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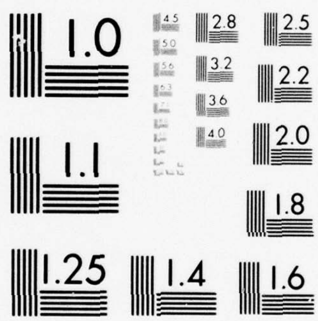

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RESEARCH AND DEVELOPMENT REPORT

REPORT 948

4 DECEMBER 1959

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CONFERENCE REPORT

Proceedings of the Symposium on Undersea Warfare Data Processing in the Naval Tactical Data System

THE SYSTEMS DIVISION, USNEL

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA

A BUREAU OF SHIPS LABORATORY

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PREFACE

This report provides a summary of information on the NTDS/USW effort in the concurrent evaluation of the Naval Tactical Data System. The results of the exchange of technical data during the symposium at the U. S. Navy Electronics Laboratory on 25 September 1959 are presented herein for the use of all personnel who need current knowledge of the USW/NTDS program. These procedures and concepts are not doctrine, and are subject to change as new knowledge dictates.

Specific details on objectives, plans, and future applications to NTDS of various aspects of USW can be found in the bibliography at the end of the report.

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INTRODUCTION

R. G. NYE

Head, Systems Equipment Branch

Two statements made at the Joint Army-Navy Instrumentation Program Conference recently held in Dallas, Texas, are appropriate to the subject of Antisubmarine Warfare Data Processing in the Naval Tactical Data System. The first is:

"A system is that organization of facilities which is required to attain an objective. A weapons complex or detection facility are strictly subsystems in this context."

The second, from the Office of the Chief Signal Officer for Army Aviation, is:

"It would be easy for the scientist to invent us into economic ruin."

The risk expressed in the second statement becomes certain if the basic truth of the first statement is not perceived. Each contributor must proceed on the assumption that his efforts, while defined as full-fledged systems in terms of objectives, are actually subsystems, not of other contributing facilities, but of the USW system.

The U. S. Navy Electronics Laboratory has an almost completely unrestricted opportunity to make important progress in the automation of USW. This will not be accomplished by individual contribution in data processing, detection, communications, or other aspects, no matter how good the effort. It can only be achieved if the contributors are matched unilaterally from the beginning. The habit of making interconnections at some future terminal point has been demonstrated as a sure road to failure. Any assumptions that system deficiencies at such a time could be corrected by adding another computer, or writing a better program, are untenable. It is probable that just one computer aboard an action vessel can tax the limits of practicability.

Coordination can be achieved only if each contributor has maximum information on all associated efforts.

A situation exists wherein knowledge of contributing systems is so sharply peaked in the cognizant organization that no one contributor can confidently direct the technical details of the whole effort. System design will be shaped by a united effort of the organizations represented at this symposium. No mythical superman in management will direct one contributing area to change its design for a better match with another. What is necessary is that each cognizant group know enough about interconnecting, interface, or parallel effort so that changes can be initiated in their own design in order to arrive at the simplest ultimate system possible.

This compilation is intended as an experimental approach to this goal. Later comments on how it, or a better procedure, can best be utilized in support of the NEL USW program are welcomed.

Military Requirements for USW and NTDS

CAPT J. F. FELTER, USN
Head, NTDS Operations Group

The Naval Tactical Data System operation group has assembled a bibliography of official directives (p. 60) that relate to the ASW program in the NTDS system. The directives are in chronological order, and the bibliography lists those directives pertinent to ASW in NTDS. Although ASW is a part of NTDS, it has been difficult to find one particular document exclusively devoted to ASW. The bibliography emphasizes the importance of ASW with regard to NTDS. In the Appendix of this report, a record of quotations that pertain to ASW is presented.

Official directives on NTDS/ASW have been received from both the Chief of the Bureau of Ships and the Chief of Naval Operations. The starting date was 24 April 1956, when the development characteristics were first distributed. This entailed a general statement that ASW was a part of NTDS, and that NTDS was to provide information for the control and direction of traffic in the air defense, ASW, and amphibious operations. The word "traffic" was used in the sense of the exchange of information.

ASW began as Task Priority 4 in a directive to NEL. Shortly after, the significance of ASW was realized and its priority was raised to a status equal to that of air defense. The most important directive in the program is highly classified and cannot be discussed in this report.

The first detailed instructions were received from the Bureau of Ships, and are referred to as the "Service Test Letter." Specific comments on the stations to be manned aboard the service test ships; the equipment required; and the functions to be performed were given. The Chief of Naval Operations, as a result of this, established a concurrent evaluation for NTDS, and ASW was a part of that evaluation. NEL, and the Commander, Operational Test and Evaluation Force, then formulated a project plan that represents the most important document pertinent to the Military Requirements for ASW and NTDS. The proposed project plan has now been approved.

The next documents of importance in regard to ASW in NTDS are the NTDS Service Test Instrumentation books, Vols. I and II, which pertain mainly to the service test ships.

If the directives are examined to determine specifically what is needed at NEL with regard to the minimum system, it will be seen that the Chief of Naval Operations letter that established the concurrent evaluation had two requirements:

1. Tests for the capability of NTDS in processing, display, and dissemination of tactical information, and
2. Tests for the operability of the NTDS unit computer in the processing of synthetic ASW information.

The concurrent evaluation is proceeding in three phases. Phase 1, 2, and 3 each contain two tasks. The odd-numbered tasks concern technical evaluation, and are the direct responsibility of NEL. The even-numbered task is operational evaluation and is the direct responsibility of the Commander, Operational Test and Evaluation Force. Phase 1 is devoted to the minimum system in the ASDEC area, and anything that comes out of this should relate to the later phases when it is tested aboard ship. The specific tasks for the operational evaluation of the ASW part of the minimum system in the ASDEC area are concerned principally with the capability of NTDS to process synthetic ASW information, and to provide evaluated ASW tactical information in suitable form to controllers and directing officers for the purpose of combat direction and coordination with air defense. Tests of how ASW information is to be utilized is also a task.

In the technical phase, the principal, specific task is to determine the compatibility of the AN/SQS-4 sonar in the NTDS system. The concurrent evaluation, Phase 1, is now underway in both the technical and the operational aspects.

Present Status of Programming for USW

DR. R. GOSS

Head, Numerical Analysis Section

The present conference is the first in a series in which progress on NTDS/USW will be reported. It seems legitimate therefore that a fair amount of attention should be given to a critical appraisal of the concepts on which a proposed solution to this problem is based. Only a few comments about these concepts as such will be stated, but they are lurking in the background throughout the entire discussion. The concepts have been, and still are, of major concern in programming, and if the right direction is not being pursued, it is important to find out about it now.

It is not that doubt exists about the soundness of approach. The evidence available so far, as will be indicated, has confirmed the belief that work is proceeding in the right way.

With the air-defense effort of NTDS well underway, it might be well to begin by briefly noting some of the points at which the USW problem is like air defense, and where it is different. To take the differences, it is clear, first of all, that the time scales in the two problems are completely different. Even the fastest submarine will not change its position much during the time the computer is processing the position information. Even stationary targets will be encountered. This gives a different aspect to such matters as tracking and interception, although the basic mathematical formulas are the same.

Second, the sources of information in USW are much more diffuse. In air defense, the only source of target data is fundamentally the return from a radar scan. In USW, there is not only sonar, but also the possibility of radar, electronic countermeasures, visual sightings, magnetic detection, and others.

Third, as a close relative to this difference, the classification of targets looms as a major problem in USW. Their appearance may be ephemeral, and the data obtained are quite likely to be highly ambiguous. In air defense, on the other hand, the classification is a comparatively minor difficulty.

Fourth, the ASW force is much more at the mercy of its environment in carrying out its task. The enemy submarine can be operating in a calm, stable medium while, a few feet above it, the surface fleet may be fighting heavy seas.

Fifth, and most important, the USW officer-in-charge has a wide variety of alternatives in making his decisions, and often the tactical situation is not very well defined. In air defense, the only decisions are essentially the fairly clear-cut ones of whether to launch missiles or aircraft, and when to launch. This last difference is by far the most important to the programming effort.

Opposed to these differences, it is evidenced that USW and air defense share common problems of detection, localization, solving tracking and intercept equations, evaluating threats, and assigning and guiding weapons. In addition, both have the problem of communication between friendly units.

The programming task that NEL has undertaken for USW is being conducted at two levels, one being the minimum system, which is designed mainly to see whether it can be done. This was assigned to NEL by BuShips and CNO. In spite of the formidable difficulties that seem to intervene, it is agreed that the aim can be ultimately on no less than a complete, essentially automatic system. This will embrace the total USW operation of a task force capable of detecting, classifying, and killing any anticipated enemy submarine force.

Although the latter system is vastly more complicated than the former, and involves much more decision-making and computational apparatus, it is believed that the principles underlying the larger version are not different from those upon which the simple system is based. For that reason, the planning has been kept broad enough to allow for programming on any scale so that, as far as possible, the mere changing of the parameter values in the system will allow for expansion in any direction.

A word about those parameters is in order. There are obviously a great many variables entering into a system such as this. Within certain limits the operation of a system does not depend on the particular values assigned to those variables. What the program for USW will do is to provide this operational framework, without specifying the values of all the variables that enter into the system. Whether the results of the tests are "right" or not will depend both upon the framework and the parameters. Many of the parameters will necessarily have to be given values based upon the best estimates of naval experts. An example of this is weapons characteristics. Other parameters can be assigned by the programmers themselves with confidence that the values reflect the correct situation

With these considerations in mind, an outline of the program is as follows:

The computer is conceived as forming a link between data input and data output. The input data will consist of information received periodically from a number of sources, the period depending on the nature of the information. For example, oceanographic parameters will be updated less frequently than those defining the current tactical situation. The output data will be of two types: (1) information about the environment and the current tactical situation, which would be a periodic output; and (2) orders for action, these orders constituting an *ad hoc* outut which depends upon the situation at hand. In between, the computer must organize the input data as it comes in, make choices based upon it, and process it to place in the proper form for output. The input and output problems are, generally speaking, quite similar, and consist largely of devising codes for the conveying of information to the computer from the external world, and routing the pieces of information to the proper storage locations and displays.

The problem for the responsible persons here has actually been one of policy-making rather than programming, and the tie-in to the instrumentation has been quite close. In order to provide concrete assistance to the instrumentation effort, early decisions have had to be made on a number of questions concerning input and output, and the later developments have proven these decisions to have been premature. Consequently, the present status represents a compromise in some instances with what hindsight indicates would have been more desirable.

Once the decisions have been made at both ends, the challenging part of the programming can be started. This is to bring to realization, in the form of coded subroutines, the intricate logical relationships connecting the input and output portions of the system. Present effort is in this area.

Since the computer is considered as a link between input and output, programming takes the form of a sandwich, with the input and output playing the role of the bread and the data-handling the ham in between. The program has been divided into three series, which for convenience have been termed the J, K, and L series, corresponding respectively to input programs, data-handling programs, and output programs. This designation is used herein.

Each series in turn is subdivided into certain categories of programs, and these are denoted by a second letter. For example, JA is a set of programs that contain input data from aircraft, and LA is a set of programs for aircraft control (table 1). This list is by no means frozen as regards either the number or the content of the items.

TABLE 1. ASW programs.

	"J" SERIES (Input Programs)
JA	Aircraft
JC	Classification
JE	Environment
JN	Navigation
JO	Orders from control ship
JR	Reports from responders
JS	Sonar
JW	Weapons
	"K" SERIES (Data-Handling Programs)
KA	Weapons assignment
KB	Bathythermograph computations
KC	Classification
KD	Detection
KE	Threat evaluation
KI	Intercept control
KK	Error correction
KM	Mode, command, and priority designation
KP	Deployment
KT	Tracking
	"L" SERIES (Output Programs)
LA	Aircraft control
LH	Helm orders
LO	Orders and information to responders
LS	Sonar orders and information
LW	Weapons orders and information

Taking the J series first, these as a class represent messages from various reporting units that are received by the computer. A task force can be considered as being made up of a number of surface vessels, some of which may have fixed-wing aircraft or helicopters aboard. The later inclusion of submarines as part of this force has not been precluded. The task force may have responsibilities in the air defense part of NTDS, but for the present it is assumed that USW is an independent effort having its own communications network and computer memory. One ship is designated the command and control ship, and the others, responders.

Under the control of the computer in the control ship, each responder is interrogated in turn and responds with a message containing certain items of information. The message that has been called the JR report, when viewed from the control ship, is this input message. The information is evaluated by the K series and results in certain orders being sent to the responders, the programs for which constitute the LO series.

The responder gets its information from the chart house, helm, sonar track, aircraft which it is controlling, etc. These reports are put together by the JA, JC, JE, JN, JS, and JW series of programs. Except for the JA report, these data are assembled, either directly or by means of keysets, in the proper locations aboard the ships. The computer in the responder samples these keysets periodically, collects the information, sends out the LR report to the control ship, receives orders from the control ship (JO subroutines), and in turn outputs to several stations on board and to its own aircraft via LA, LH, LS, and LW programs.

Meanwhile the control ship receives a JR report from each responder, and also from its own sonar, aircraft, and so forth. However, in its relations to these stations, it functions just like any other responder. It interrogates and issues orders to itself. Thus the computer in each responder has in its memory those programs that it needs to control its own stations and to participate as a responder in the task force. The control ship has superposed on these functions those of data-handling for the task force as a whole. It is contemplated that, in the event the control ship is unable to exercise control for any reason, its function could be taken over by any other responder, and this would be done automatically according to a predetermined line of succession. It is also considered that from time to time SAU's would be detached, in which case the SAU commander would become control ship of the SAU with its own responders. No work has been done so far on the implementation of this aspect of the problem.

A block diagram that summarizes these relations is shown in figure 1. The flow

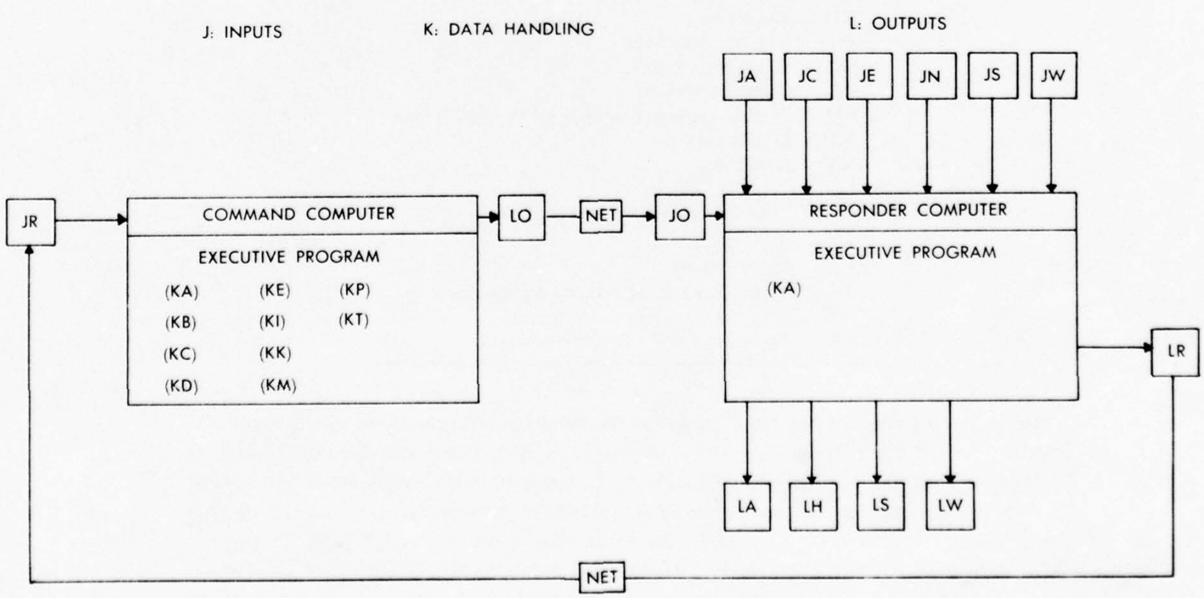


Figure 1. ASW data series.

from top to bottom is the intra-ship flow, and that from left to right the flow beween the control ship and responder. Only one responder is shown besides the control ship itself, but there can be any number in the net. It will be noted that in some cases, such as JO and LO, the J series and L series designations actually refer to the same thing. The difference lies in whether a particular message is viewed as an input or an output.

The J and L series are implemented largely by means of keysets. The executive flow charting has been completed for all of them. The first consideration can be the data that come into the computer via the J series (tables 2-7). The executive SR merely decomposes the message and puts the various data into a master data list. This series requires certain auxiliary subroutines, examples of which can be shown in figures 2-4.

TABLE 2. JA.

Name	Item	Bit Position
JA0(i)	A/C Number	8-0
	C.S. Number	20-15
	Bng to C.S.	29-21
JA1(i)	Rng to C.S.	11-0
	Mode	17-15
	Fuel	26-18
JA2(i)	Armament	5-0
	Sonar/Sonobouy Status	8-6
	Radar Status	11-9
	ECM Status	14-12
	MAD Status	17-15
	XXXAR Status	20-18
	Target Class.	23-21
JA3(i)	Target Bearing	8-0
	Target Range	29-15
JA4(i)	Target Depth	8-0
	Target CSE	23-15
	Target SPD	29-24
JA5(i)	A/C HDG	8-0
	A/C SPD	14-9
	A/C ALT	23-15
JA6-9	Spares	

TABLE 3. JC

Name	Item	Bit Position
JC0	DOP	0-1
	PIP	2-3
	LEA	7-9
	TEA	10-12
	TL	13-14
JC1(17)	Known Sonar Obstructions	0-29
JC2	Bng Foul	0-14
	Rng Foul	15-29
JC3	Target Motion Steady	0-2
JC4-5	Spares	

TABLE 4. JE.

Name	Item	Bit Position
JE0	Depth of Sea	14-0
JE1	Swell Direction	8-0
	Swell Amplitude	20-15
JE2	Wave Height	5-0
	Wave Direction	23-15
JE3	App. Wind Direction	8-0
	App. Wind Velocity	20-15
JE4	Lat. of Ref. Point	29-0
JE5	Long. of Ref. Point	29-0
JE6	Magnetic Variation	29-0
JE7(64)	BT Depth	5-0
	BT Temperature	23-15
JE8-9	Spares	

Format for reference point Lat. and Long.

UHW degrees		LHW min
X X X X X	XX . XX 0	Scaled 2^9

Minutes positive and scaled 2^9

Degrees in UHW 0 — 180 E are positive

Degrees in UHW 0 — 180 W are negative

Complement used for West

	UHW	LHW
Example: 64°30′ EAST =	[00100	36000]
64°30″ WEST =	[77677	36000]

TABLE 5. LR-JR.

Name	Item	Bit Position
JR0(i)	Responder Number	20-15
	Heading	14-6
	Speed	5-0
JR1(i)	Own Ship Y Coord.	23-0
JR2(i)	Own Ship X Coord.	23-0
JR3(i)	Resp. Mode	2-0
	Sonar Status	5-3
	Radar Status	8-6
JR4(i)	D/C Avail.	5-0
	D/C Aboard	14-6
	H/H Avail.	20-15
	H/H Aboard	29-21
JR5(i)	Weapon A Fwd. Avail.	5-0
	Weapon A Aft Avail.	11-6
	Weapon A Aboard	23-15
JR6(i)	ASROC Avail.	5-0
	ASROC Aboard	14-6
	Torp. 1 Avail.	20-15
	Torp. 1 Aboard	29-21
JR7(i)	Torp. 2 Avail.	5-0
	Torp. 2 Aboard	14-6
	Torp. 3 Avail.	20-15
	Torp. 3 Aboard	29-21
JR8(i)	Dash Avail.	2-0
	NUC Proj. Avail.	20-15
	NUC Proj. Aboard	29-21
JR9(i)	Target A X Coord.	23-0
JR10(i)	Target A Y Coord.	23-0
JR11(i)	Target A Depth	8-0
	Target A Class. and Contact Status	20-15
JR12(i)	Target B X Coord.	23-0
JR13(i)	Target B Y Coord.	23-0
JR14(i)	Target B Depth	8-0

TABLE 6. JS.

