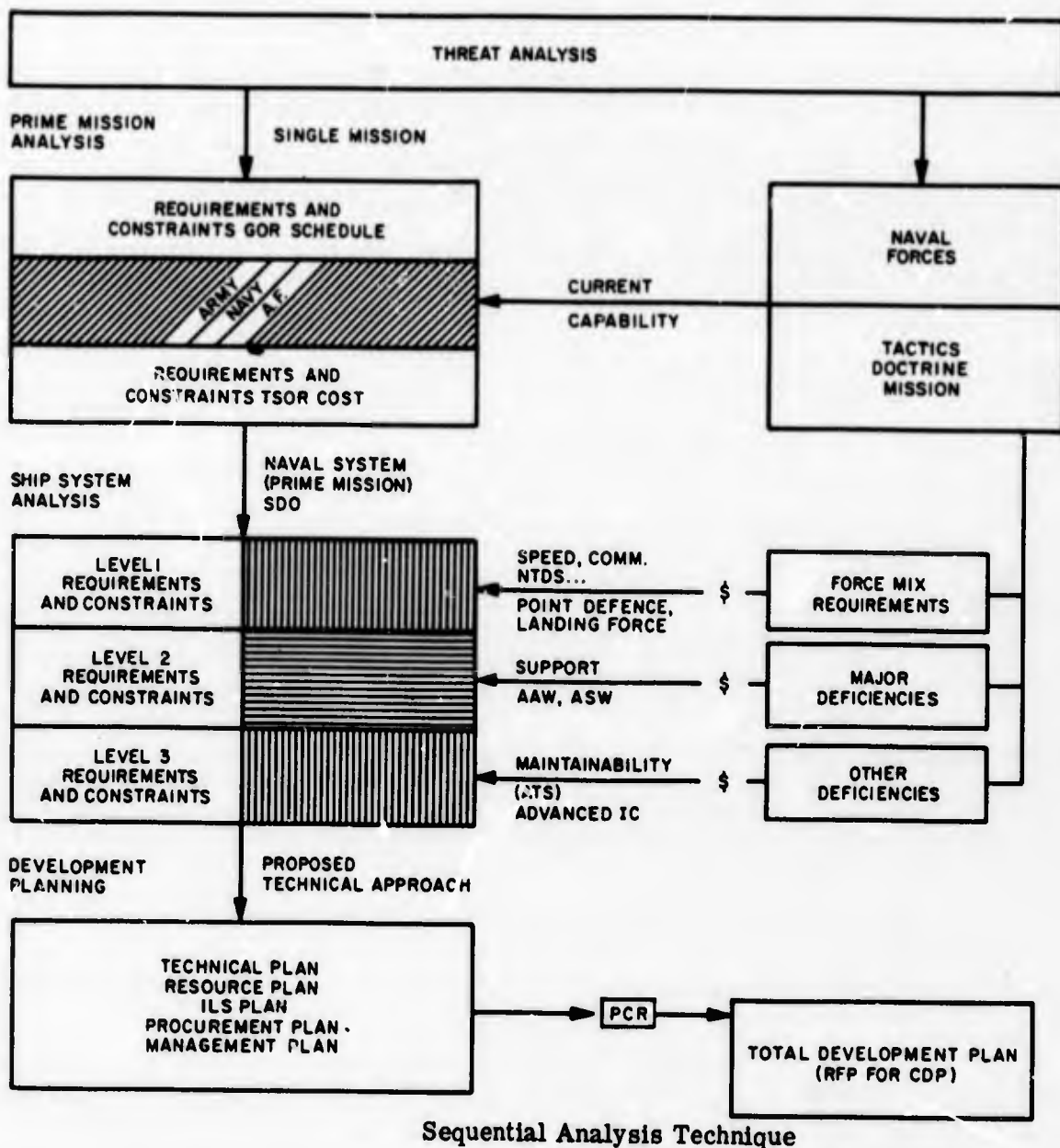
TECHNICAL OUTLINE

Procedural outlines for concept formulation can take many forms. The number of boxes and flow lines shown is usually limited by considerations of available space and complexity to be depicted. This is necessarily true because the process is one of many interfaces and iterations. All forms, however, are geared to satisfy the prerequisites of DOD directive 3200.9. It can be stated therefore, that more is known about the end point of the process than the method of getting to a contract definition decision. In its simplest form, concept formulation can be shown as overlapping the activities of many exploratory and advanced development projects as in figure 2. However, in order to explore the interfaces and help guide the process, concept formulation can be broken down further as in figure 3. In figure 3, we can begin to describe the CNO/CNM interfaces in terms of requirements, organization, etc.



User Producer Relationships

Figure 3



Sequential Analysis Technique

Figure 4

The Sequential Analysis Techniques follows this pattern very closely as shown in figure 4. In sequential analysis, there are three distinct levels of analysis done at the ship system level. Prior to the three level analysis, requirements are defined in a manner which allows the multimission nature of ships to be fully accounted for. As seen in figure 4, there is a prime problem for which OSD requires a solution. DOD-wide competitor examination is made only for that

problem area. On the other hand, it is also true that the over-all projected threat will result in many additional problem areas not adequately covered by current programs. These areas are usually documented by studies such as: Navy mid-range objectives, long-range strategic studies, General Operational Requirements, etc. The heart of the Navy problem then, is to satisfy the specific prime requirement for the specific threat and still maintain an over-all fleet capability