Name	Item	Bit Position
JS0	Target 1 Bng	0-8
	Target 1 Rng	15-25
JS1	Target 1 Depth	0-8
	Target 1 Class.	15-17
	Target 1 Contact Status	18-20
JS2	Target 2 Bng	0-8
	Target 2 Rng	15-25
JS3	Target 2 Depth	0-8
	Target 2 Class.	15-17
	Target 2 C.S.	18-20
JS4	Target 3 Bng	0-8
	Target 3 Rng	15-25
JS5	Target 3 Depth	0-8
	Target 3 Class.	15-17
	Target 3 C.S.	18-20
JS6	Target 4 Bng	0-8
	Target 4 Rng	15-25
JS7	Target 4 Depth	0-8
	Target 4 Class.	15-17
	Target 4 C.S.	18-20
JS8-10	Spare	

TABLE 7. JW.

Name	Item	Bit Position
JW0	DC Aboard	0-8
	DC Avail.	9-14
	H/H Aboard	15-23
	H/H Avail.	24-29
JW1	W/A Fwd. Avail.	0-5
	W/A Aft Avail.	6-11
	W/A Aboard	15-23
	Dash Avail.	25-27
JW2	ASROC Aboard	0-8
	ASROC Avail.	9-14
	Torp. 1 Aboard	15-23
	Torp. 1 Avail.	24-29
JW3	Torp. 2 Aboard	0-8
	Torp. 2 Avail.	9-14
	Torp. 3 Aboard	15-23
	Torp. 3 Avail.	24-29
	NUC Aboard	0-8
	NUC Avail.	9-14
JW4-5	Spare	

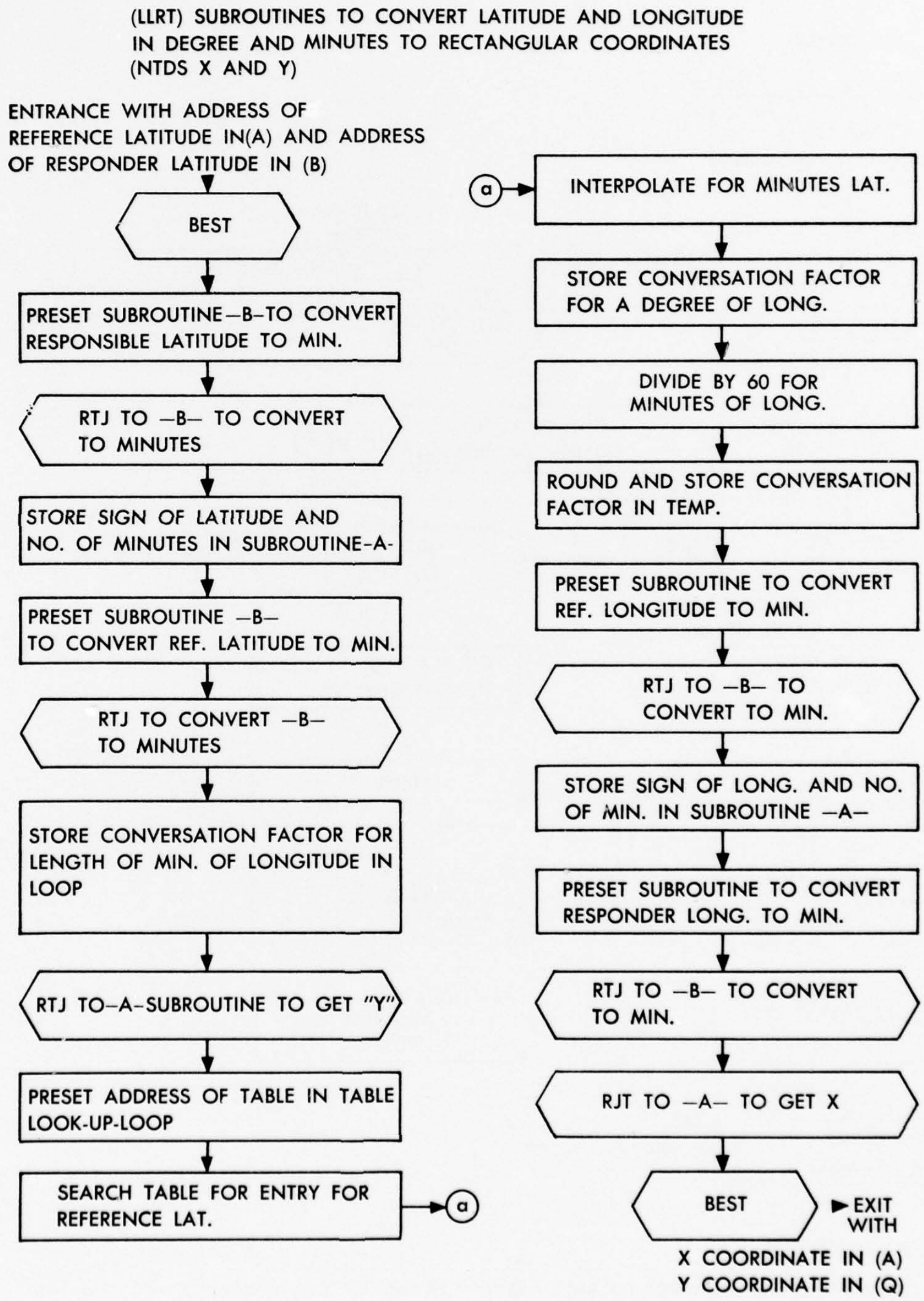
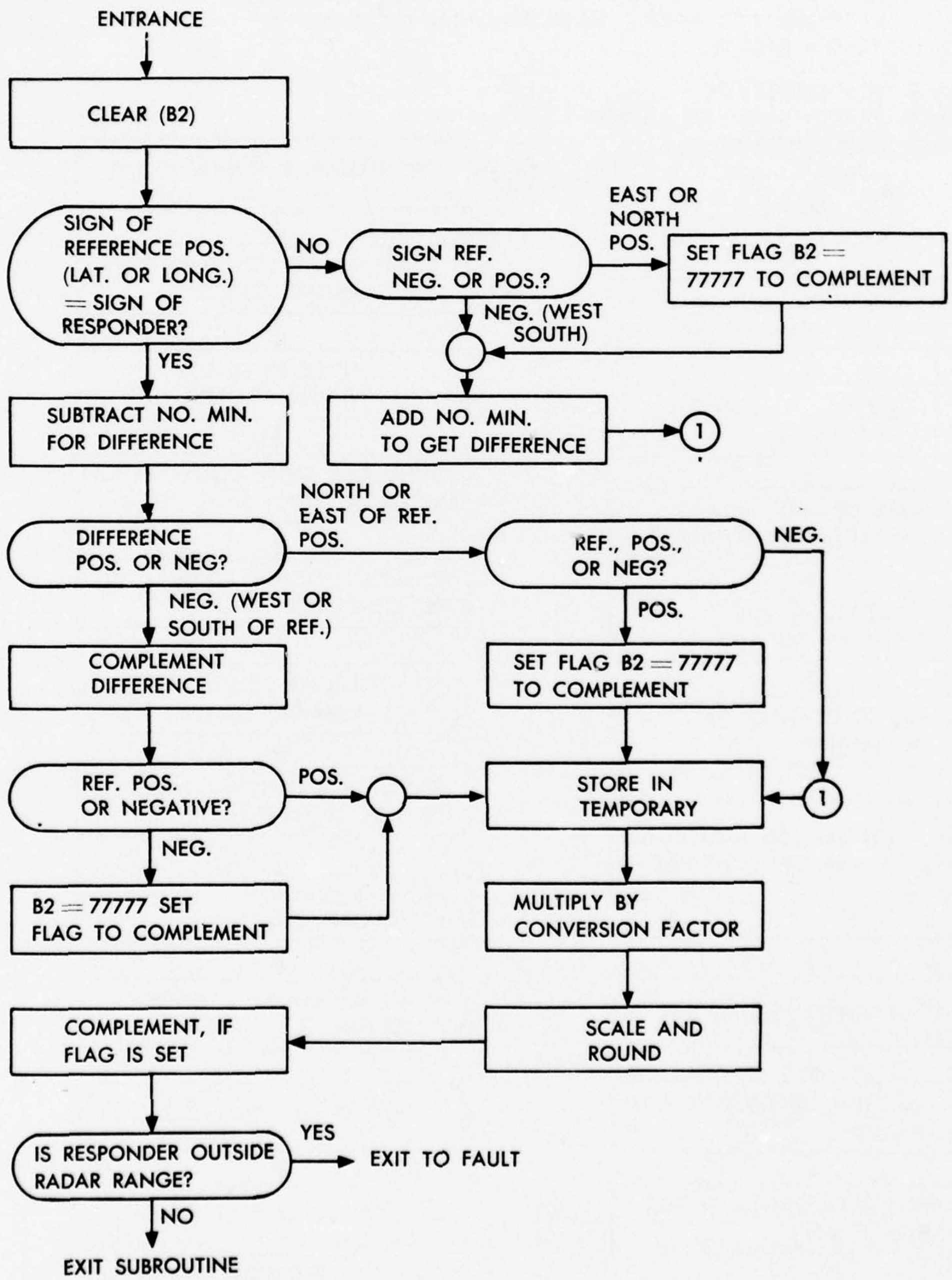


Figure 2. LLRT subroutines.



—A— SUBROUTINE TO CONVERT TO RECTANGULAR COORDINATES

Figure 3. LLRT subroutines.

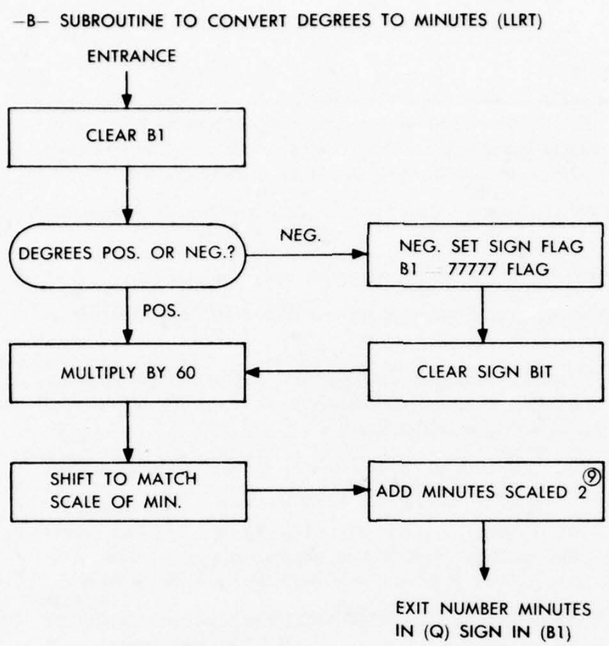


Figure 4. LLRT subroutines.

Turning now to the K series, it is found that each one of the categories is potentially a whole collection of subroutines. First of all, the names must be explained. Tentatively, brief statements have been laid down to indicate the categories as guides for the programmers. These are shown in table 8 and are not intended to be definitive. It will be seen that in some cases the objectives implied by these statements are rather ambitious. They have deliberately been made so in order not to lose sight of the ultimate goal of complete automation. However, an effort has been made to be realistic over what can be achieved in limited periods of time.

In reference to the status of these programs, it is not really possible to state that any one set is finished or not, for this is relative to the particular goals of the moment. Second, some arbitrary choices have had to be made as to where to start, and the guideline here was the desire to prove the feasibility of automatic USW. Consequently, not much effort has been devoted to those areas where ample precedent from air defense is available to help. The effort has been directed into completely virgin territory, and attention has been concentrated on those parts unique to USW. KB and KC were undertaken to prove that they could be done, and are both far enough along to establish that point. KC results have exceeded expectations. KA and KE are well under way, with the relative weights of all the factors as yet undecided. KI and KD will be first cousins to the corresponding programs in NTDS A/D. KK and KM are being left to the very last, for by their nature they must be superimposed on the others. KP is being considered only in its simplest aspects at present and probably will be for some time to come. It is possible here to have the computer recognize standard tactical situations and to recommend standard maneuvers (screens, attacks, search plans, etc.). What this would gain is not clear at this time. In the matter of deployment, USW operations cease to be independent of air defense.

TABLE 8. K series programs.

KA	WEAPON ASSIGNMENT: Determine and assign best weapon to be used in the destruction of a target based upon range to target, kill range, probability of kill, weapons available, cost, classification, safety of own forces, etc.
KB	BT COMPUTATIONS: Compute predicted sonar range based on bathythermograph information.
KC	CLASSIFICATION: Classify a contact as submarine or nonsubmarine.
KD	DETECTION: Process sonar and other inputs to determine that a target is present.
KE	THREAT EVALUATION: Considering classification, deployment, possibility of effective defense and offense, and all other pertinent data, decide whether offensive, defensive, or no action is called for.
KI	INTERCEPT CONTROL: Control all types of units to intercept target after detection.
KK	ERROR CORRECTION: Monitor continuously all programs to detect errors of all types (transmission, machine malfunction, incompatibility of data, etc.) and to prevent these errors from resulting in wrong decisions or actions.
KM	MODE, COMMAND, AND PRIORITY DESIGNATION: Maintain accounting of mode, command, and priority designations of all units and actions, and control programs based on that accounting. MODE is the action status of a unit (*i. e.*, search, attack, transit, screen, etc.). COMMAND is the function of the unit in the chain of command. PRIORITY is the order in which the actions are carried out.
KP	DEPLOYMENT: Determine dispositions of units best suited to meet the current situation and to carry out the decisions of the Commander.
KT	TRACKING: Maintain contact with target and supply position information during all phases of investigation and engagement.

In efforts up to the beginning of September 1959, the USW programs have been treated as separate pieces. These pieces have to be fitted together by a master program which gathers in all the data, performs the bookkeeping, and knows at each instant what actions are required. This is now being worked on, and it is expected that the first version of a USW tactical program will be available soon.

It is appropriate in reporting progress on the USW problem to mention a parallel effort, the NEL Compiler NELCO. One of the major considerations in developing NELCO has been to make it useful in USW programming. Certain capabilities have been built into it, such as bit handling, which were initially dictated by the requirements of USW. With NELCO available, it means that once the programming to the flow chart stage has been completed, the production of the machine code is accomplished in a matter of hours as compared with weeks without it. This is a fact demonstrated by the programs for classification and bathythermograph reading. Before NELCO was available (and this was the case with the A, B, and C series of NTDS programs), many weeks of routine programming were required after the flow charts were made. This tended to produce a certain inflexibility in the programs in that changes could not be readily implemented. Now, however, experiments in coding parts of the USW programs with NELCO have demonstrated that required changes, major or minor, can be incorporated into the product at any time with little difficulty.

Automatic USW Data Processing and Presentation

ROBERT H. HARWOOD

Head, Experimental Application Section

A brief review of the over-all requirements of NEL Problem N4-3, Task 18, is not easy because the many changes have made it difficult to give a precise problem statement at this time. However, the aspects that have not changed radically will be considered.

Task 18-a states:

"Make the modifications required to allow the SQS-4 mock-up now located in the ASDEC area of NEL to operate with the AN/SSQ-25(V) in the same area."

Task 18-b states:

"Make recommendations to the Bureau of Ships for equipment modifications of additions required to integrate USW search and USW weapons direction systems with the Naval Tactical Data System (NTDS)."

Both of these tasks were scheduled for completion by the end of October 1959, based on the presumption that the "A" link net tests would have been finished and the report written several months ago. Task 18-a will come close to meeting this date even with the interruptions. Task 18-b will not then be completed. Interruptions, and the unavailability of some material, have caused effort to be several months behind on Task 18-b. Some data have been gathered, but not enough to make more than a dent in the problem.

Another trend to be considered is the change in character of the task as a result of the recent increasing emphasis on USW. It might be better to make this task merge into some of the recommendations made by the USW Committee in the report entitled "Proposed Program for Application of Automatic Data Processing Techniques to Undersea Warfare," and make it a continuing one. Some of these implications will be treated later.

Continued work on Task 18-b is planned. As soon as the "A" link net tests are completed and manpower is available, Task 18-b will be conducted at an accelerated pace so that the information will be obtained as rapidly as possible. Instead of recommendations being made to the Bureau of Ships for changes required to integrate these equipments piecemeal into NTDS, the information should be routed to the System and Operational Analysis Branch for integration into Phase 2 ("Develop System Functional Design") of the program mentioned above. The recommendations that would then come out of Phase 3 ("Develop Specifications for System Components") would be integrated with the entire plan and not involve a "shotgun" approach. This would delay some of the initial procurements, but would reduce the time required for a satisfactory working system in the Fleet.

If the over-all program is to proceed at a satisfactory rate, it will be necessary that technique studies, and the development of personnel competence in such techniques as are required to perform Phase 4 ("Develop Equipments as Required"), be conducted concurrently with Phases 1, 2, and 3. New methods are appearing so rapidly that past experience can be taken only as a basis for new effort. It is important to develop personnel competence in the new techniques if a large part of the work entails monitoring contracts. It is possible, although not efficient, to learn about techniques while work is being performed, but teaching requires a more expanded knowledge.

The limited manpower situation that exists, and the pressure of the current work load, makes it impossible to investigate all avenues of approach. It is therefore necessary to make the best estimate possible of the direction that the development will take.

A hypothesis was started to describe the possible system. This hypothesis will probably not be correct in all of its implications, but it should be close enough to indicate any serious weaknesses in technique requirements. Personnel of various areas have been contacted for suggestions to make the hypothesis more accurate. This will be completed as soon as possible and put in written form.

The hypothesis is at present only in outline form, and the outline is in an early stage because not enough knowledgeable personnel have been contacted to give a high degree of confidence in it. However, certain implications, which may change later, are arising that might make interesting discussions. Some of these may be considered as follows:

1. It appears that two major types of equipment problems (and probably philosophical problems) exist that must be solved in the USW program. One concerns the DLG class and larger ships that will be fitted with complete NTDS systems. The other concerns smaller platforms such as DD's, DE's, hydrofoil boats, helicopters, blimps, fixed-wing aircraft, and other units too small, or too expendable, to carry the full system. Some of the equipments will be common to both types, but others may be radically different. The smaller platforms will probably require some equipment, differing from any now available, to enable them to send and receive target messages and orders, or to assist them in weapons employment, navigation, multiship operation, etc. This may require some specialized computation and data transmission equipment if the size is to be kept small enough to be usable.

2. The smaller ships will probably require some method of controlling aircraft, or other small, highly mobile platforms, sent to assist them in USW operations, particularly in the case of a detached surface attack unit.

3. Some new types of displays are needed. The operator's display for detection and/or tracking can be very similar to the present display, but it should have better information coming to it in the form of improved rate-aided tracking, classification, etc. This could possibly be a modified unit display. The displays in the underwater battery plot and/or combat information center, however, should have a record of the immediate past history and predicted future position. Whether it would be better to make this past history a result of long-persistence phosphors, of a partial degenerative storage tube, or computer generated, cannot be stated at this time.

4. A method of weapons direction and/or coordination is essential. Whether it is better to feed the target information to the Bureau of Ordnance computers, or whether it is better to combine the weapons direction, target prediction, and "bookkeeping" in one computer is not known at this time. The results of such decisions should be known at an early date because of their effect upon instrumentation.