for the over-all threat. Thus the unique Navy "Multimission Requirement for Ship Systems." In order to cope with this problem and allow analyses of economic and tactical effectiveness of multimission platforms, the sequential technique starts with a definition of requirements which isolates prime requirements and major fleet deficiencies. It is this separation of requirements, prior to the three level analysis, which is referred to as "ordering" of requirements. By treating the prime requirement as a go/no go gate function, the effect of adding multimission capability can then be assessed. By fixing the go/no go point as that crossover where added capability does not impede the prime mission, one can maximize multimission capability of the vehicle within bounds generated by the prime requirement. As one allows degradation of the prime mission to occur, in order to get still more multipurpose ships, management visibility of this tradeoff becomes apparent. When considerations such as lead-time-to-deployment, initial costs, ownership costs, manning requirements, etc. are added to analysis outputs, one sees how the complex process of ship concept formulation lends itself to a procedural format. This allows Navy management decisions to account for most of the variables in its task of achieving an over-all Naval force able to combat both specific threats and over-all contingencies not yet forecast. After competitor examination is made for the prime mission and a ship system is deemed a tentative requirement, the analysis proceeds in the following order:

(1) **Level 1—Force Mix Requirements** for ships generated by over-all tactical considerations are added to the system definition and their effect on the prime mission assessed. Examples of this type of requirement are those elements of a ship which allow it to work in diverse task groupings. A prime example is ship speed. Another is communications.

(2) **Level 2—Major Fleet Deficiencies** developed from analysis of GOR's, NLRSS, NMRO and advanced development objectives are then considered. An example of this requirement would be: addition of AAW capability to a small ASW ship to satisfy a major

fleet AAW deficiency where the ASW problem was classified as the prime requirement. Shore bombardment, satellite communications gear, helo platforms etc. are all possible major areas where analysis is done in level 2. Both initial outfitting and refit potential are considered in the cost/effectiveness analyses performed. As each deficiency is treated in turn, the requirements and decisions from the prior analysis becomes the constraints on the next.