5. If submarines are to be used in the complex, a better method of communication with them is necessary. If computers are used in the small units, some of the functions might be performed by them.

A number of areas need intensive effort, and work is underway on some. The following list of such areas may be of possible interest:

1. Sonar improvement (a continuing program)
2. Automatic raw data processing
3. Automatic classification
4. Improved automatic tactical data processing
5. Improved USW data display
6. Fire-control computer coordination or computation
7. Automatic maneuvering for torpedo evasion, etc.
8. Drone ship control
9. Air platform control and communications
10. Communications with and control of SS, SSK, etc.

The following outline is not intended as a design of the system. This is an attempt to outline the problems sufficiently to locate any omissions in the technique structure. A code number of the Navy Electronics Laboratory is shown after each item in the outline in an effort to indicate the personnel possessing the latest information on the subject.

I. PROBLEMS TO BE INSTRUMENTED

A. USW Applications of DLG and Larger Ships

1. DLG 10 and 11 (see NTDS Service Test Instrumentation, or "Purple Book")
2. Integration of advanced signal-processing and information-processing techniques.
   a. Detection and tracking by automatic-signal processing (2600)
   b. Classification (2600)
   c. Maneuvering and station-keeping (2240)
   d. Control of aircraft for USW (2840 and 2860)
   e. Communications — electromagnetic, subsurface, and transbarrier (2600 and 2700)
   f. Tactical situation summary — past, present, and predicted (2860)
   g. Weapons direction coordination (2860) (BuOrd)
   h. Safety monitoring (2240)
   i. USW status and orders (2850)

B. Minimal System USW Ships (smaller than DLG)

1. Service test period (none)
2. 1963 to 1970 models
   a. Automatic detection and tracking (2600)
   b. Automatic classification (2600)
   c. Maneuvering and station-keeping (2240)
   d. Control of ASW aircraft (2240 and 2860)
   e. Communications — EM, SS, and TB (2600 and 2700)
   f. Tactical situation summary (2860)
   g. Weapons direction coordination (2860) (BuOrd)
   h. Status and orders (2850)

II. DESCRIPTION OF POSITION AND EQUIPMENT FUNCTIONS
(Methods of Instrumentation)

A. USW Applications of DLG and Larger Ships
   1. DLG 10 and 11 (see "Purple Book")
   2. Integrated models
      a. USW raw data processing (2600)
         (1) Detection and location (2600)
         (2) Classification (2600 and 2100)
      b. USW tactical data processing
         (1) Tracking (2240 and 2860)
         (2) Underwater battery plot (2860)
         (3) Combat information center plot (2860)
         (4) Internal communications with NTDS and summary plots, and data sources (2860)
         (5) Communications (2600 and 2700)

B. Minimal System USW Ships
   1. Service test period (none)
   2. 1963 to 1970 models
      a. USW raw data processing
         (1) Detection and location (2600)
         (2) Classification (2600)
      b. USW tactical data processing
         (1) Tracking (2600 and 2860)
         (2) Underwater battery plot (2860)
         (3) Combat information center plot (2860)
         (4) Bridge summary plot (2860)
      c. USW aircraft handling
         (1) Summary plots (2860)
         (2) Air controller position (2860)
         (3) Data transmission (2700)
      d. Radar data processing
         (1) Detection and tracking (2862)
         (2) Summary plots (2862)
      e. Communications data processing (2700 and 2600)

USW Data Control System

J. P. WARD

Project Leader 1, Experimental Application Section

The task assigned was that of the design and production of a minimum system for the entry of selected keyset-stored, USW information into the Naval Tactical Data System. This information may be inserted into the keysets automatically, semiautomatically, or manually.

An example of both automatic and semiautomatic insertion would be the simulated "SLANT RANGE" and "BEARING" target information that will be taken from the SQS-4 sonar equipment located in the ASDEC area. This may be automatic and/or semiautomatic since the information is taken automatically from the cursor, and the cursor may be positioned automatically by the rate-aiding computer, manually by the sonarman, or by both methods simultaneously. The group performing the task is primarily responsible for the Data Control System that is inserted between the outputs of the keysets and the input to the unit computer.

A brief treatment of the philosophy of operation follows:

USW information is collected in the keysets in 30-bit words. These words of information, which are essentially similar in content, and require updating at approximately the same rates, are then assembled in the form of a report consisting of one or more 30-bit words. The unit computer will request complete reports from the control system at predetermined intervals. The control system will then present the words of the report to the unit computer in a predetermined sequence.

In order to meet, as nearly as possible, the time schedule initially set up with the manpower available, rapid determinations had to be made about the system. After cost, simplicity, and time were considered, it was decided to use printed-circuit, solid-state logic, and switching packages. These packages were to be designed and produced locally for static-type operation. The circuitry would be basically similar to the Remington Rand Univac transfer circuits and use negative logic internally. The input and output packages are also basically similar to those used in the unit computer. Positive logic is used externally, with the input and output characteristics essentially meeting the Remington Rand specifications.

This control system is relatively slow in that it can present words to the unit computer at a maximum rate of only 20,000 words per second. However, it is certain that once the system is in operation, this rate can be increased to make the most efficient use of the register time in the unit computer, and without major modifications. Twenty thousand words a second probably exceeds requirements when compared to the rates of acquisition of most USW information, but it may be wasteful of unit computer register time. However, during the preliminary tests for which this system was designed, register time will not be a problem.

Figure 5 is a block diagram of the system, including keysets. In this configuration, the system is capable of handling from one to six reports consisting of six

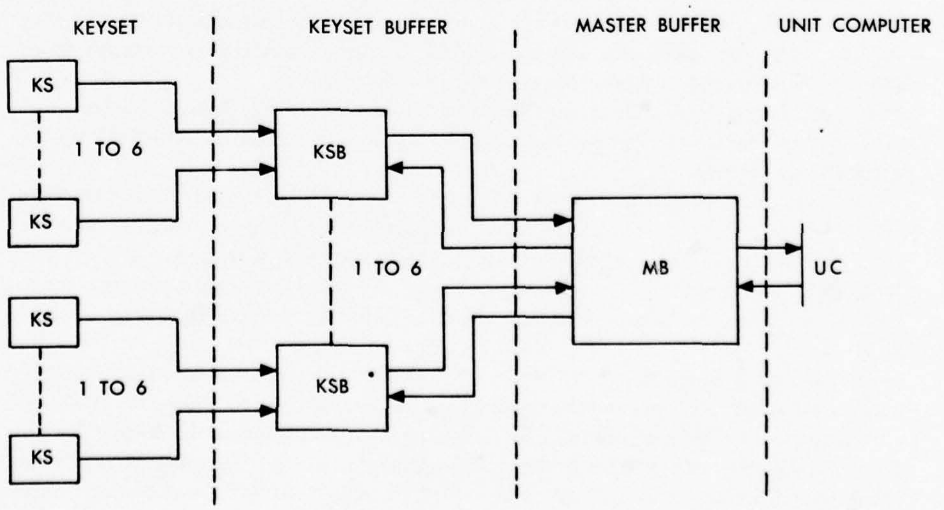


Figure 5. Simplified USW keyset entry system.

30-bit words each. When the system is going to handle one report, it need not be in this configuration. In this figure the master buffer is connected directly to the unit computer and is capable of selecting, at random, any one of up to six keyset buffers. This depends upon the report requested by the unit computer through the function code. The keyset buffers represent reports, and each is capable of presenting in sequence to the master buffer (and thus to the unit computer) a maximum of six words, which are stored in the keysets.

The projected sequence of operation is as follows:

1. The unit computer requests a specific report by sending the proper function code followed by the function code READY command.
2. The master buffer then opens the required input gates to its register, and the proper keyset buffer is selected and set for operation.
3. When the first communication ready command is received from the unit computer, the first word, from the appropriate keyset, is gated into the keyset buffer register and thus on to the master buffer register.
4. The RESUME command originates in the keyset and, after a timing operation in the keyset buffer, is fed to the master buffer and thus to the unit computer.
5. After the unit computer has accepted the data and sent another communication ready command, the next word in the predetermined sequence is set into the registers and the READY-RESUME operation continues until all words of the report have been accepted by the unit computer.

Figure 6 is a block diagram of the system still in a multi-report configuration. But here is shown at least one report consisting of more than six words. In this configuration the first keyset processes the first three words through the second keyset buffer to the master buffer, and the second keyset buffer processes the last five words. These keyset buffers may be stacked in this manner to handle "n" number of words for a report, and with only a slight deterioration in word rate.

Figure 7 shows the system in a single-report configuration. Note that the master buffer has been removed and that the keyset buffer is connected directly to the unit computer.

Figure 8 is a block diagram of the keyset buffer. Each buffer recognizes the function code, which designates the report it processes and sets the sequencing control ready for operation. The data READY control initiates the change from word to word as the sequence operation continues.

The timing control delays the RESUME command to the master buffer until all registers contain the proper word. Then the sequence control and the register are self-explanatory.

The function code, function code READY, data READY, and RESUME lines are available to the next keyset buffer in cases where a report consists of more than six words, and keyset buffers must be stacked as shown in figure 6. Only the RESUME line is available to the keysets, and the RESUME command is present on this line continually except during the time that data are actually being updated or changed.

Figure 9 is a block diagram of the master buffer. The function code control and its READY control contain amplifiers for feeding the code and its READY command to the keyset buffers. These controls, together with the keyset buffer selector, also open the proper gates in the register to accept the information from the selected keyset buffer. The data READY and RESUME controls are only buffer amplifiers to accept the READY command from the unit computer and feed it to the keyset buffers, and then to accept the RESUME command from the

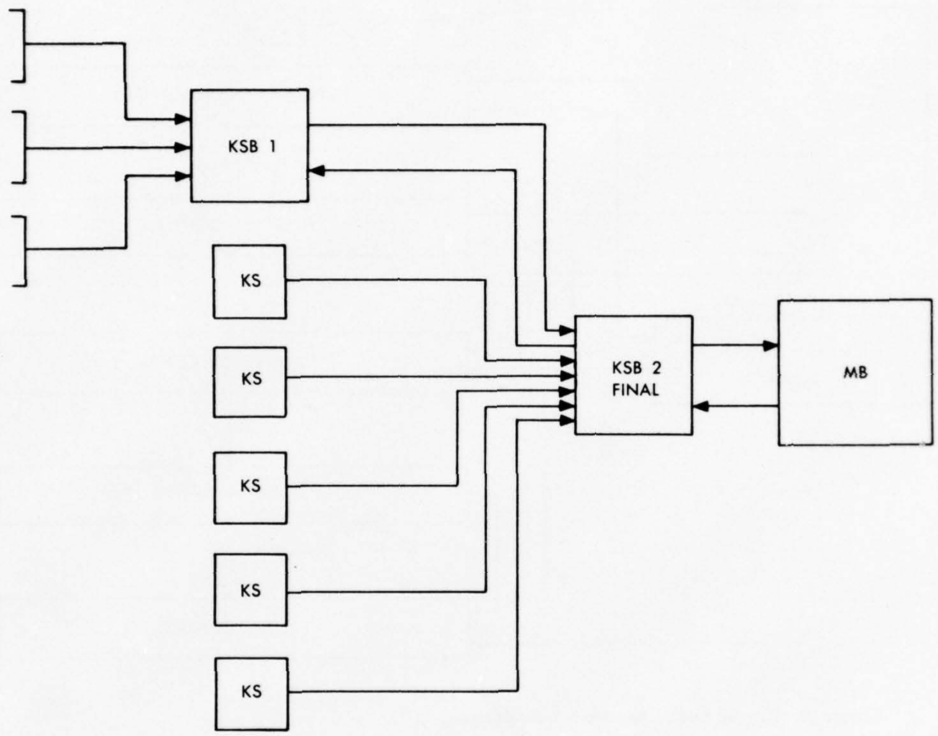


Figure 6. Connections in which one complete report consists of more than six words.

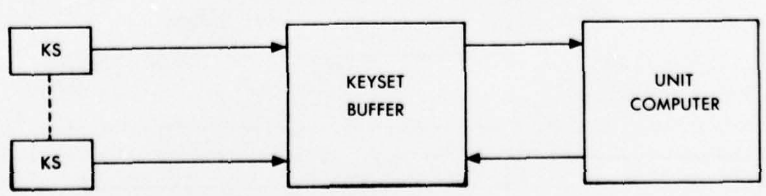


Figure 7. USW keyset entry system for entry of only one report.

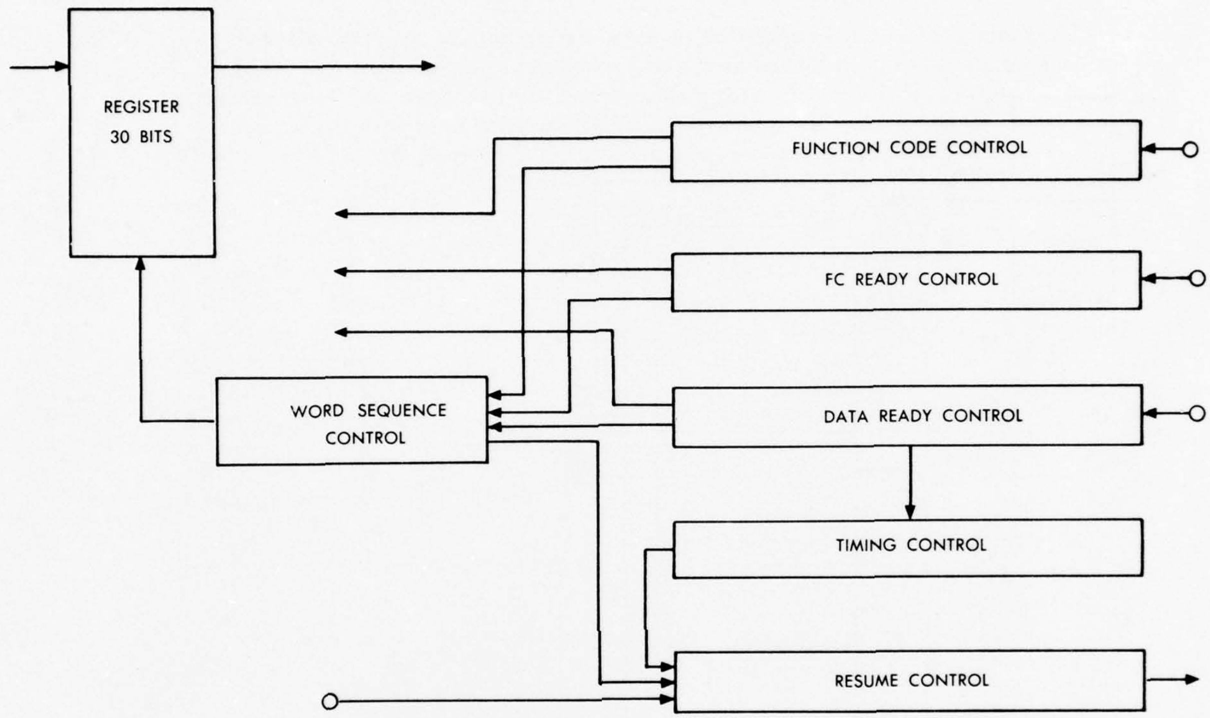


Figure 8. Keyset buffer functional diagram.

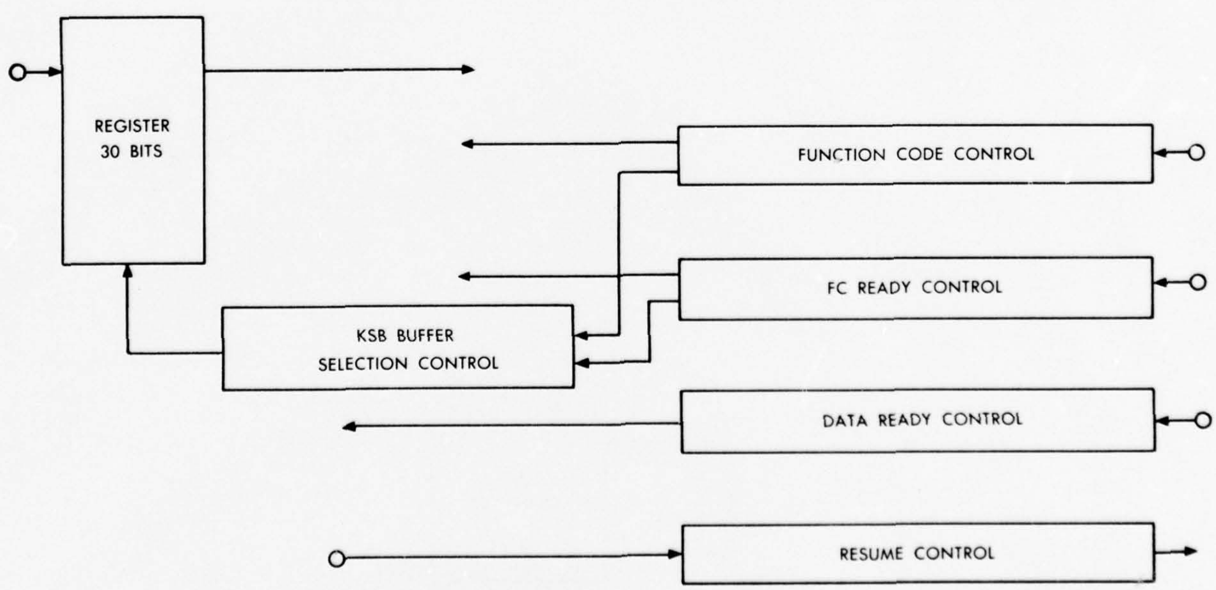


Figure 9. Master buffer functional diagram.

keyset buffers to feed to the unit computer. No special timing networks are necessary in this unit as were used in the keyset buffers.

One possibility not included in this system is random access to words rather than to reports. However, with a very minimum of modification, up to six words could be handled in a random access manner. With a relatively moderate amount of modification, more could be handled in this manner, or a combination of both random access report with sequenced words and random access words could be handled simultaneously.

The USW Data Control System in a refined, miniaturized version could be used to process any data, but especially relatively slow-changing data, and in any type of access required. On small, non-NTDS ships, it could be utilized to assemble and present data for transmission on a communication link. This latter use would require some additional development work.

If future events indicate the feasibility of approach, the necessary refinements to the system will be made to bring it up to the state of the art. When the amount of data and the manner of their presentation to the computer are fixed, a major portion of the versatility built into the system can be eliminated, with some simplification to follow.

TASK 18-b

The effort extended on Task 18-b has as yet been small. This task entails the integration of sonars and fire-control systems with the Naval Tactical Data System. A brief study of the possibility of exchanging information between NTDS and the Fire Control Group Mk 102 has been conducted, and an investigation of what would be required of and by the unit computer to solve the fire-control problem associated with current "hedgehogs" has also been made. These are exploratory studies of the integration problem, and involve essentially obsolete weapons and direction systems.

Keyset for the Insertion of USW Data

C. KIRKPATRICK

Project Leader 2, Experimental Application Section

The keysets are based on simple switching techniques. The task is to provide a family of switching keysets by which a human operator can feed information into the system, for much of the sonar information of necessity must be fed in manually. Studies have shown that the information contained in sonar can best be analyzed by a human operator. Many attempts have been made to make this equipment automatic, but a human being comes up with the best answers, particularly in areas like classification. Although the long-range intention is to make everything automatic, it is not believed that this is going to be accomplished very soon; therefore we are preparing a few different types of keysets for the manual insertion of sonar data.

The computer accepts data in its inputs only in binary form. Humans are not used to binary notation, and for large numbers there are too many digits (bits) to keep in mind. However, three binary bits are not too difficult to remember. This leads, for convenience in quick conversions, to a form of notation known as the octal system. A brief explanation of this system is therefore in order.

The octal system uses numbers only from zero through seven. Any binary number, or decimal number, has an octal equivalent. Each octal number can be represented by three binary bits. The binary equivalent is the same for either octal numbers or decimal numbers up to number 7, as follows:

Decimal	Octal	Binary
0	0	000
1	1	001
2	2	010
3	3	011
4	4	100
5	5	101
6	6	110
7	7	111

For decimal numbers from 7 through 63, a second bank of three binary digits is needed:

Decimal	Octal	Binary
8	10	001 000
9	11	001 001
10	12	001 010
11	13	001 011
12	14	001 100
13	15	001 101
14	16	001 110
15	17	001 111
16	20	010 000
17	21	010 001
18	22	010 010
19	23	010 011
20	24	010 100

For decimal numbers 64 through 511, a third group of three binary digits is needed, etc.

The octal numbers never contain any digit greater than 7. Therefore if the binary number is broken up in groups of three, it is easy to read, back and forth, the binary or octal equivalents. However, to be able to convert from octal to decimal, or from decimal to octal, some sort of conversion chart becomes necessary. One chart, prepared for decimal numbers up to 1024, took seven well-filled pages to show the equivalent decimal, octal, and binary numbers. If the chart were prepared to show only the decimal and octal equivalents, much more information could be shown per page.

The programs being set up for the insertion of USW information will employ 30-bit binary words. The bits will be, in most cases, bunched in groups of three with various types of information appearing in definite bit positions. Each three-bit group can be represented by a single octal number; therefore the 30 binary bits can be expressed with a 10-digit octal number. Information can be changed anywhere in the word, three bits at a time, by changing the appropriate octal number.

A number of different types of octal switches are under consideration for manual insertion of data. The decision as to which type to use depends upon the speed with which the switching has to be done, and also upon the space allowed in the equipment involved.

The speediest, but most expensive, switch appears to be the pushbutton type. A special keyset is being built to show sonar classification that uses some of these switches. The wiring of the pushbutton type will be different than all the others since it will not use the group-of-three octal code. It will also feed directly into a special section of the computer.

Reasonable speed can be obtained by using the multiple-wafer rotary switch, a single one controlling three binary bits. Another switch uses 10 switches to control 30 binary bits.

Another switch is a very compact, octal type employing printed circuitry. This has an output of 30 binary bits, the same as the bigger unit mentioned previously. This smaller keyset is slower to operate, and one must employ care in moving the drums to be sure the detents land in the right place, but for slowly changing data, it will be very useful. Several of this type are ready for operation. Figure 10 shows a typical circuit to be used with these switches to furnish information to the computer via the master buffer.

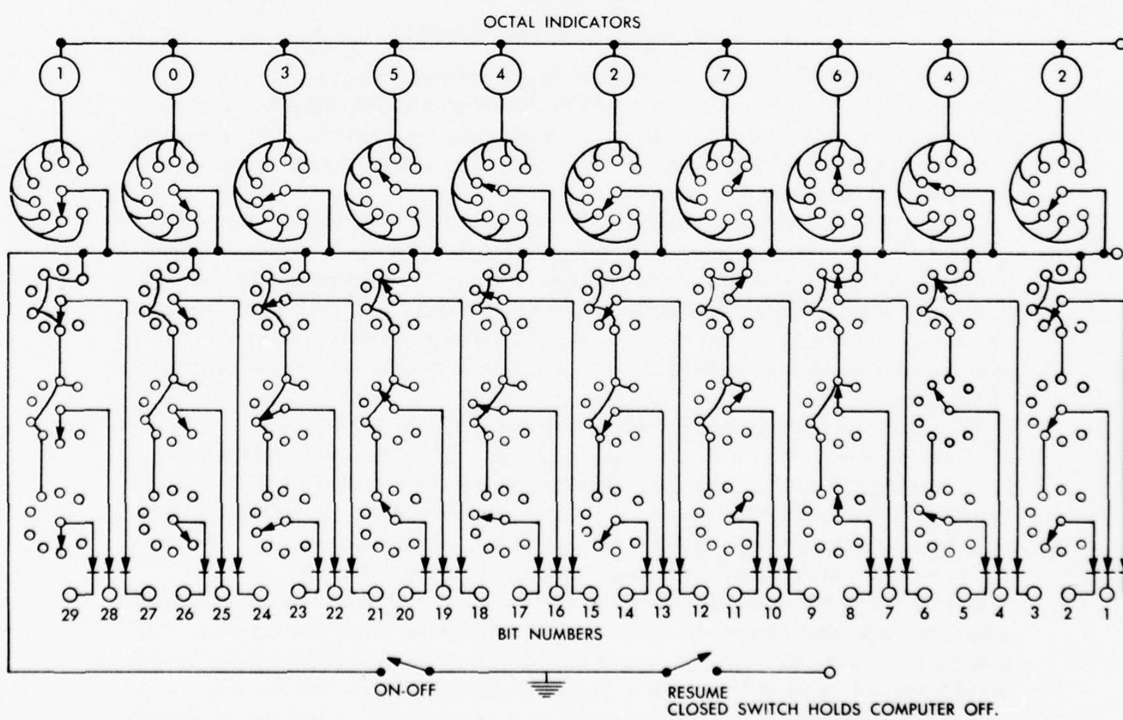


Figure 10. Typical 30-bit keyset.

A minor problem exists in providing suitable means for displaying the octal number being inserted, particularly in poorly lighted areas. If the illumination level is sufficient, the position of the switch itself can point to an engraved number, or display only one number engraved on a dial. Where illumination levels are low, auxiliary glowing indicators can be operated through a separate set of switch contacts. These indicators can be in the form of illuminated pushbuttons, Nixie tubes, "Idea INC" types, or any other of the many available.

Certain types of sonar information can easily be assembled at high speed, and more or less automatically. Facilities for doing this have been developed for both range and bearing in the form of a rotary shaft pulse counter. Additional logic circuitry has been developed for converting and displaying this information in binary bits. The present equipment has been designed to work into the computer via the master buffer. Should it be required, circuitry is on hand that could permit entrance into the computer directly.

The present plans for feeding sonar data into the Naval Tactical Data System entail use of the AN/SQS-4 sonar installation already in the ASDEC area. Four racks of equipment will be installed adjacent to the AN/SQS-4 where data can either be manually inserted into the keysets while the sonar displays are being observed, or automatically inserted with the equipment servo-connected to the sonar system.

Automatic Entry of Range and Bearing

W. ELLIS

Experimental Application Section

It is not intended that this equipment be an automatic tracking for the sonar. The sonar operator will manually position the range and bearing cursor, and the equipment will automatically convert the shaft position of range and bearing to a binary number. The equipment will be used to provide inputs for remote displays and the fire-control computer.

In general, the technique entails taking a voltage proportional to range from a linear potentiometer attached to a calibrated shaft. The shaft is manually positioned by the operator to adjust the range stroke on the sonar contact. For bearing, the stroke is positioned by a synchro on a mechanical shaft, which is calibrated in degrees and positioned by the operator. Both shafts are available in two-speed synchro outputs. A single-speed servo is being used to drive the serial bit reader (figure 11).

The next step is to convert the shaft position to a binary number.

It was decided not to utilize one of the available binary coded wheels because their apparent simplicity can be a delusion when the problem of ambiguity is considered. A detent code wheel involves no problems, but to read out during rotation requires special treatment and introduces a complication that increases the complexity of the mechanical unit and/or the logic circuitry.

Accuracy and the ambiguity problem impose close mechanical tolerances, with attendant high cost and limited life due to wear. After these factors were considered, it was decided that an electronic equivalent of the binary coded wheel would be used. This will provide a complete digital system for low-order accuracy applications. If the electrical contacts on a binary coded wheel are visualized for a given count position, it can be seen that they correspond to the outputs of successive stages in a binary counter for the same count impact. To utilize this, a mechanical unit may be constructed to read serially the number of bits between two displaced positions on a drum or disc. One of the positions must have a pulse at the zero position to reset a binary counter; the other must be an adjustable input shaft that will provide a pulse for reading into a store the binary number (figure 12).

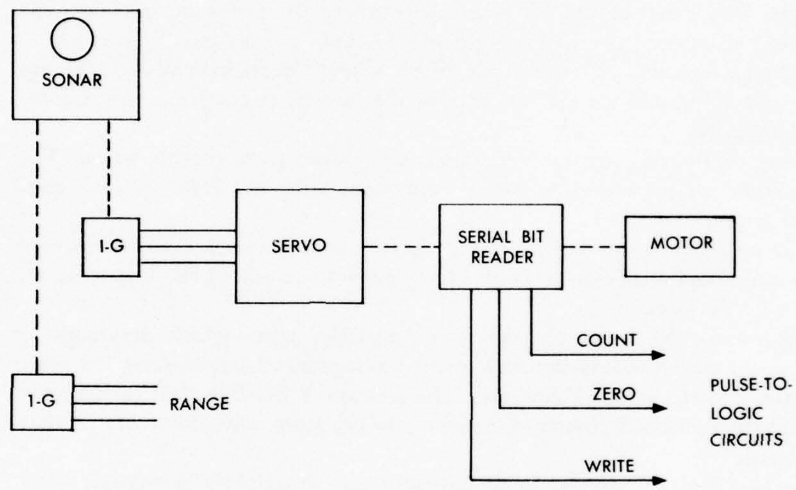
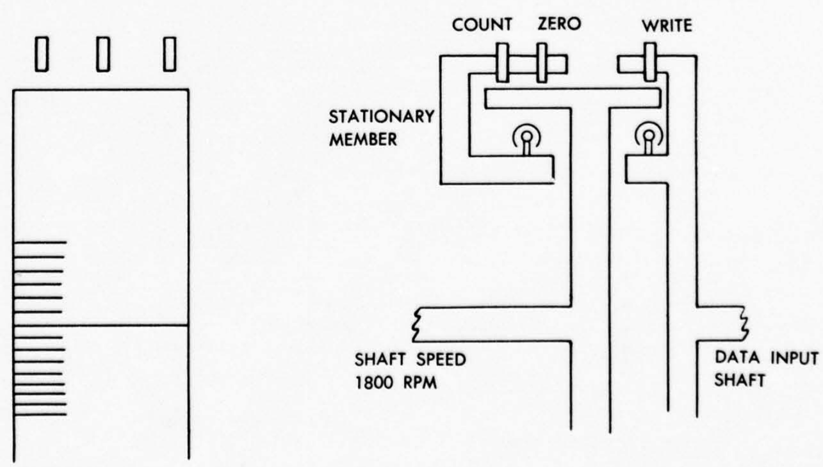


Figure 11. Block diagram of sonar shaft position to serial bit reader.



360 BITS/360°
ACCURACY ±.5°
RESOLUTION ±.5°
UP-DATE DATA STORE 30/SEC
MAX. INPUT SHAFT SPEED 12 RPM

Figure 12. Serial bit reader.

If a zero position is placed on a wheel, with equally placed bits put around the wheel, and a stationary reading device is used for both, a zero position and the serial input bits for the binary counter are obtained.

The shaft input is accomplished by a movable reading device that is activated by the zero position on the wheel. The input shaft, when displaced from the stationary zero reading device, will provide a pulse that will write a binary number into the store that is equal to the number of bits contained within the displaced angle. The speed of the bit wheel determines the updating rate into the store. At 1800 rpm, the store will be updated 30 times per second (figure 13).

The electronic circuits associated with the bit wheel consist basically of a binary counter, a data store, and a gate for writing the desired count from the counter into the data store.

The binary counter counts the 360 consecutive pulses from the bit wheel. The zero pulse from the bit wheel, which is coincident with the 360th count, resets the counter to zero.

The write pulse from the variable input shaft, which is variable with reference to the zero pulse, operates the write gate and causes to be stored the binary count with which it coincides.

Associated with the basic circuits is a RESUME gate, which interrupts a RESUME signal and prevents the data control equipment from reading the store while its data content is being changed. There is also a flip-flop that inhibits the normal write function and inserts all "ones" into the store when there are no data to be reported.

An associated item of interest in this general consideration of automatic entry of range and tracking is that the serial bit reader may be used without modification for conversion to any number system for which a counter can be built. Simultaneous conversion in two or more number systems is also available from one serial bit reader.

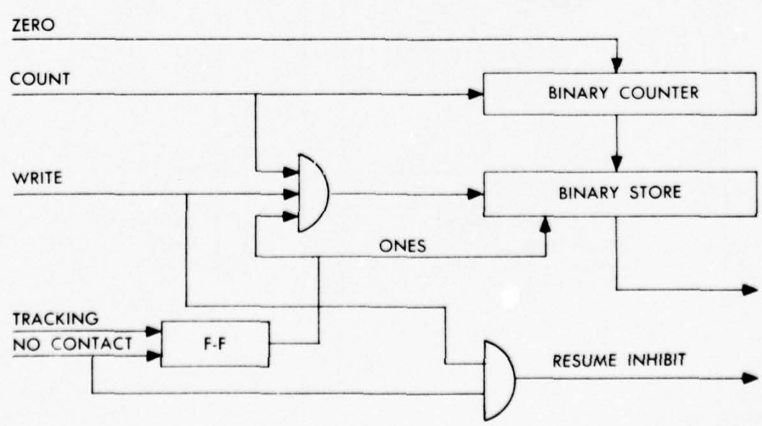


Figure 13. Logic circuitry.

NTDS "C" Communications Link

D. GIBSON

Head, Special Development Section

It is assumed that current interest in the NTDS "C" communications link varies from only slight to moderate. As the pediatrist said of the newborn infant, however, there may be a lot of changes over the next few months.

It cannot be stated that the link was born of necessity. NEL was not a participant at the time of its conception. Its birth, however, seems more fortuitous as it grows older. Some of its features appear to be rather arbitrary. There may be difficulty for some to grant it full acceptance and to accord it a purposeful existence. While its hereditary characteristics are already established, there is good reason to hope that, through proper manipulation of its environmentally developed characteristics, it may be nurtured to the stature of a full-grown and useful entity. It may achieve a functional status beyond the capabilities of its contemporaries. Let us now meet this stranger, the "C" communications link, and become better acquainted. It could prove to be an interesting and valuable friend.

The Special Development Section has had some of the commercial "C" link equipments for only 2 months and has not acquired all of it. Fortunately, there has been time to prepare special instrumentation for its evaluation. These observations are probably somewhat opinionated and in many respects are *preliminary*. Any consideration of the link's attributes at this time is "like looking through a glass, darkly."

The items to be discussed consist of the following:

First, a physical description and the technical characteristics of the "C" communications link subsystem; second, instrumentation capabilities and test objectives; third, predicted performance potential; fourth, the effects of the "C" link on other associated equipments; and fifth, some aspects on possible service employment.

Figure 14 is a simplified block diagram of a typical station employing the communications "C" link. Basically, the unit computer (the T-46) will be used in

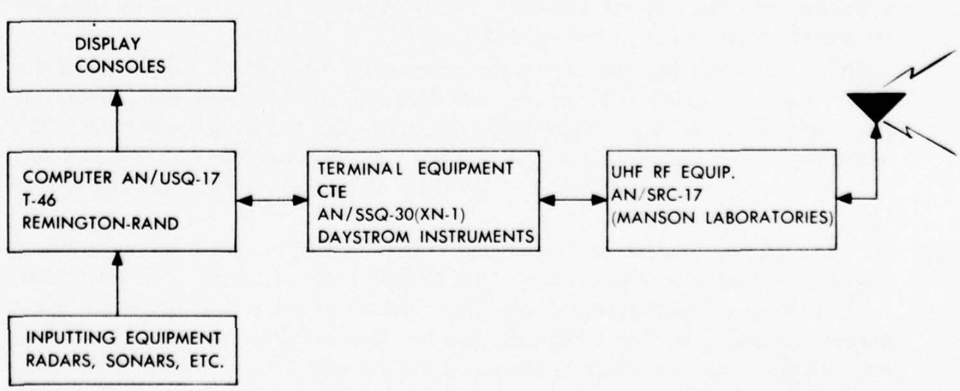


Figure 14. Simplified block diagram, typical station configuration, NTDS "C" communications link.

conjunction with special data transmission terminal equipment (provided by Daystrom Instruments) and the radio equipment (provided by Manson Laboratories). There will be appropriate information inputting from radars, sonars, etc., and outputting to the display consoles, etc.

The function of the computer, as it pertains to the "C" link, is to process and distribute the data transmitted around a net of two or more stations. The computer responds to both transmit and receive commands from the terminal equipment. It may also perform certain error detection and correction functions.

The terminal equipment (also called the CTE) joins the computer (the requirements of which are parallel data) to the rf equipment, whose requirements are serial data. This is accomplished through the use of shift registers in a buffer and storage process. The terminal equipment translates the computer logic into the rf equipment logic and vice versa. The terminal equipment generates a 6.5-kc/s signal, *e. g.* a 13,000 bit-per-second data rate, to synchronize the transmitting station with all other stations in the net. It also generates the proper codes and commands to begin the message, to translate commands to the computer, to call up the next ship at the end of a message, to call up an alternate ship if the next ship fails to respond, and to identify and display on a Nixie tube readout any station casualties. The terminal equipment functions to recognize the proper codes for the end of message and its own ship's call. The message structure is very similar to that of the "A" communications link — there are 26 information bits per word and one word is approximately 2 milliseconds long. Currently, the "C" link is capable only of a continuous-transmission, round-robin mode of operation and is difficult to shut down. If one station secures power, it is displayed as a casualty at all other stations of the net. The net continues to function until the alternate ship also becomes a casualty. One station may turn off the link, however, by switching in fictitious calls for the next and alternate ship's call.

The radio equipment receives frequency-shift-keyed signals from the other stations, demodulates them, and feeds the data to the associated terminal equipment. When transmitting, the output power may be either 10, 100, or 1000 watts. The FSK signal has a plus or minus 20-kc/s deviation, being either one of two frequencies corresponding to either a "1" or a "0." Each pulse is of 77 microseconds duration. The carrier frequency is controlled by a frequency synthesizer having a stability of 1 part in 10^6 and may be varied in 100-kc/s increments over the frequency range of 225 to 400 megacycles.

Figure 15 shows the Manson rf equipment, the AN/SRC-17 (XN-1), less the kilowatt linear amplifier. From top to bottom the units include the 100-watt rf amplifier, the 10-watt amplifier-modulator unit, the frequency synthesizer, the converter-keyer-monitor, and a URR-13 radio receiver modified for FSK and frequency control by the synthesizer. A low-noise preamplifier will be added to this equipment.

Figure 16 is a picture of one of the AM-1976 (XN-1)/SRT kilowatt linear amplifier equipments (also known as the NV/SRT-20), made by Electronic Communications, Inc., St. Petersburg, Fla. When driven by more than 100 watts input, output powers up to 2 kilowatts are possible. It is an alternative to the Manson one-rack kilowatt unit which is scheduled for delivery by the end of 1959.

Figure 17 shows the antenna installation mounted above the meteorological tower of the Navy Electronics Laboratory. They are two standard Navy AT-150 1-kilowatt, 225-to-400-megacycle broadband antennas.