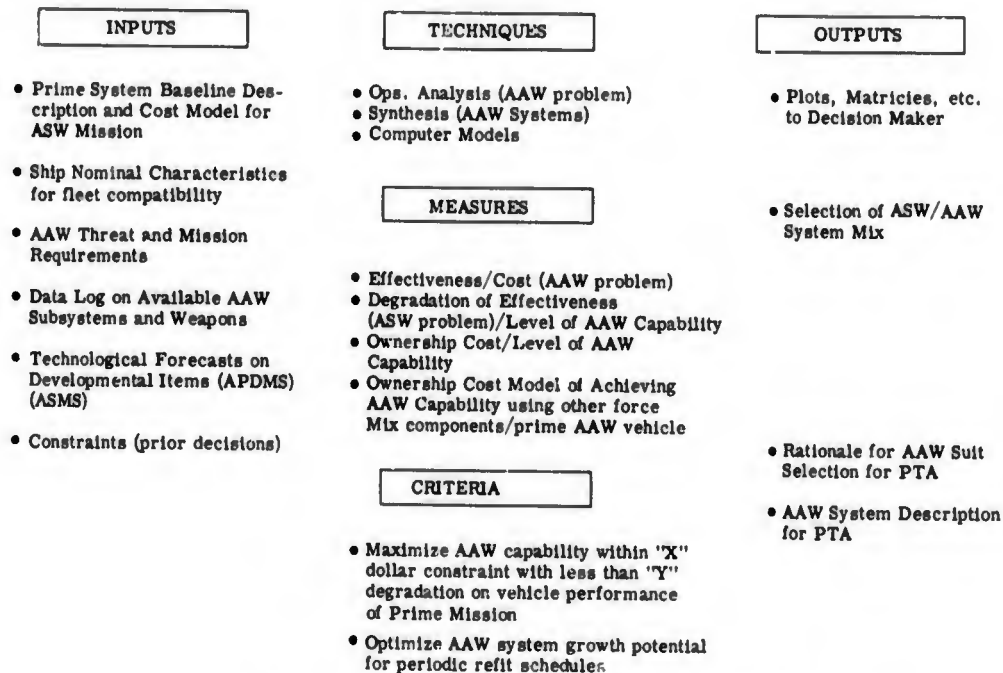
(3) **Level 3—Minor Deficiencies**, documented by historical data, personnel problems, maintenance burdens, and the like, are treated in level 3. Considerations of automatic test equipment, from both economic points of view and effect on ship prime missions, is an example of level 3 analysis. Standardization, materials selection, automation, etc. are also level 3 type analysis. It is in level 3 analysis that the first serious consideration of reliability, maintainability, and integrated logistic support factors occurs. Upon completion of level 3 analysis, a proposed technical approach for a multimission ship is generated. Rationale for the prime systems and additional warfare area systems are presented in the same logical sequence for which they were synthesized. This approach facilitates subsequent program justification.

(4) **Development Planning**, the final phase of sequential analysis, considers the elements of a total development plan including organization, type of procurement, plans for integrated logistic support and resource plans. Its purpose is to provide an acquisition and deployment plan for the fully constrained design developed via sequential analysis. Key program documentation such as PCR and RFP are generated in this phase. It is during this phase that the PTA is "sold" as an acquisition program. Serious discussion on the conduct and nature of CDP, extent of Government Furnished Equipment, multi-year procurement funding and penalties for termination, type and specification of incentives, and contractor/government validation and risk sharing is all made in this phase. This is usually the result of economic analyses and organizational dialogue during numerous briefings and formal presentations,

CONCEPT FORMULATION PHASES	ACTIVITIES	KEY OUTPUTS	MAJOR DECISION
<u>PRIME MISSION</u> <u>ANALYSIS</u> FORCE MIX DETERMINATION	<ul style="list-style-type: none"> Threat Analysis in terms of Prime Mission Requirements/Constraints and Resource Requirements/Constraints Overall categorization of Force Mix Requirements DOD Wide Competitor Examination for Prime Mission 	<ul style="list-style-type: none"> Threat Definition Mission Profiles Military Utility Prime System Definition Economic Baseline Projection 	Decision to enter formal Ship Concept Formulation
<u>SHIP SYSTEM ANALYSIS</u> Level 1 Level 2 Level 3	<ul style="list-style-type: none"> Synthesis of baseline ship system for Prime Mission - Required Ship function for fleet tactical compatibility added Synthesis of additional system alternates for each major fleet deficiency - Analysis of incremental effectiveness and effect on Prime Mission, Refit warfare system analysis over useful life of ship. Design Integration and Cost Optimization 	<ul style="list-style-type: none"> Program objectives and goals Ship Requirements Alternate ship system candidates Preferred system selection Ship System Description allocated goals Ship Ownership Cost Projections Technical Feasibility Established 	
<u>DEVELOPMENT PLANNING</u>	<ul style="list-style-type: none"> Management Plan Development Resources Plan Development Procurement Plan Development Integrated Logistic Support Plan Development 	<ul style="list-style-type: none"> Program Change Request Total Development Plan Request for Proposal 	Decision to enter GDP

Overview of Typical Activities during Concept Formulation

Figure 5



Example of Partial Level 2 Analysis for AAW Deficiency on ASW Ship Baseline Design

Figure 6

It is precisely to promote an effective dialogue that this technique stresses broad information presentation over figure of merit approaches.

In order to provide some additional background on sequential analysis, typical activities are broken down in figure 5. The process of identifying and using existing resources and tools adequate for each activity completion is the primary task in achieving workable procedure. The process of defining the activities themselves, and their logical order, is the key to effective procedure.

The inputs, techniques, measures, criteria and outputs for a typical level 2 analysis, for the case of an ASW prime mission ship, are shown in figure 6. Although this is not intended to provide a complete description of level 2 activity, the information presented in figure 6 shows the basic approach which could be employed in analysis. New measures and techniques required for ship concept formulation will be highlighted by this approach, and serve as a useful guide to Navy allocation of resource development budgets beyond FY68.

SUMMARY

The preceding discussion has described a general approach to concept formulation for

ship systems. It is general, in the sense that no approach could substitute for the detailed and complex system engineering tasks that must be done prior to the major commitment of resources for a new ship acquisition program.

The primary advantages of a formal procedure approach are twofold:

First; the use of a logical guide, geared to organizational decision points, and based upon information oriented outputs, allows the process to be turned off or changed substantially whereby only those incremental tasks needed up to that decision are performed.

Second, and most important; the approach provides maximum information retention and use on subsequent concept formulations. The resulting constant cross fertilization, coupled with the evolutionary growth of a data base will have tremendous payoffs at the time when all new ship programs are preceded by concept formulation. In addition to assisting in acquisition of new ships with broad responsive multi-mission capability, the growth of a usable information base should provide more lucid direction to sub-system and weapon system exploratory and advanced development projects.

APPENDIX

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QUESTION AND ANSWER PERIOD

Session II May 8, 1968 PM

Participants: E. Jehle (Moderator), Capt.
V. Warriner, R. Kulp, B. Bernstein,
J. Sanderson

JEHLE: The first question is: Have you any measure of the increased equipment complexity required to run the program of the DSOT?

WARRINER: The test set MK37 as well as the 474 is an increase in complexity as a necessity because they weren't there before. But the time and the manpower saved and the assurance that we are getting a time system evaluation, offsets the cost as well as the complexity of the test equipment. However, insofar as the maintenance of the test equipment goes, it has a very low failure rate. Extremely low, as a matter of fact. They are dependable pieces of equipment.

JEHLE: What is DSOT?

WARRINER: DSOT stands for Daily System Operability Test. When it was first devised, it was, in fact, a daily system operability test. This was for the whole missile system from beginning to end, less the radars. With the advent of the automated system, (the 474 and the 37 test equipment), we are able to perform tests on a watch-by-watch basis and increase our capability. This lets us know where we stand in the operability of the system.

JEHLE: Mr. Kulp, was the model mentioned in your paper validated?

KULP: In setting up a validation process, our biggest problem has been acquiring data. That is, enough data to make a statistical comparison between the model and the real world. We found that there were enough data in some of the exercises run in the mid-Atlantic. We were able to do this in the area of probability of initial detection. Due to the environment, we were also able to get temperature profiles. We have an N layered medium in the model. We also needed input data with respect to water depth.

JEHLE: Mr. Bernstein, how well organized is the Navy's effort to feedback Fleet operational data to original designers and developers, so that they can gain from Fleet experience?