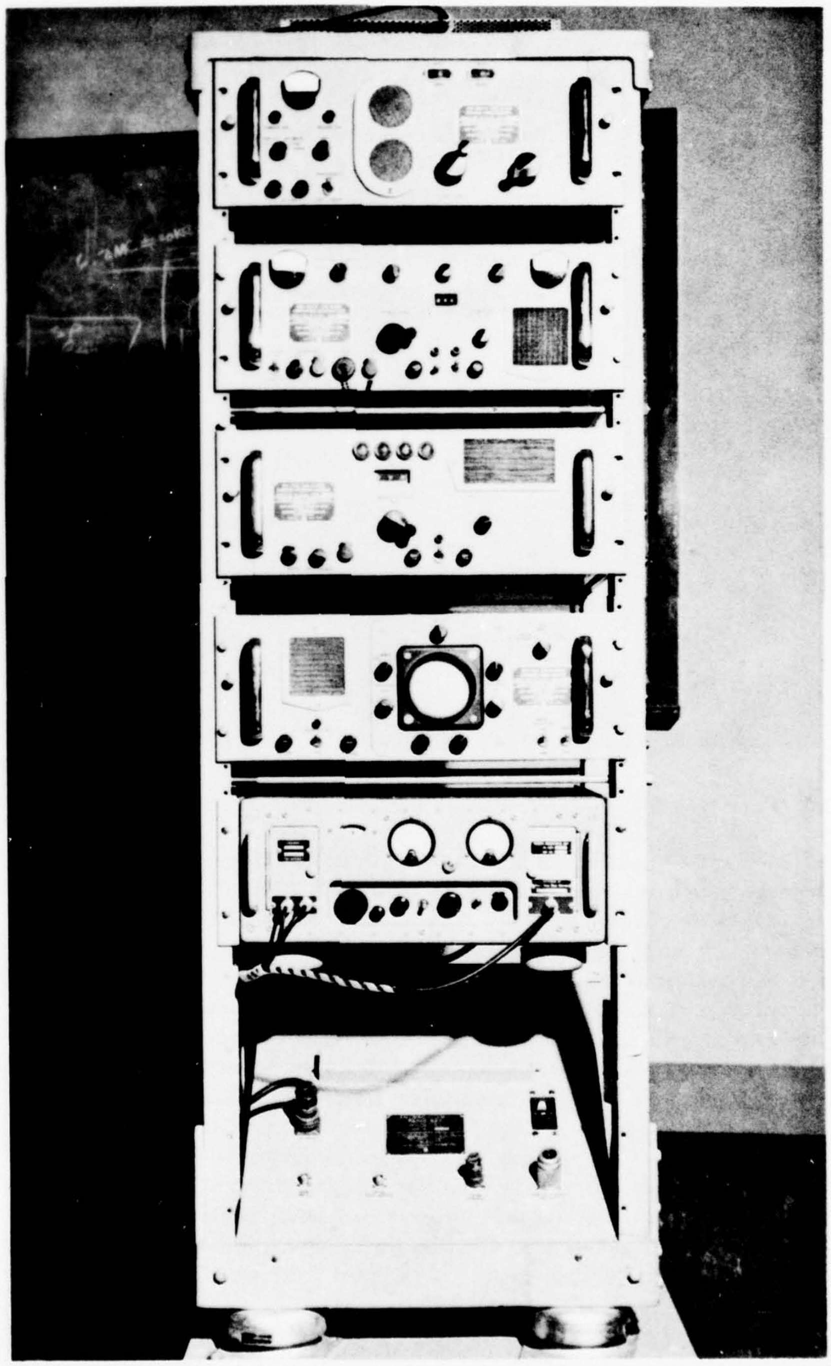


Figure 15. The Manson rf equipment, the AN/SRC-17 (XN-1), less the kilowatt linear amplifier.

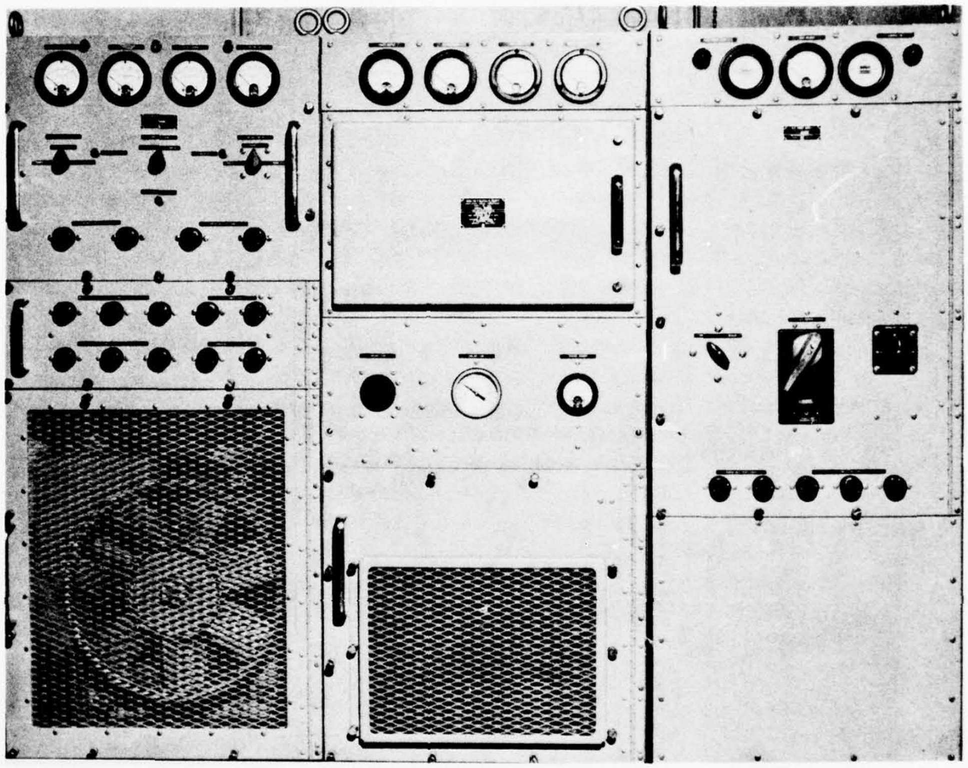


Figure 16. The AM-1976 (XN-1)/SRT kilowatt linear amplifier equipment.

Figure 18 shows Chu Associates' CA-4001 2-kilowatt, 225-400-megacycle broadband antenna, which is designated the AS-1018 (XN-1)/URC. It has a gain of approximately 4 db. In the ship installation on USS MARYSVILLE, one antenna is mounted on a special bracket on the mainmast above the radar, and another is mounted on an extension of the kingpole. A similar setup, simulating a ship installation, has been provided near the shore at Border Field. Two antennas are used at each site since a kilowatt duplexer is not yet available.

Figure 19 shows a little of the special instrumentation. It includes a sync tester, a pattern generator, and a bit and word error detection and counting capability. This equipment, which employs some "home-brewed" logic circuits and a broadcast receiver, makes possible one-way rf propagation testing without the requirement of using either the computer or the terminal equipments.

Figure 20 shows the data transmission terminal equipment, the AN/SSQ-30 (XN-1). In the center right drawer, the casualty readout tubes and the group of toggle switches for setting up "own," "next," and "alternate" ship's calls may be seen.

Figure 21 is an equipment called "IVAN," which was provided originally for the "A " link evaluation by arrangement with Remington Rand Univac. The government has some $50,000 invested in it. It will function as an eight-word storage repeater in lieu of the computer at one of the remote stations. It has no other capability and hence will be the limiting factor in any netting tests.

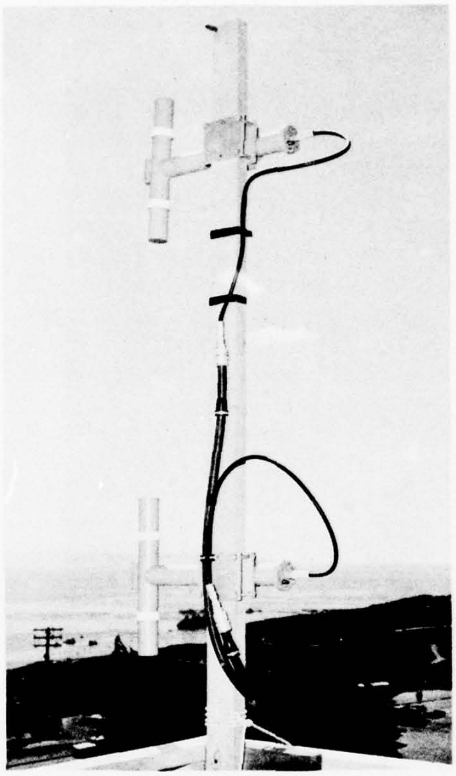


Figure 17. Antenna installation mounted above the NEL meteorological tower.

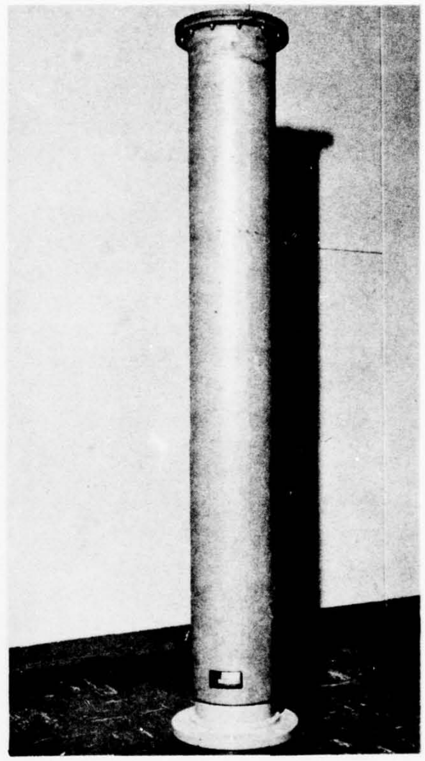


Figure 18. The AS-1018 (XN-1)/URC antenna.

Figure 22 depicts some additional NEL-developed test instrumentation. The two top chassis of Computer Control Corporation logic cards and memory cost about $15,000, but are the equivalent of several racks of vacuum tube circuitry. Called "BUD," it is a special-purpose computer, less the arithmetic portion, and contains a word generator (having an 18-word capability), a storage capability or memory, and an error detector-classifier-counter. It will also total messages (hence total word, or bits) that are transmitted over a certain period of time. BUD is used, as is IVAN, in lieu of the T-46 computer which will not be available at the remote stations. The T-46 computer in the ASDEC installation at the Navy Electronics Laboratory, with the associated Remington Rand tape unit, will yield which words are in error; the location of the error bits; when the errors occurred; plus a summation of the errors by bit position and the number of words with a given number of errors. These data will provide a comparison with the data obtained from BUD. It will also provide the information required for any other desired type of analysis.

Figure 23 lists the characteristics of the "C" link as it now exists, and compares the basic features with the "A" link.

Figure 24 depicts typical test configurations, including Stations C-1 at ASDEC, C-2 located in the communications van, and C-3 aboard USS MARYSVILLE.

The computer or computer simulator functions at each station are as follows:

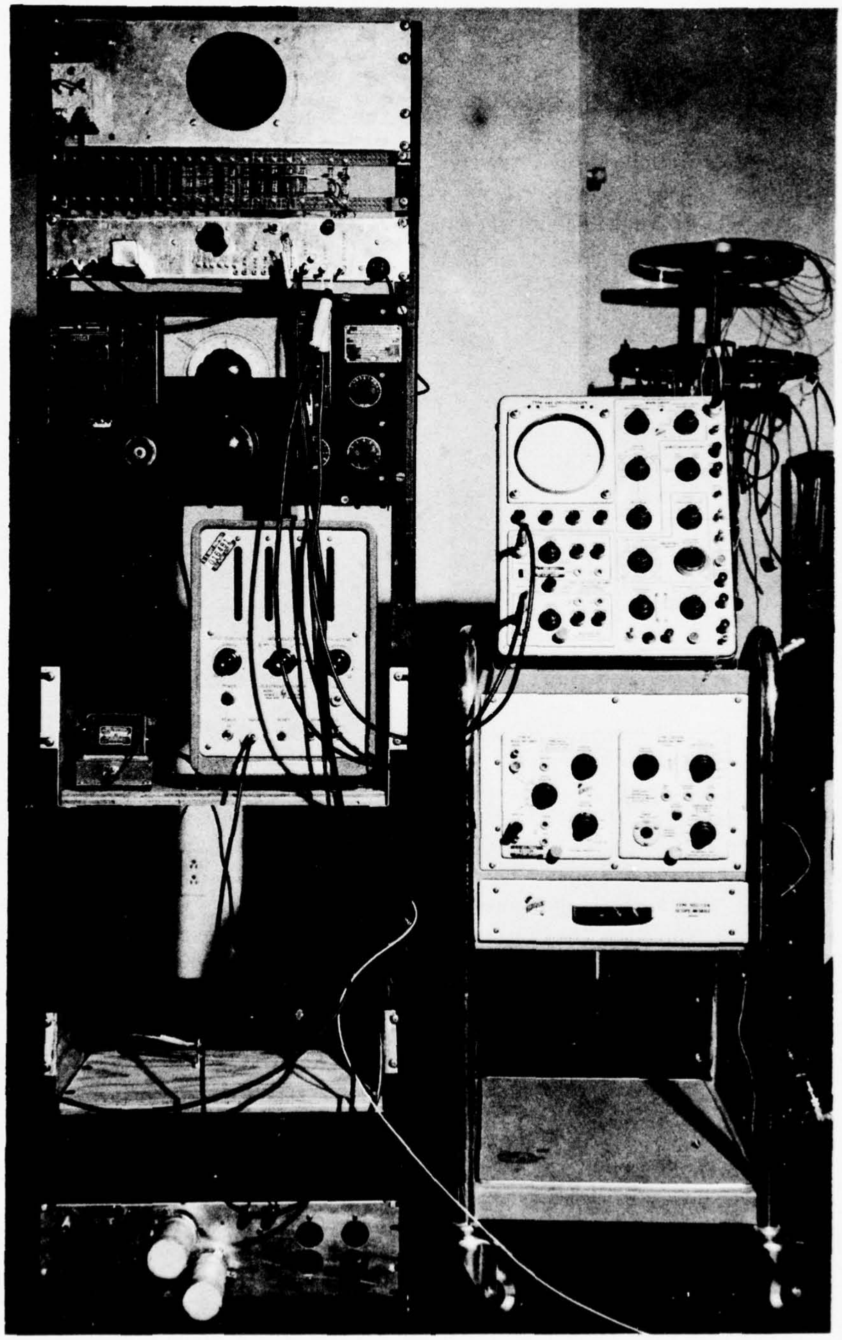


Figure 19. Special instrumentation, including sync tester and pattern generator.

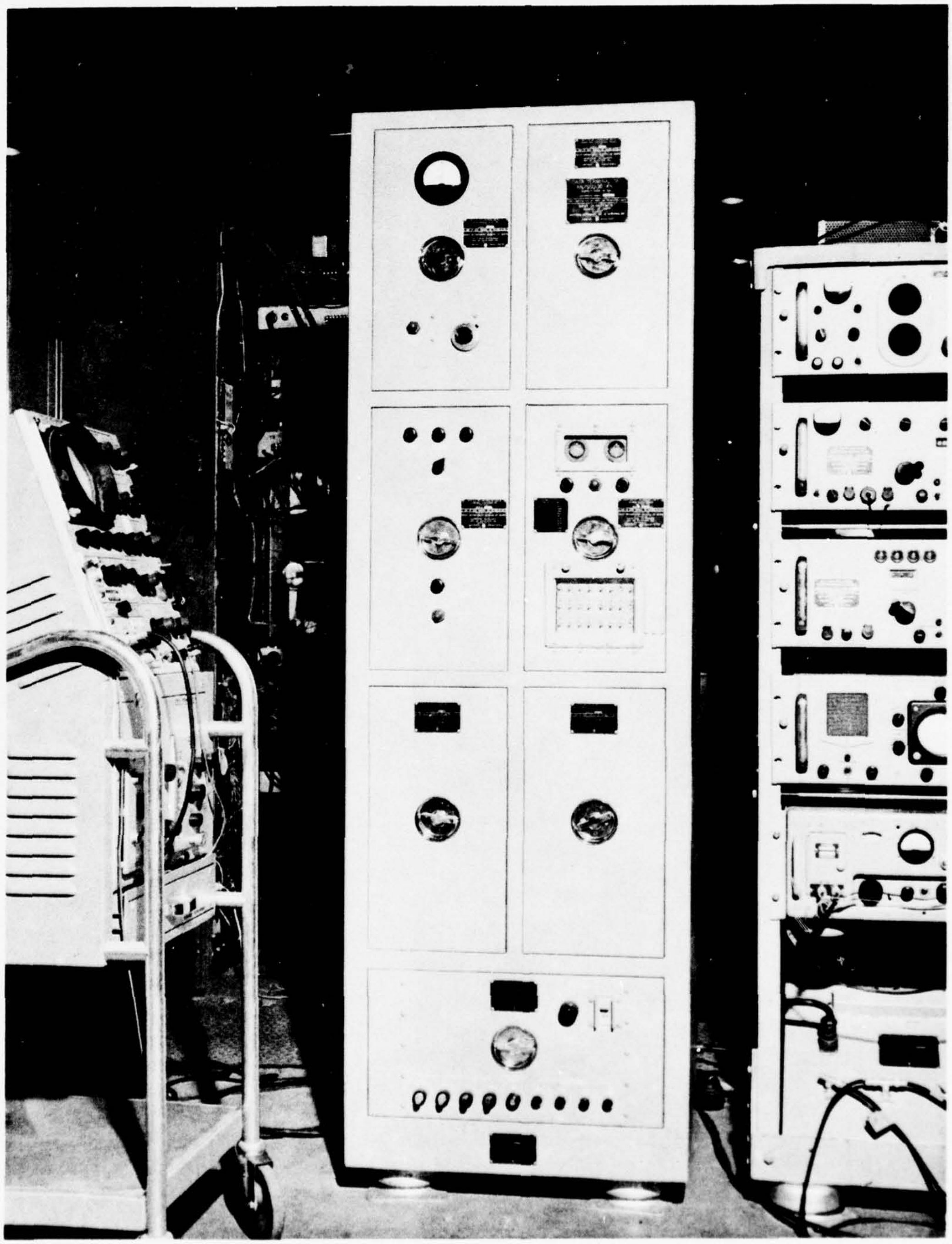


Figure 20. Data transmission terminal equipment [AN/SSQ-30 (XN-1)].

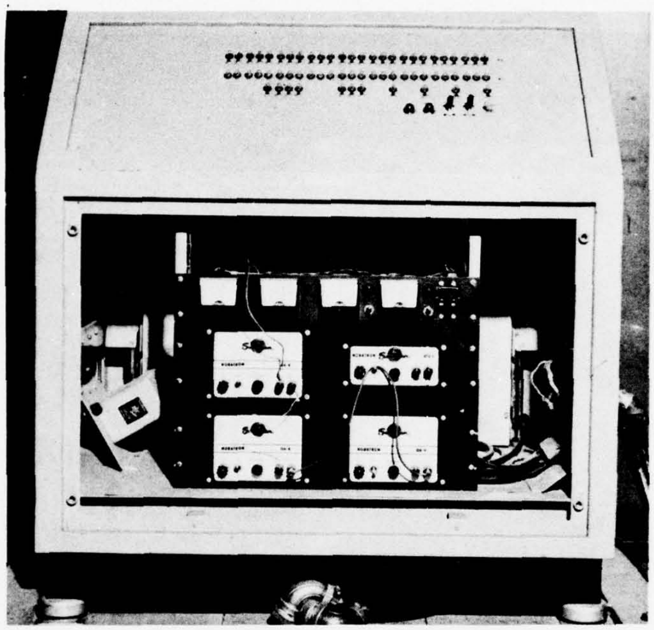


Figure 21. "IVAN" equipment.