BERNSTEIN: I can refer you to the FADAC program as one possible source of data. This program has recently been put under the cognizance of the manager of the ASW systems project office. We have a lot of data which has been collected by SUBDEV Group II in a series of exercises. This data is available but is classified.

JEHLE: Mr. Sanderson, is industry invited as a user of the GEM program?

SANDERSON: Yes. The program, however, is still evolving and there are a lot of iterations. At this time it merely interfaces with the CDC 6600 computer at N.Y.U. This program cannot be taken as a package and delivered around the country at this time. However, many people have come to the Laboratory (NASL) for consultation and we have helped them program their problems on the CDC 6600. I recommend that if a company has a Navy contract, it contact us via their Navy project office.

JEHLE: Mr. Kulp, what are the time requirements to run your model?

KULP: A model of this type and complexity can vary from a few seconds to a few minutes depending on the scenario. The IBM 7030 Stretch computer is used. We have a new generation computer system coming which will be 10 to 12 times faster.

JEHLE: Mr. Bernstein, is the error model applicable to both destroyer and submarine type ships?

BERNSTEIN: No.

JEHLE: Mr. Sanderson, does the GEM program have the facility of remote station access?

SANDERSON: No.

JEHLE: Is there any intention on the part of the Navy to include operating times in the 3M system?

SANDERSON: Planning and Research Corporation (PRC) is working with the Navy to update the data collection of the 3M systems. They are going to recommend changes. The weakness of the 3M system, as far as design is concerned, is the fact that failure rates and repair rates cannot be derived.

JEHLE: Mr. Bernstein, has P.A.U. been officially designated by any Navy office as a recommended approach to system effectiveness?

BERNSTEIN: I refer you to NAVMAT P3941 which is a guide put out by NAVMAT and which was developed by NASL.

JEHLE: How does PAU refer to WSEIAC?

BERNSTEIN: Dependability in the Air Force approach is equivalent to reliability and utilization in the Navy approach. Capability in WSEIAC is equivalent to performance, and availability is the same in both cases.

SANDERSON: I would like to comment. Both are frameworks. Neither is analytic. You have to do good system engineering to come up with analytic equations to solve the system parameters. The difference between the two, as a framework, is the U in PAU. U is for utilization. The Air Force approach does not take into account the environmental vectors inherent in the U in PAU.

QUESTION AND ANSWER PERIOD

Session III May 9, 1968 AM

Participants: F. Schiavi (Moderator), G. Giorgi, J. Jacobs, H. Levine, M. Gerrity

SCHIAVI: Mr. Giorgi, will there be any reports available on your work for general distribution?

GIORGI: We have quite a few reports available at the present time. We have done work for the Defense Communication Agency, on the NIKE X system and for the Air Force on NORAD. Most of our publications are in DDC. The Naval Civil Engineering Laboratory in Port Hueneme, California, can be contacted for more information on these reports.

SCHIAVI: Is the transient data acquisition monitor the only piece of equipment available for use elsewhere, particularly aboard ship?

GIORGI: This is a prototype equipment presently undergoing evaluation and debugging. The equipment was designed for use aboard ship and meets all requirements. It comes equipped with shipping containers and can be moved to any location having power problems.

SCHIAVI: Can you give an estimate on cost?

GIORGI: The prototype unit costs \$60,000.

SCHIAVI: Mr. Jacobs, there are several questions concerning other programs in the

surface launched missile area. Can you describe these?

JACOBS: We are presently conducting a no test program in both the homing and beam riding areas. A reduced test program is being conducted on the TALOS missile at the engineering station in Port Hueneme, Cal. The standard missile, which has just gone into production, will not require any shipboard testing at all. This was based on the results of the TARTAR program.

SCHIAVI: Mr. Levine, what degree of cost analysis do design review engineers perform?

LEVINE: We don't perform a cost analysis. We make sure that the system will perform to its specifications. We make sure that the design follows Mil-Standard, Mil-Specs and good engineering approaches. If we think the design is too complex we may suggest a simpler approach to the contractor.