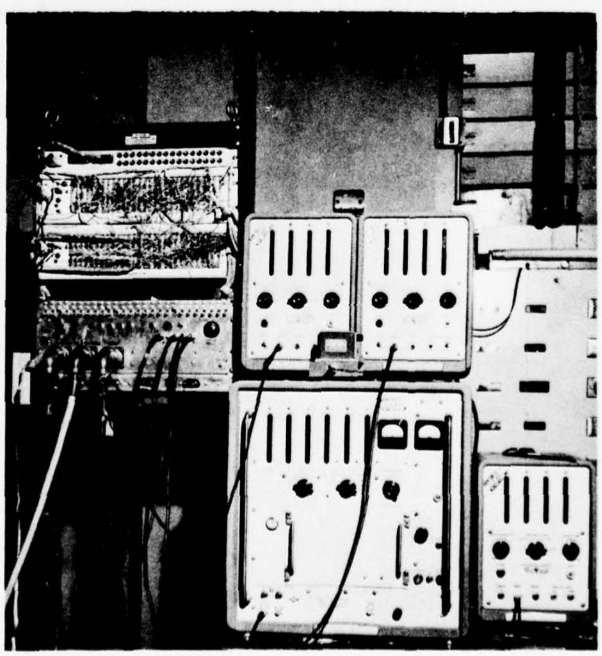


Figure 22. "BUD" equipment.

FEATURE	"C" LINK	"A" LINK
FREQUENCY	UHF (225-400 MC/S)	HF (2-6 MC/S)
DATA TRANSMISSION	SERIAL	PARALLEL
CALL-UP	ROUND-ROBIN	ROLL CALL
MODULATION	FSK	KINEPLEX
DATA RATE	13,000 BITS/SEC	1200 BITS/SEC
SYNCHRONIZATION	PULSE TRAIN	INDEPENDENT OSCILLATOR
DATA CODING	SIMILAR IN BOTH SYSTEMS	SIMILAR IN BOTH SYSTEMS
WORD LENGTH (TIME)	2 MILLISECONDS	21 MILLISECONDS

Figure 23. Characteristics and comparison chart, NTDS communications links.

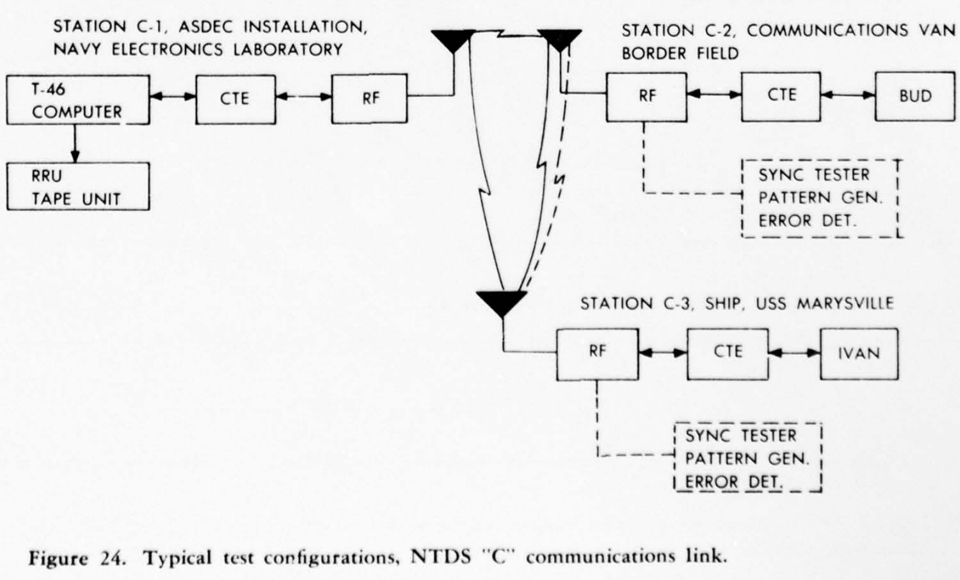


Figure 24. Typical test configurations, NTDS "C" communications link.

T-46 AT C-1

1. Stores and generates messages transmitted around the net.

2. Compares the received word with the correct word, counts errors of various types, and stores words in error which are subsequently buffered out of memory and stored on magnetic tape.

3. Responds to both the transmit and receive comands from the CTE.

BUD AT C-2

1. Receives, stores, and transmits up to 18 words in a fixed sequence.

2. Counts word errors, bit errors, single-bit word errors, and parity detectable errors.

3. In some test configurations where the T-46 computer is not used, may be employed also to generate words.

4. Responds to commands from the CTE.

IVAN AT C-3

Its memory is capable only of receiving and transmitting eight words in fixed sequence upon command from the CTE.

Back-to-back and propagation tests may be conducted on a limited basis between Stations C-2 and C-3 equipments independent of Station C-1 and the T-46 computer. Receiver signal strength and data error rate may also be correlated.

As shown by the dotted blocks, propagation tests may also be conducted by using the rf equipments of two stations independent of the CTE's and computer or computer simulation.

Figure 25 depicts a timing diagram for the three-station netting test in round-robin mode of operation. Initially Station C-1 sends an approximate 13-millisecond signal for the purpose of providing synchronization and the start code. This is followed, in the test configuration, with an eight-word message of approximately 16 milliseconds. Then follows a stop word and the next ship's call, which takes about 4 ms. If the next ship called fails to respond, the stop word and the alternate ship's call are repeated. Should the next ship fail to respond after three transmission sequences, it will be noted as a casualty at all stations on the fourth transmission.

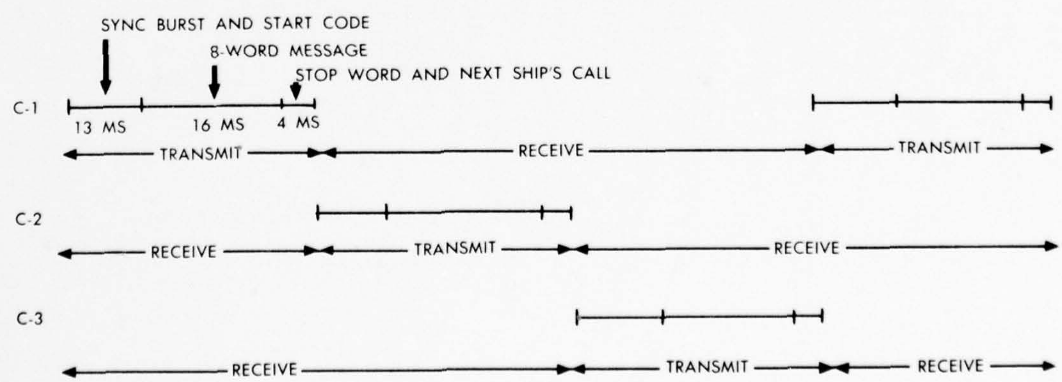


Figure 25. Test message structure timing diagram (three-station netting test), NTDS "C" communications link.

The round-robin mode of operation requires that all stations must hear all other stations. Station C-1 turns the net over to C-2 at the end of its messages, C-2 to C-3, and C-3 to C-1, etc. Obviously, such a system may readily "hang up." Currently, no "self-healing" feature is included in the link terminal equipment. Also continuous transmission from a given geographical area is very unsatisfactory from an ECM standpoint.

In order to obtain information on the statistical distribution of errors to determine optimum error detection-correction techniques, a broadcast mode of operation is necessary. This can be done between the ship and communications van directly; however, through use of telemetering links, the T-46 computer on-line analysis and magnetic-tape unit storage facilities may be "transplanted" to Station C-2 for simulated ship-to-ship evaluation .

The computer programs thus far written have been confined to test programs. Operation computer programs presumably are to be written by Remington Rand. It is expected that analysis computer programs will be prepared by the NEL Theory Analysis and Computer Branch. The difficulty of preparing adequate computer programs of such complexity cannot be over-emphasized.

The test objectives for the evaluation are to make a complete evaluation of the "C" link digital communication subsystem to ascertain its capabilities and characteristics and to develop improvements leading to acceptable service test equipments.

This will entail a three-phase program as follows:

1. Perform propagation, broadcast, and netting tests, including ECM effects, on the basic subsystem. The estimated completion date is January 1960.

2. Modify and improve the CTE's and rf equipment as necessary, providing as a minimum the "self-healing" feature to automatically reinstate the link following a net failure. Other modes of operation will be considered, including "demand," "burst," etc. The modified link will be subjected to netting and ECM tests. The estimated completion date is April 1960.

3. Provide error detection and correction capabilities to achieve the desired communications reliability at an adequate range and effective data rate. Perform broadcast and netting tests, with and without ECM. Estimated completion date is September 1960.

In support of the above effort, there are extensive requirements for logic design and modification, data analysis, etc. Regarding the rf equipment, there are a number of considerations such as use of low noise preamplifiers to reduce the AN/URR-13 receiver noise figure; the effect of antenna orientation corresponding to roll and pitch of a ship at sea; the effect of transmitted power on received signal strength at ranges beyond the horizon; value of diversity combiners; improvements possible by post-detector filtering; and changes in sampling methods, range extension by duplex relay operation, etc.

Observations on predicted performance potential are very preliminary. In the San Diego area, temperature inversion effects are significant at uhf and result in considerable enhanced range capabilities most of the time. Only after certain storm fronts and atmospheric disturbances can conditions more typical of world conditions be realized. With the elimination of ducting, beyond-line-of-sight uhf communication depends primarily on tropospheric scatter. Consequently, propagation tests must properly be qualified in terms of the existing inversion effects.

Assuming typical world conditions, line-of-sight and tropospheric-scatter forms of communication are possible.

Transmitter power requirements are based upon the following system parameters: antenna height and gain; feeder and duplexer loss; receiver noise factor; required signal-to-noise ratio; fading factor; free-space transmission loss; and beyond-horizon loss. Making substitutions for these parameters, including antenna heights of 75 feet and an assumed 99.9 percent reliability (0.1 percent error rate), approximately 5 watts of transmitted power are sufficient for a range of 24 miles line-of-sight. Transmission beyond the horizon would require approximately 20 kilowatts for 99.9 percent reliability at a range of 50 miles. A 100-mile range would require an additional 7 db of power. Improvement to the rf equipment might provide as much as 15 db gain and yield a 40-mile coverage at 99.9 percent reliability with only 1 kilowatt of transmitter power. If the height of one antenna were raised to 1000 feet (in an airborne radio relay station), a 50-mile line-of-sight range is possible with less than 10 watts power, and considerably greater ranges are possible as a function of antenna height and transmitter power. Shipboard noise interference was not considered in these estimates and would be a limiting factor.

In a radio link, special features and increased capabilities are obtained at a cost. As previously noted, extended range at uhf ultimately requires greater power or increased antenna height or other techniques. One such technique would capitalize on tropospheric scatter; such an approach appears to have some advantages, but would require the use of directional, stabilized antennas and would result in a reduced effective data rate due to the need for a communications control ship. Another alternative is the use of a vhf system employing synchronous communications; however, such a link is neither secure nor free from "ionospheric bounce" type interference from a distant station. It is likely that the uhf "C" communications link, as improved, will be more satisfactory and more readily provided than other potential links that have been considered.

The effect of the "C" link on associated equipments is a very important consideration. Preliminary thoughts regarding methods of error detection and correction, acceptable error rate criteria, operational modes and doctrines, and computer capacity limitations indicate that these factors are interdependent. Based upon an extrapolation of the "A" link computer requirements, it is indicated that the current "C" link used continuously at the full data rate would impose a time requirement on the unit computer of approximately 180 percent. This, obviously, is impractical and hence different operational modes are indicated. The link must be capable of control by one or more stations with a "burst" or "demand" or "time-sharing" operation. Provision for acknowledgment on certain categories of data (*i. e.*, status, orders, threat evaluation-weapon assignment) should be provided. Error detection and correction should be accomplished ahead of the unit computer in either the CTE or an intermediate "wired program computer," thus eliminating much of the work load from the T-46 and freeing it for other important functions.

An interesting possibility for comparatively simple error detection and correction is the employment of a three-transmission redundancy technique. A given message would be sent three times, the third transmission being compared as received, bit by bit, with the corresponding bits of the previous two transmissions stored in special CTE memories. The best two of three would be buffered into the computer as a corrected data input. The radio link efficiency would be reduced to approximately two-thirds, but the effective system data rate would remain sufficiently high and permit more effective computer employment.

Service employment for the "C" communications link has not been determined. It is assumed that its use will evolve from its improved capabilities. ASW applications, requiring a short-range, secure subsystem between surface ships, appear appropriate; however, a different and very special communications link would be required if helicopters and/or submarines are to be included in such a complex. At least in part, the "C" link equipment may be applicable in surface-to-air communications such as ATDS. Perhaps its greatest potential, as a comparatively high-speed digital communications subsystem, will be as back-up or as a reliable reduced range replacement for the NTDS "A" communications link. The inherent weakness of the "C" link is its restricted range which, ironically, is responsible for its probable advantages of better detection and jamming immunity.

Digital Signal Processing Trends in Sonar

R. ISAAK

Head, Communication and IFF Section

In sonar data processing, conventional sonars of two types have heretofore been used. One is a scanning sonar and the other a searchlight sonar. Similar problems are evident in both. In order to get maximum signal-to-noise ratio, it is desirable to receive on a narrow beam. With the searchlight sonar, the beam can be gradually trained around and cover 360 degrees, and then a complete examination of bearings is possible. The difficulty in this is that too long a time is required to make the 360-degree search. Another approach is to send out a transmitted pulse in all directions, let the receiving scanner rotate rapidly, and display this on a cathode-ray oscilloscope. In this case the receiving beam is trained around quickly, each bearing is observed for only a short time, and the integration time for signal-to-noise processing is less than optimum.

A possible solution to this problem is to have a large number of receiving beams that look simultaneously in all directions. Each beam is to be narrow and encompass only that noise which falls within its limits. This allows processing gain against noise, but a difficulty in this method is that a receiver is necessary for each of the beams. Therefore, if narrow beams are employed, a large amount of receiving equipment will be required.

In many techniques proposed today (for example: Dimus, the SQS-4 modification, or the Lorad system), multiple-receiving-beam processing is employed, and therefore a large amount of equipment is required. It is of interest to note the problems involved in the processing of the multiple beams and the uses to which the processed data can be put. The observations are derived from Lorad, but are applicable to all types of multiple-beam sonar systems.

Figure 26 is a simple block diagram of a 360-degree Lorad system. On the left is the noise generator, which provides the signal to a beam-forming network, and above, a projector. The projector sends out power in a 30-degree beam from one of the projector faces. It transmits a 5-second pulse, and simultaneously sends information down to a group of range rate references. The reference signals are stored at this point and later compared in the signal processing computer with the information received from the sea.

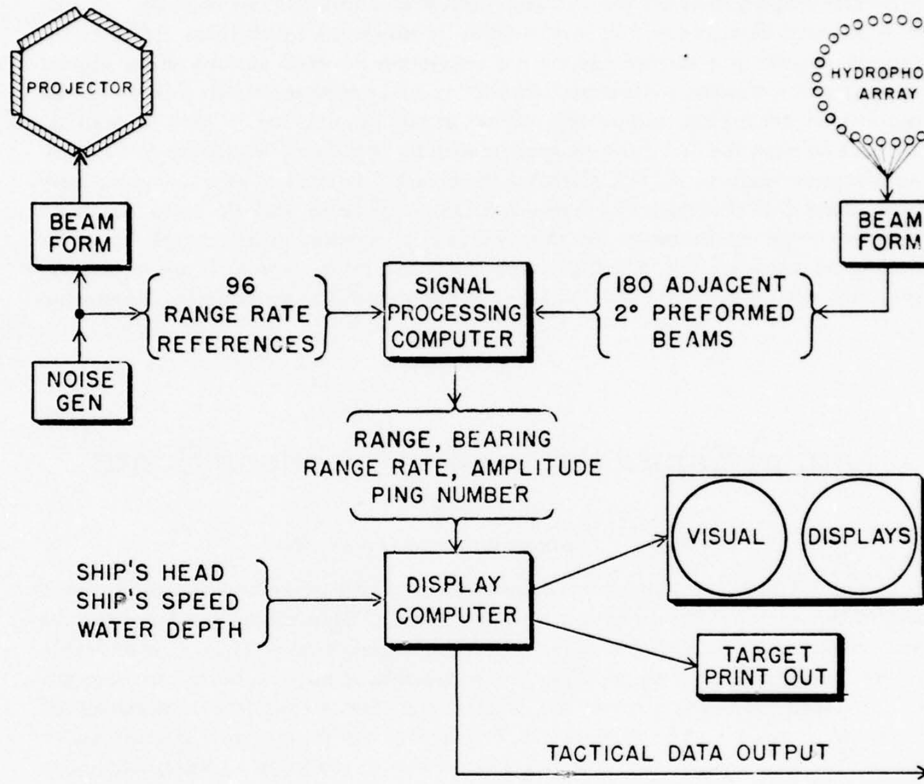


Figure 26. 360-degree Lorad.

The 30-degree transmitting beam is aimed in one direction for 5 seconds. During the next 5 seconds it is trained on a bearing 30 degrees removed from the first. This continues until a total of four 30-degree beams are transmitted on four adjacent sectors. This will cover 120 degrees.

The information coming back from the four different transmissions must be separated because they went out at different times. Otherwise all information regarding range is lost. Each one of the four beams will be of a different noise sequence to identify the one coming back. Since this is a three-convergent-zone sonar subsystem, echoes are expected back from the first zone at 30 miles, the second at 60, and the third at 90. To save time, a total of three pings will be sent out before all of the information returns from the first ping. To separate these from one another, there are three different frequencies. The noise generator shown in figure 26 is actually filtered to provide three separate frequency bands. Thus there are three frequencies and four noise sequences to aid in sorting the received signals. For a full 360-degree coverage, three equally spaced, 120-degree subsystems are needed. The three equally spaced beams, each 30 degrees wide, will be transmitted simultaneously, and all rotated in 30-degree, 5-second steps. Thus in four steps requiring a 20-second transmission interval, all 360 degrees will be illuminated.

After about 70 seconds, echoes are returned from the first zone. When echoes have been received from the first zone, a second group of pings is sent out, and when the echoes have been received from the first zone, as a result of the second group, a third group is sent out. Now it works out in each receiving interval that third-zone echoes are received first from a ping sent two times before, then second-zone echoes are received from a ping sent the last time, and finally, first-zone echoes are received from the ping that was just sent out.

Although this entails a flow of data arriving at the receiver that seems somewhat confusing, these data are separated and identified by noise sequence, frequency, or by the direction from which echoes return. The system described thus far will accommodate only a narrow frequency spread due to Doppler. If there is considerable range rate between the Lorad ship and the target, something must be done to accommodate the frequency shift and spread due to the Doppler effect. It is not difficult to cover a 6-knot Doppler spread with just one reference signal. However, more than a 6-knot range rate capability is desired. To do this, eight reference signal units are employed to cover range rates of roughly minus 20 to plus 30 knots. In order to accommodate three frequencies and four noise sequences, 96 range-rate references are required at all times. These are stored in delay-line-type circulating memory units.

Data, now presumed to be largely target information, are received at the hydrophone. There are 180 beams, each one 2 degrees wide. The 180 beams are then compared with the 96 range rates. A very large number (180×96) of processing units might be used for this purpose, but since all of them are not needed simultaneously, it is only necessary to compare eight range rates with all 180 beams at any one time.

The first computer shown in figure 26 consists of a Deltic correlator or signal-processing computer. This unit makes possible a signal-to-noise improvement of approximately 27 db, and it enables the selection of targets. The computer has a very high input and output rate. It is a wired program computer, and is specifically designed for Lorad functions. By contrast, the NTDS unit computer has, on a comparative basis, a slow input-output rate; however, it is very versatile and can handle almost any problem when directed.

The signal-processing computer has analog-to-digital conversion equipment built into it so that its output will be in the form of 30-bit words describing the range, bearing, range rate, amplitude, and ping number of each correlation conducted. This happens at a high rate. A correlation is performed on each beam for every 4 yards of range. Thus words come out at such a high rate that the display computer cannot accept them all. An adjustable amplitude threshold at this point in the system permits only the relatively high amplitude correlations to enter the display computer.

The NTDS type display computer will make decisions regarding the information received. The input information will include ship's heading, ship's speed, and water depth. This information will be used by the computer to make corrections for true heading and nullify own ship's Doppler, and the corrected data will be delivered to a display system and tactical data output line.

Figure 27 shows a 120-degree portion of the full 360-degree system. It depicts the four transmitting beams 30 degrees wide, energized through a noise generator, power conversion equipment, etc. It illustrates the path from the generator up to the reference Deltics. The correlator, the receiving beam setup, and signal

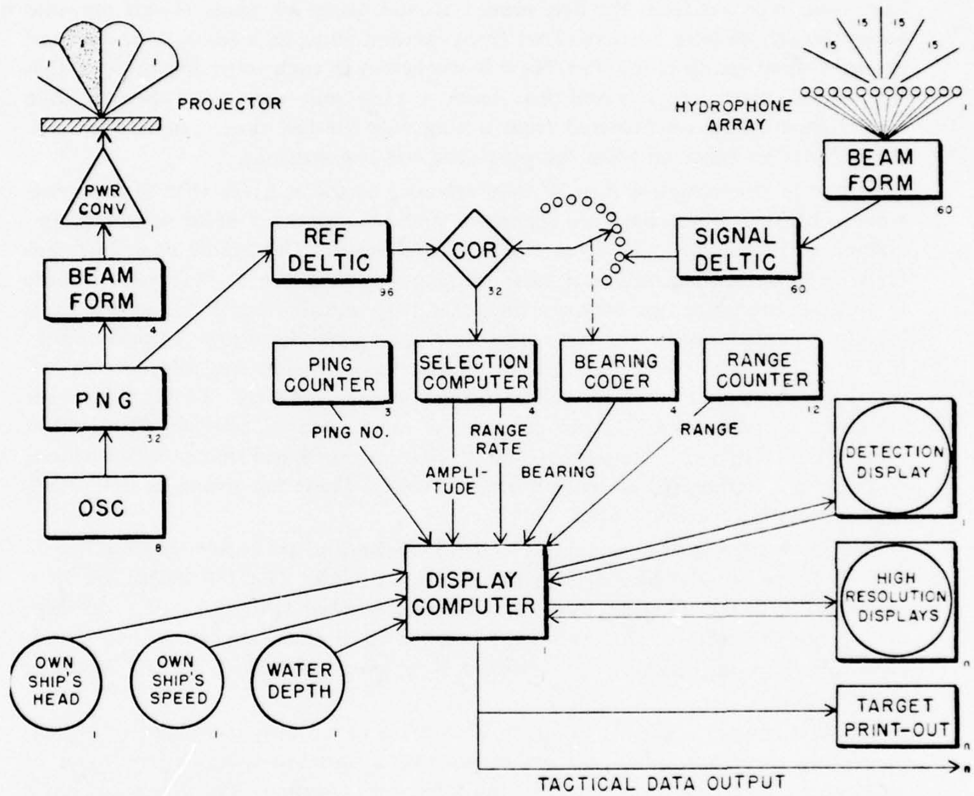


Figure 27. 120-degree Lorad.

Deltics are shown. The signal Deltic is somewhat different from the conventional Deltic that has been used locally for several years. This is a multiplex Deltic, and sampling is performed once for every 15 revolutions of the data in the storage line. This means that it is possible to examine data in the line 15 times before it is altered by the addition of a new sample.

The switch illustrated in figure 27 will permit looking at one signal Deltic for one revolution, the next Deltic for another revolution of the data, and so on. Thus the outputs of 15 different signal Deltics can each be correlated with the outputs' appropriate reference Deltics before the data change. This permits serial processing at a great reduction in equipment. For example, 32 correlators can handle the 120-degree system instead of 15 times 32. For each 313-microsecond correlation time, 32 correlations are performed. By use of indicator "OR" circuits, this number is reduced to four, which results in one output every 78 microseconds.

The output will be mostly noise, but occasionally it will be target information. Each time an output comes from the correlator, it proceeds into a selection computer. Its amplitude is measured, and if the amplitude exceeds the threshold, a data word will be allowed to enter the computer. This data word will include the amplitude which has just been measured. It will describe which of eight range rates steps the datum falls in, and it will include range, bearing, and ping number.

Each time a ping is initiated, a range counter is started. There are then 12 range counters to provide for the different conditions. Each time the amplitude of a correlation output exceeds the threshold, suitable interconnections are made so that the range counter reads out the binary code of range into the computer. The position of the Deltic selector switch is read out as the target bearing. The ping counter provides the necessary information for "dating" displayed data.

Occasionally, computer processed and stored information will be put out to a detection display. During each transmission there is a 20-second period when the noise level is so high that reception is impossible. This would be an opportune time to illuminate the storage-type display tube. Echoes from ping No. 1 will be printed out first, then in perhaps 4 seconds, echoes from ping No. 2 will be printed out. This will continue until perhaps five pings are printed and retained on the storage tube.

The information built up on the scope could then be seen, and some idea of the ping-to-ping integration acquired. Even though the pings come back something like 70 seconds apart, they would be printed on the display tube at 4-second intervals, which would simplify the interpretation.

The operator can pick out a target area that looks interesting, and then send information back to the computer, saying "I would like to see this more carefully." The interesting area will then be displayed on a high-resolution display. The next operator may then deduce that this is a submarine target of interest, so he presses the "target" button, whereupon the computer sends the information out to the print-out display.

The operation of the display computer should be examined in more detail. All words that enter the computer end up in one large bin, but the "ship" information words must eventually be separated from the "target data" words. Therefore the data word is identified by the first bit, the word type, and for data words this bit will always be a zero. The next five bits give the amplitude of the correlation function as received on the system, so there are 32 different levels of amplitude possible.

The next six bits give the beam number. It is desirable to use single-length, 30-bit words as long as possible. In order to conserve bits and still cover a full 360 degrees, each beam will be given a number. The bearing of that particular beam number will be stored inside the computer. Then it is only necessary to transfer a number through the input register. The bearing can be determined later on. This can be done very late in the processing, and double-length, double-precision words will not have to be used until much later.

The next three bits of the data word will describe target range rate to an accuracy of ± 3 knots. The last 15 bits will be used to describe the target range with a resolution of 8 yards.

The "ship information" word is also identified by the first bit. In this case, the first bit of the word is always a one. The other bits of this word are used to describe ship's heading, own ship's speed, water depth, etc.

Figure 28 shows the computer input threshold and input register arrangement. The four sectors for a 120-degree system are numbered 1, 2, 3, and 4. Each has a 30-degree coverage and includes 15 beams. Simultaneous data on any of the four sector inputs which exceed the thresholds are held by the "C" register buffers and entered into the temporary storage bits sequentially.

If the amplitude of the correlation is not sufficiently great, it will be rejected at the threshold circuit and never enter the computer. The storage lists will be

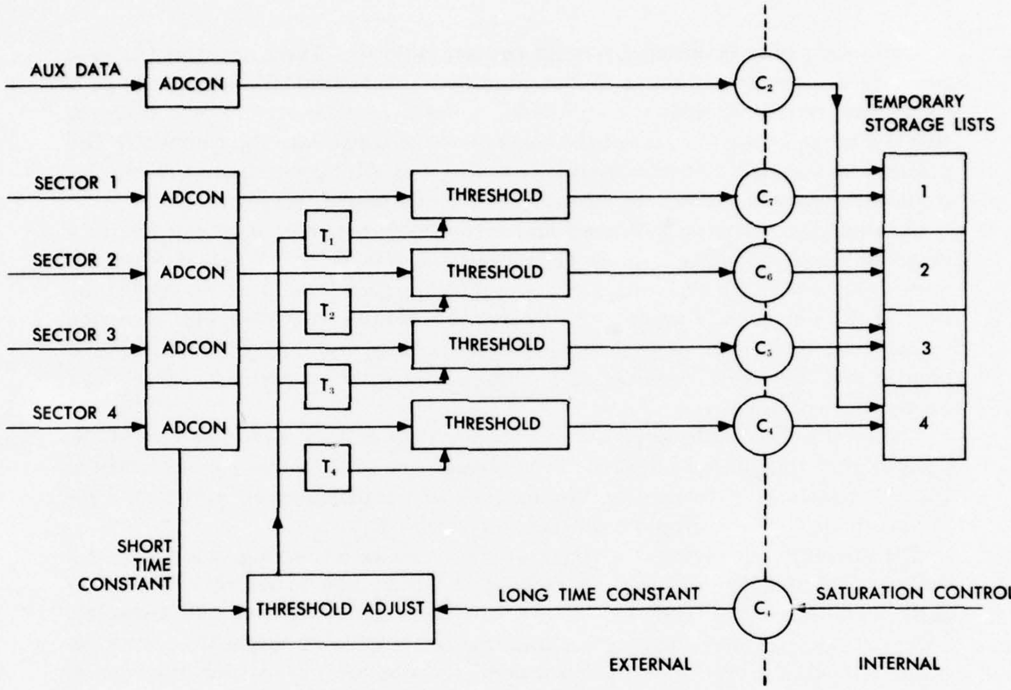


Figure 28. Data input to computer.

quite long. Perhaps a third to a half of the computer storage capacity will be required for the temporary storage lists.

The analog-to-digital converters will control the level of the threshold adjustment in order to prevent a very rapid rise or decline in the amount of information sent to the computer. The reason is that normally a noise background of rather low amplitude exists, but when a zone beginning is encountered and reverberation limiting occurs, suddenly a large number of very high amplitude inputs may be received. Were it not for this threshold control, the computer input rate could become very high and the temporary storage list would be filled faster than the data could be processed. The circuit is designed to make certain that never more than 10 percent of the words get into the computer.

An additional input to the threshold is called the saturation control. This is to insure that the computer is always saturated. Since more than sufficient input data are on hand to keep the computer available at all times, it is considered good policy to keep the computer busy. This saturation control line, which is governed by the internal computer work load, will gradually raise the threshold level if the computer cannot keep up, or gradually lower the threshold level if the computer is not busy enough.

The data storage in the input or temporary storage lists is of interest. From the bottom of a list up, the list is filled sequentially with words as they come in. Since a portion of each word is target range, words can easily be sorted by range when needed. Each sector represents a 30-degree portion of the ocean, so no sector coding is needed for that portion, but it is necessary to remember the beam number within the 30-degree sector. Each time a ship's heading or ship's speed changes by a certain amount, a word will be entered via the C-2 register into all four of the temporary storage bins, in time sequence with the rest of the data. Through this means, the target data words can always be associated with the proper auxiliary data words.

Figure 29 shows a simplified flow diagram of the main Lorad processing program at the present time. It does not yet include many of the features needed for the ultimate program. Starting at the upper left of figure 29, the first word in the temporary storage list is examined, and the question is asked, "Is the amplitude of the correlation represented by that word greater than some arbitrary value?" There are 32 levels possible since amplitude is described by a five-bit portion of each word. The arbitrary value, *P*, which will probably be between 25 and 30, will be adjusted to admit (yes) perhaps 1 percent of the words and reject (no) 99 percent. If the word is rejected, the next question that is asked is "Is this the end of the list?" Since the first word is being discussed, the obvious answer is "No." Indexing to the second word in the temporary storage list, the question is again asked, "Are you greater than *P*?" The usual answer is "No," next address, and so on to the end of the list. This loop, which has been made as short as possible, has been termed "the garbage chute." The intention is to save the important information but to discard the "garbage" as rapidly as possible.

When something of value is tested, it will pass *P* gate with a "Yes," and will then be asked the next question, "Are you a data word?" All that is needed here is to determine if the first bit is a one or a zero. If the first bit is a one, the word is an auxiliary information word which is placed in a special memory cell for future reference. Note that all auxiliary data words will pass the *P* gate since

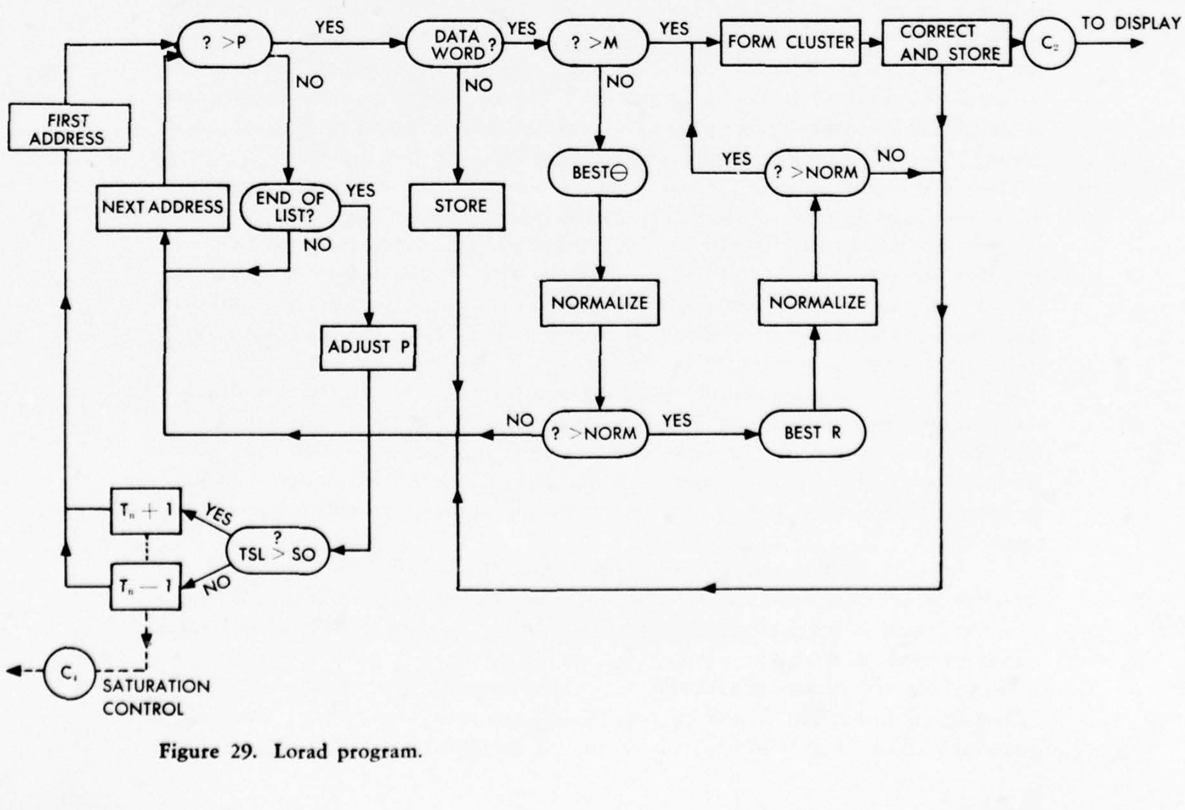


Figure 29. Lorad program.

they all have a "one" in the first bit position. If the word had been a target data word, and ordinarily it will be, another question is asked, "Are you greater than *M*? *M* is a threshold value believed necessary here because occasionally it will be possible to get a single correlation from a target and no more. If there is a strong target, and a good correlation is received from it, this constitutes sufficient justification to save it. The probability of getting a noise spike that is greater than *M* is extremely remote.

Once decided that a correlation is greater than *M*, a cluster is formed that will consist of a block of information, plus or minus 50 yards in range, 50 plus or minus 4 degrees in bearing. Thus the datum that passed the *M* gate and all of its neighbors will be preserved. These will be corrected for ship's zone heading and entered in a potential target storage bin. Later these whole blocks of information will be sent to the display system. In order to form a cluster about a datum that is good enough to save, it is necessary to go back to the temporary storage list, pull out its adjacent neighbors, and store those along with the datum.

If the amplitude of a datum in question is not greater than *M*, and perhaps 999 out of 1000 will not be, it is essential to make several tests to ascertain whether or not the density of correlations in the cluster area is sufficient to call the cluster a probable target. Thus it is now assumed that the datum in question has gotten a "No" answer at the *M* gate. The next step is to select the most probable bearing. This is done by examining the density of correlations (stored in temporary storage) on several bearings and selecting the bearing of highest density.

A normalizing circuit counts the number of correlations on a given bearing over a given range increment. An average is kept of this count, and each time the best bearing is picked. The average count obtained over many seconds of operation is subtracted from each particular count, and when this difference is obtained, the question is asked, "Is this particular value greater than normal?" If it is, the datum is potentially a target, and if not, it is rejected. The effort in all subroutines is to get back to the "garbage chute" again as fast as possible without going through any more tests. If the datum is retained, the next question is asked, "What is the most probable range rate?" Once more the same problem exists. There are eight different range rates possible. The number of correlations for each range rate are counted, the best picked, the average subtracted from the best one, and then the question "Is this greater than normal?" If the answer is "Yes," the datum is kept, a cluster is formed, the data are corrected for true bearing and own ship's speed, and stored in memory. If the answer is "No," the program returns to the next word in the temporary storage list.

This procedure is time-consuming. In order to get one word all the way through the program, including the collection of neighbors to form a cluster and to correct them, takes seconds. To store all the words obtained in three-zone Lorad would take a 6,000,000-word storage. It should be clear that unwanted data have to be rejected as often and as rapidly as possible in order to eliminate memory overflow.

Another box on the more complete flow chart (not shown in figure 29) asks whether or not each datum considered is a member of a previous cluster. Without this box, much valuable time might be lost in studying data that are already preserved in the final memory section.

When the end of the temporary storage list is reached, *P* is adjusted in the following manner: The length of the list is known, and every time the *P* box puts out a "Yes," one is added to a counter. If the counter reads less than 1 percent of the total number of the list, the *P* level is adjusted downward. If the count is greater than 1 percent, the *P* level is adjusted upward. When *P*, which can have any one of 32 possible levels, is properly adjusted, it will permit the highest 1 percent (in amplitude) of the words stored in the temporary storage list to be analyzed in detail. The value of 1 percent is tentative, and can be set at any level.

By the time this data-processing procedure has progressed through the entire temporary storage list, the new data entering the computer will have filled the list once and be started from the top again. As a matter of fact, it should have filled the list down to the 50 percent mark. Because at this time (after *P* has been adjusted), the question is asked, "Is the temporary storage list 50 percent full?" If it is less full, a threshold is lowered to admit more data. If it is too full, the threshold is raised to admit less data. This threshold is the computer input threshold described above, and this mechanism is called the saturation control. Once the adjustment has been made, the program returns to the top of the list to start processing the new data.

This dynamic threshold adjustment acts as a "phase control" as well as a quantity control in that it keeps the temporary storage list about half full of unprocessed data at any time. Now if there is a rapid change in the input data rate or in the time consumed for data processing, the 50 percent space available for storage, or the 50 percent new data available for processing, will allow the maximum buffer space to damp out the change.

The program is actually set up to analyze the first word from the first temporary storage list, the second word from the second storage list, etc., through the four lists, and then return to the second word in the first list, the second word in the second list, etc. In this way the program effectively progresses through all four lists at the same time.

To make this procedure successful, the input on all four lists must be synchronized. A separate threshold, controlled by a separate saturation control line, which is set by a separate "50 percent" decision box, makes it possible to keep all four lists independently full to 50 percent.

The above data processing only represents that which will be performed for a single ping. This information is stored in the potential target storage area of memory. Now all of the data stored per ping are retained in memory until perhaps five to ten pings have been transmitted, then a condition is reached where memory is full and rewriting is necessary in lieu of the oldest stored data. All of the old information for some five to ten pings back is now available for "ping to ping" integration by the computer and/or displaying to an operator.