SCHIAVI: Mr. Gerrity, what data base was used for generating the maintenance man minutes per utilization hour requirements?

GERRITY: The particular choice of this parameter to be tested was selected on the

basis of the overall A7A Aircraft Program. As I stated in my speech, this was our first attempt at a maintainability and integrated logistic support program. The particular numbers chosen were based on the limited data derived from utilization reports for previous devices that were never manufactured with this integrated effort in the support area.

SCHIAVI: Mr. Jacobs, what was the missile test success rate, based on six months storage?

JACOBS: This information is classified but the figures were based on missiles kept on board ship for 24 months. Presently there are some missiles which will be on board 36 months by this Fall.

SCHIAVI: Mr. Levine, what specific methods do you use to obtain user feedback of operational effectiveness from the tactical or equipment operator?

LEVINE: I interpret this question to mean reports we get from sailors, Captains, or Laboratory personnel who ride ships. We read the reports of on-board Lab personnel to determine what areas need further study. Sometimes field engineering people interview officers and sailors to find out problem areas.

SCHIAVI: What do you consider a realistic reporting frequency which does not overtax the user in accomplishing his normal mission and reporting?

LEVINE: This is a difficult question to answer.

SCHIAVI: Mr. Gerrity, do you have an electronic parts count for the A7A weapon system trainer?

GERRITY: No, but the figures are available at NTDC, Orlando. I would like to point out, however, that one of the design goals was to eliminate the diversity of spare parts. A particular part was reused, where possible, to minimize variations.

QUESTION AND ANSWER PERIOD

Session IV May 9, 1968 PM

Participants: E. Nucci (Moderator),
J. Schuler, M. Dubinsky, F. Berg, J. Rosen,
J. Von Sas.

NUCCI: Jim Schuler, for the Landing Craft program, how did you determine what the payload and speed should be?

SCHULER: We started with the present Marine Corps payload, projected a specific time period in the future, and determined what the craft size should be.

NUCCI: How will you measure effectiveness and weigh each effectiveness parameter?

SCHULER: Part of the problem is that we don't know the total answer to that question. We are searching for the variables and are presently trying to get them sorted out.

NUCCI: I wonder if I can help Jim a little bit even though I don't know too much about his program. Sometimes we think that every parameter we put into the effectiveness equation must be accounted for. Maybe we are wrong in this kind of thinking. The parameter we must account for is the total

effectiveness measure parameter. For instance, in the FDL we boil it down to speed times payload over the life cycle cost. The life cycle cost parameter takes into account reliability, maintainability and crew size. In this way we were able to catch quite a few parameters in one single element of the equation. Let's watch this so our eyes will be trained for prediction on the total array of parameters, but for demonstration and compliance we may want to revert to the basic effectiveness measure.

The next question for Jim is: Do the system concepts include electronic subsystems such as radar, communications, command and control etc?

SCHULER: Yes, in the requirements sense but not in a hardware development sense.

NUCCI: In the development of new landing craft systems, do you use the two step system for soliciting ideas from industry or do you use the modification of this system?

SCHULER: We are really using about a ten step system. We used a couple of steps in the preliminary case and will use a couple of steps in the test craft case, and when we get to production hardware we will use a multi-step approach. We are set up so that we can introduce new companies and concepts anywhere along the line.

NUCCI: Mr. Dubinsky, will the method of evaluating and weighing effectiveness measures and components be available?

DUBINSKY: Military worth is equal to the Military utility times systems effectiveness divided by the total cost. This may be evading the question, but our source selection evaluation board will determine some weighing of the effectiveness values for this equation. There will be criteria established in the RFP for this data.

NUCCI: Will DDF, per the XWS 12033 and WS4616 and Mil-M-2410C, be a firm requirement for ASMS CDP?

DUBINSKY: XWS 12033 and WS 4616 are firm requirements in the RFP. Mil-M-24100 is listed as a study. We are providing copies of 12033 with the data package which we obtained from the Naval Applied Science Lab.

NUCCI: Mr. Berg. How does the plan mentioned in your paper keep current with the technological development in industrial advancements? What measure determines a standard?

BERG: In answer to that question, I'd like to quote a CNO document:

"The attainment of an optimum degree of standardization by curbing component equipment make and model multiplication and resulting spare parts proliferation must be within the bounds of the ASPER. We address the ASPER first because it preferentially talks about competition and the governing requirements of the defense standardization program. Standardization cannot be mandated arbitrarily but must result from thoroughly considered trade-offs generally on the basis of cost versus effectiveness."

Specifically, if we talk about oscilloscopes and standardization of general purpose test equipment, we consider the terms of the

state-of-the-art in addition to what the oscilloscope can do in terms of satisfying a large number of requirements. In terms of the broad spectrum of equipments involved we can consider useful scan, sweep, frequency response (both vertically and horizontally), sensitivity, and rise time. By virtue of the latest state-of-the-art we get into MTBF, weight and those requirements of the environment in which the oscilloscope has to operate. This is one part of the program of standardization. Another part is directed from the office of the Chief of Naval Operations. It comes from an SOR-TDP dialogue and takes a number of years. This is particularly true in the tactical area. The equipment resulting from development leads to a standard equipment.

NUCCI: Does your program utilize an automatic computerized data system for classification updating purposes?

BERG: Yes, we have an equipment dictionary file called EDICT, in NAVELEX which we use for this purpose.

NUCCI: The next question is for Mr. Rosen. Is space reserved on the DX to install CATS or TEAMS?

ROSEN: The DX characteristics call for automatic testing but it does state a specific system.

NUCCI: As you have pointed out, the configuration management relationship to automatic testing success is critical. Is this a program to firm up the Navy's configuration management discipline?

ROSEN: There is a definite plan in connection with the TEAMS system. This is because TEAMS is nearing shipboard operational status. We believe that the things being developed for the TEAMS will be applicable to CATS and NELAT.

NUCCI: I'd like to add that there is quite a bit of effort underway at the tri-service level to establish a set of standards for configuration management, as well as the DOD policy and set of instructions.

Mr. Von Sas, in utilizing historical data, you took portions of various systems and put them together in a prediction to assess

the feasibility. This is fine, but you are plugging in failure rates which are conservative. In the new system you may design around this failure mechanism so that you will get conservative answers. You may even become so conservative that you will kill your program. Also you haven't mentioned anything about utilizing the new state-of-the-art pieces of the new systems and how they will affect the reliability.

VON SAS: I agree with your statement completely. What was in the paper was just one of several techniques to be applied to a program. The technique itself is conservative and I think Jum Schuler made the point very well when he said you go around the circle twice; first, to find out where you've been. The total program requires use of a prediction method to get an upper bound or an optimistic look at the situation and then take an assessment research to get a conservative look. Depending upon your specific requirements, you can continually reiterate through these two processes and close down very tightly on what actually is realistic state-of-the-art.

NUCCI: I'd like to add one more point. When you take previously used units and reconfigure them on new systems, you may establish new failure mechanisms that didn't exist in the previous system. So you have to be careful in using prediction techniques be-

cause you may be coming up with some new worms.

I'd like to wind up this session by thanking the speakers for a job well done in advocating the different techniques that will enhance system performance effectiveness. I am very heavily oriented toward the systems engineering point of view and the first two papers of this session hit the heart of the problem of SPE. The systems engineering effort is based on the total systems approach. This includes hardware, facilities, software, personnel and logistic support. In a full systems engineering approach, the many techniques and special efforts will be adequately considered and integrated into the design effort. Here, I am talking about reliability, maintainability, test equipment compatibility and some of the other things we have heard today. Effectiveness measures will probably be the knottiest problem. We have to define these measures to properly orient the optimization the way we want it, and the optimization which will best suit the mission requirements. This optimization must also be oriented toward a total cost of ownership. In summary, a true system engineering management effort will be applied to appropriately select and apply the available system effectiveness techniques to give us a system with the required effectiveness at minimum cost of ownership.