An additional task yet to be programmed is to examine the bearing of the various correlations that are on adjacent bearings, pick out the best bearings, and then to examine the amplitudes of correlations on adjacent bearings and interpolate between them for greater bearing accuracy. It is hoped to obtain approximately half a degree bearing accuracy by interpolation. This is another reason for storing a particular word and all of its neighbors. Later, if it is believed that there are certain characteristics about the clusters of correlations from which some deductions might be made as to target classification, it is reasonable to believe that the computer can make these deductions as well as, if not better, than a human operator.

It appears that one might eventually hope for a computer program that selects, classifies, and prints out all real targets, and the operator merely stands by to monitor the results.

Application of Set Theory to Contact Classification

H. R. EADY

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In any type of classification system, the categories of system performance and system parameters shown in table 9 are dealt with. These are a set of inputs, a set of outputs, a set of decision processes, a set of results of those decisions, and a set of values placed on these end results. The proper operation of the system cannot be determined until all of these factors have been related one to the other. In previous considerations, it has been implied that certain *a priori* conclusions had been reached about the value of certain types of information. When that is done, the system discussed herein will furnish knowledge of how good those conclusions were. On the other hand, the system can be used without any such *a priori* assumptions and will, when carried through to completion, determine what the best set of asumptions will be.

Of first consideration can be the relation of inputs to outputs. In the classification case, the inputs consist of two classes of objects: submarines, S, and nonsubmarines, N. By the word input, an electrical signal is not implied. The meaning is simply that the input consists of contact with a submarine or a nonsubmarine object. On the other hand, in the case of the output, q, what is meant is a set of electrical signals that may have been transduced to a display or fed to a computer.

Figure 30 shows the relationship between S, N, and q. First there is a sensor system or systems, either one or a collection. The inputs to the system are S and N. For an input of either class, an output is observed that may be expressed in terms of the values of a set of variables: $V_1, V_2, \ldots, V_i, \ldots, V_n$.

TABLE 9. Categories of System Performance and Parameters.

Input	Output	Decision	Result	Value
S		s	$S \cdot s$	$V_{S \cdot s}$
	q		$S \cdot n$	$K_{S \cdot n}$
N		n	$N \cdot s$	$K_{N \cdot s}$
			$N \cdot n$	$V_{N \cdot n}$

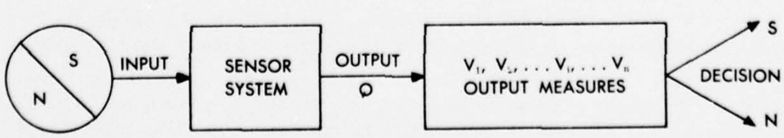

Figure 30. Schematic of classification system.

Examples of variables for a sonar system could include Doppler, echo amplitude, echo duration, amplitude envelope structure, etc. The only limits placed on the variables are that they must have k values where $2 \leq k < \infty$, and that the values of each variable can be measured reliably on the output signal.

If we designate the number of values for each variable as $k_1, k_2, \ldots, k_i, \ldots, k_n$, then the total number of possible ways, r, in which the output can be specified is:

$$r = k_1 \times k_2 \times \ldots \times k_i \times \ldots \times k_n \tag{1}$$

If the jth value of the ith variable is v_{ij}, then the general expression for the output as a combination of values for each of the variables is:

$$v_{1j}, v_{2j}, \ldots, v_{ij}, \ldots v_{nj}$$

We shall retain the symbol, q, to represent a given output, realizing that any q can be expressed as a combination of values for the N variables.

The total number of q's defined on the variables is equal to r; this set of output combinations we designate as the universal set, U.

Now, suppose that we place the sensor system into the environment and take a representative sample of the two classes of inputs, S and N. A representative sample of inputs won't be defined, except to say it is operationally representative of the characteristics of these two types of targets. We can then observe for each known input in the sample an output q. A frequency table such as table 10 can be constructed for the sample.

TABLE 10. Frequencies.

Output	Input	
	S	N
q_1	a_1	b_1
q_2	a_2	b_2
.	.	.
.	.	.
.	.	.
q_i	a_i	b_i
.	.	.
.	.	.
.	.	.
q_r	a_r	b_r
	$\sum_{i=1}^{r} a_i$	$\sum_{i=1}^{r} b_i$

In the table, a_i and b_i represent, respectively, the number of submarine and nonsubmarine inputs which resulted in the output q_i. $\sum_{i=1}^{r} a_i$ is the total number of submarine inputs in the sample and $\sum_{i=1}^{r} b_i$ is the total number of nonsubmarine inputs.

The conditional probability of any output, q_i, given that the sample input is S, may be stated:

$$P(q_i \mid S) = \frac{a_i}{\sum_{i=1}^{r} a_i} \tag{2}$$

and the conditional probability of q_i, given an N input is:

$$P(q_i \mid N) = \frac{b_i}{\sum_{i=1}^{r} b_i} \tag{3}$$

Analogous to detection theory, the likelihood ratio for q_i is defined as :

$$l(q_i) = P(q_i \mid S)/P(q_i \mid N). \tag{4}$$

These definitions, which apply to a unit subset, q_i, in the universe can also be applied to larger subsets which are formed by drawing a certain number of single q's from the universe and putting them together in a subset which can be called Q. The conditional probability of the subset Q given an S input is simply equal to the sum of the conditional probabilities for each of the q's which is a member of the subset Q ($q \epsilon Q$) and likewise for the conditional probability of Q given an N input. Thus:

$$P(Q \mid S) = \sum_{q \epsilon Q} P(q \mid S) \tag{5}$$

$$P(Q \mid N) = \sum_{q \epsilon Q} P(q \mid N) \tag{6}$$

Similarly the likelihood ratio for Q is:

$$l(Q) = P(Q \mid S)/P(Q \mid N) \tag{7}$$

Up to this point we have demonstrated the relationship between the sample of inputs and the outputs in two ways: for a single output or a subset of outputs. The use of the subset Q has been for illustrative purposes only, to show the parallels between probabilities for a single output and a collection of outputs.

Now can be defined a subset of U, the universe, which can be called M. M will be defined such that for any q, which is a member of M ($q \epsilon M$):

$$P(q \mid S) + P(q \mid N) > 0$$

and for any q which is a member of the subset $U - M$:

$$P(q \mid S) + P(q \mid N) = 0$$

This has been kept in set theory terminology, but all it amounts to is discarding all of the outputs that were not observed for any sample input, *i. e.*, any unit subset, q, which was not observed for any input of S or N, is not in the subset M.

Now there will be selected from the subset M a group of subsets: M_1, M_2, . . . , M_i, . . . , M_x, each being made up of q's with equal likelihood ratios. If all the q's in a subset have equal likelihood ratios then for $q \epsilon M_i$:

$$l(q) = l(M_i)$$

The subsets are selected so that $l(M_1) > l(M_2) > \ldots > l(M_i) > \ldots > l(M_x)$.

Now suppose that there is set up a decision rule that any observed q which is a member of the subset M_1 is called a submarine, s. When that rule is made, the conditional probability, $P(s \mid S)$, of a submarine decision given a submarine input may then be stated. That probability is equal to $P(M_1 \mid S)$. From equation 5 we know that:

$$P(M_1 \mid S) = \sum_{q \in M_1} P(q \mid S) \tag{8}$$

We may also write the conditional probability that, given a nonsubmarine input, we get a submarine decision:

$$P(s \mid N) = P(M_1 \mid N) = \sum_{q \in M_1} P(q \mid N) \tag{9}$$

We continue this process for the subset comprising the union of M_1 and M_2 (expressed $M_1 \cup M_2$). Any q which is a member of $M_1 \cup M_2$ is logically a q which belongs *either* to the subset M_1 *or* the subset M_2, but not to both since the subsets do not overlap. If our decision rule is changed to give a submarine decision for any $q \in M_1 \cup M_2$ then:

$$P(s \mid S) = P(M_1 \cup M_2 \mid S) = \sum_{q \in M_1 \cup M_2} P(q \mid S) \tag{10}$$

and:

$$P(s \mid N) = P(M_1 \cup M_2 \mid N) = \sum_{q \in M_1 \cup M_2} P(q \mid N) \tag{11}$$

Repeating this process for $M_1 \cup M_2 \cup M_3$ and so on through the subset $M_1 \cup M_2 \cup \ldots \cup M_i \cup \ldots \cup M_x$ (which is the same as subset M) we observe that $P(s \mid S)$ and $P(s \mid N)$ increase monotonically with each new subset.

We may plot $P(s \mid S)$ vs $P(s \mid N)$ as shown in figure 31 to obtain the so-called

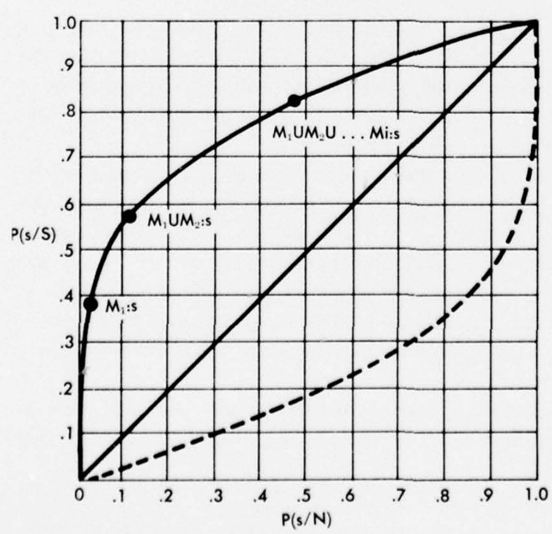

Figure 31. System operating characteristic curve.

"operating characteristic" curve for our hypothetical system. The diagonal line on this graph represents the values of $P(s \mid S)$ and $P(s \mid N)$ which would be obtained if classification decisions were made on a chance basis. The upper solid curve represents the values generated by application of the set functions we have discussed. This curve is the upper bound of system effectiveness. The lower dashed curve, obtained by rotating the upper curve about the center of the graph, represents the lower bound of system operation. The area between the two curves contains all points at which the system can operate. To operate at a point outside this area, we would have to change the system (by adding more output variables, for example) or get a new system.

To complete the picture, two additional concepts must be introduced: (1) the concept of the *a priori* probability that a submarine target will be detected, *i. e.* represented in the set of inputs to the system, and (2) the concept of a value, V, of system operation, which we wish to maximize.

As shown in table 9, the inputs S and N are coupled with decisions s and n resulting in the following joint conditions: (1) submarine input and submarine decision, (2) submarine input and nonsubmarine decision, (3) nonsubmarine input and submarine decision, and (4) nonsubmarine input and nonsubmarine decision.

To each of these four possible results we may assign a value or a cost. Respectively, we can designate these as $V_{S \cdot s}$, $K_{S \cdot n}$, $K_{N \cdot s}$, and $V_{N \cdot n}$ where V denotes a value and K a cost, both being real, nonnegative numbers.

It can be demonstrated[1] that to maximize V (the over-all value of system operation), we must maximize the expression:

$$[P(s \mid S) - \beta P(s \mid N)]$$

where

$$\beta = \frac{1 - P(S)}{P(S)} \cdot \frac{V_{N \cdot n} + K_{N \cdot s}}{V_{S \cdot s} + K_{S \cdot n}}$$

$P(S)$ = *a priori* probability of S input

There are other methods of handling operational value than the one just indicated. The point that should be made is that all these methods require the same type of model described. Without deriving the operating characteristic of the system and applying it in a value treatment including the *a priori* probability, we cannot make any sensible decisions about any classification system.

This is a very important point, and it is one that hasn't been appreciated in the past. It has been typical practice to go into systems of this type, and pull out separate parts and work on them independently of any over-all treatment. For example, some workers have conceived and developed classification devices solely on the basis of expected relationships between S and q, ignoring the relation of N to q. Others have evolved procedures for classification based on arbitrary single-point measures of $P(s \mid S)$ and $P(s \mid N)$, not realizing that the system has no inherently fixed values for either of these quantities.

It can be flatly stated that without full use of the techniques outlined herein, the attack on the classification problem is without meaning, or at best is governed by blind luck.

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[1] W. W. Peterson and T. G. Birdsall, *The Theory of Signal Detectability. Part I. The General Theory: Part II. Applications with Gaussian Noise.* Univ. of Mich. Electr. Defense Group Tech. Rep. 13. June 1953, p. 6-7.

Large gaps have been left in the mathematical treatment throughout, and the prematurity of the presentation at this time is realized. However, flesh is being put on the skeleton as rapidly as possible, and in the near future a full treatment of the subject will be published.

Present Effort on Phase I Small Ship ASW Combat Direction System

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The Naval Tactical Data System, as presently being designed, engineered, and tested, is not scheduled for installation on any class of vessel smaller than the DLG, and its dimensions are such that it would be difficult to do so. With the growing importance of undersea warfare, however, the Navy realizes that other ships in the service Fleet, to be used primarily for undersea warfare applications, may also need a more automatic data-processing system. Ship types involved are CVS's, DD's, and DE's, working with fixed- and rotary-wing aircraft and shore installations.

In view of this, action was taken recently at NEL to draw up a plan entitled "Proposed Program for the Application of Automatic Data Processing Techniques to Undersea Warfare." By a letter to the Bureau of Ships dated 2 June 1959, NEL indicated that it intended to prosecute this program unless directed otherwise. The Bureau of Ships concurred on 17 June 1959, and a favorable, but as yet unofficial, attitude has been shown by CNO. It is now understood that NEL will conduct this program through the system design stage, at which time the Bureau will review progress and assess the desirability of system development.

A problem proposal has been submitted by NEL, and action is now underway on the program. NEL Problem J3-2 or N4-3, Task 18, can be utilized pending approval of the problem proposal. The completion date for the program is tentatively set at 3 years after its inception.

Phase I of this program, Operations Analysis, entails the creation of a functional block diagram of the system that shows within its blocks the functions performed at the various system positions. The analysis must also show the information required at the blocks; where this information comes from; what actions are taken and where they are directed; what information is sent on, and to whom.

In addition to delineating the functional requirements and the information and action flow, it is also necessary to specify the amount and type of information, the time rates of flow, the accuracy requirements, and the time delays that can be tolerated.

In order to determine the type of combat direction system required for ASW vessels, it would be desirable to place the ships figuratively in practically every conceivable ASW situation in which they might be found, and examine in detail the operation of the ships in those situations. An examination and analysis of the tactical information available, where and when it is obtained, what actions are necessary, etc., would determine the system's functional requirements. In view of time limitations, however, this is not feasible; instead, one or two situations will be examined in detail, and a somewhat cursory look taken of some others to determine if necessary functions have been overlooked.

To establish the situations to be considered in detail, many possible circumstances were considered with four criteria in mind:

1. What is the military importance of being able to cope with the given situation?

2. What is the probability that the situation will exist, *i. e.,* that naval forces will be called upon to handle such problems?

3. How heavy a load will the situation place on the data system? Will the situation uncover most of the necessary functions and indicate maximum data rates, etc.?

After various types of naval warfare and associated environmental factors were considered, for example, hunter-killer operations, barriers, convoy screening, carrier task group protection, etc., it was decided that the first situation to be studied would be that of large-area surveillance, with back-up hunter-killer operations, necessitating redetection, tracking, and a kill capability. It would be tedious to elaborate on the wide variety of inputs in this situation. Information is received from shore-based centers, patrol aircraft, and surface ships. With a carrier nearby there are fixed-wing and rotary-wing aircraft available. In view of the variety of information sources and platforms involved, many data processing, coordination, and control functions must be performed.

The U. S. Navy recently extended an invitation to the Royal Canadian Navy to participate in this study. The Royal Canadian Navy agreed and assigned officers who have since proven to be a very valuable augmentation to the effort. The main interest of the Canadian Navy is antisubmarine warfare, and the Canadian representatives had considerable background in operational work of this nature. Prior to the assignment of the Canadian officers, NEL representatives also received considerable first-hand orientation in current operational procedures and doctrines.

A word of caution may be in order here. It is not claimed that any particular ASW problem is being solved by the design of the Combat Direction System. ASW problems cannot be solved simply by determined efforts to process and display information of doubtful value. The fundamental requirements are better input data, *i. e.,* better detection and classification capabilities, and improved weapon-guidance systems. However, it is believed that the development of a system such as may be described would be of considerable benefit to the timely coordination of actions, and would not injure over-all ASW effort unless the development of this system was conducted at the expense of the development of improved sensory equipment.

The goal is to produce the functional requirements of the system. Since, according to the time scale of the program, the system is scheduled for completion in September 1963, it is being designed to be operable in the Fleet of 1963 and beyond. As to the definition of "beyond," no calendar date can be assigned. It would, however, be that date by which significant improvement in detection or weapon capabilities has been achieved. Therefore the system must operate in 1963 to 1965, or possibly to 1967, and it must posses a growth potential to permit the incorporation of new sonar systems such as Lorad. For the study now being conducted, however, only those equipments are being used that will be in the Fleet in 1963 to 1965. It is not intended, for example, that hydrofoil boats and Lorad-equipped vessels be utilized.

The present manpower force engaged in the study seems to be adequate, and the time has not yet arrived for the services of engineering, programming, and other specialists. Operational features are at present the sole consideration, and the questions of target classification, the positioning of knobs and buttons, are not yet of moment. So far the subject of what ships and platforms to be utilized in this force, the type of detection equipment to be employed, and the command structure, have been of prime interest. Consideration of the command structure, for example, has not been aided by the presently available literature, which depicts command structures configured to fit present equipment and current locations of such equipment. The system being studied at present will be located in one room except for a few input sources and weapon equipments.

So far, a command organization has been tentatively specified. (The combat direction organization is, of course, the sole interest; the complete ship's organization is not of concern.) Our and the enemy's capabilities in terms of detection equipment, weapons, speeds, maneuverability, and so forth, have been specified. A detailed chronological functioning within the chosen situation has been determined, and this has been a minutely detailed examination. The results of the scrutiny will produce the functional block diagram of the system. Although a reasonably clear view of the system is now in existence, it is still in the formative, or even argumentative, stage, and even the examination of the first situation is not yet complete.

The system as presently envisioned is far from completely automatic. It can be described as a computer-aided manual system, with the people involved being given a heavy decision-making responsibility. This is largely because of the variety of actions peculiar to antisubmarine operations. In the air-defense situation, decisions are made as to whether or not an attack on a target will be made with a manned aircraft or a missile and, if with a missile, whether a TERRIER, TARTAR, or TALOS. In undersea warfare, however, a more varied situation exists. A wide variety of weapons, platforms, and tactics may be available, and it is believed at the present time that tactical decisions can be left to well-trained ASW officers.

It is expected that by the time the Canadian representatives depart NEL, about 1 November 1959, there will be a fairly good agreement on the general nature and size of the system, the functions to be performed, and where, and that there will exist at least a rough-cut on such things as data rates, data accuracy requirements, etc. New situations to introduce higher data rates than those now under study will be examined.

It is currently expected that effort can be started on Phase II, System Design, earlier than anticipated in the program proposal. The operational analysis phase was originally considered to require about 8 or 9 months. However, it can now be estimated that this will be reduced by 2 to 4 months.

Summary and Final Comments

CDR L. FRANZ

Senior Program Officer

When the NTDS/USW program is viewed in perspective, a question is posed by the recurring statements of participating groups that ASW will be made part of the Naval Tactical Data System. If this is defined as meaning that ASW characteristics will be evaluated during the service test evaluation of NTDS, this is acceptable and important in view of CNO policy. However, it must be borne in mind that NTDS will be of value to the ASW program only insofar as NTDS increases the efficiency of antisubmarine warfare.

The ASW problem can be aided by increasing the capacity to detect and classify targets, and in this compilation, theoretical approaches were discussed and an example given of how this was being accomplished on one equipment. NTDS can assist the ASW program through a rapid interchange of information that will aid a tactical commander in the offensive and defensive disposition of his forces. NTDS can also have a role in the ASW situation by bringing suitable weapons to bear upon a target.

It is considered that the Navy Electronics Laboratory, more than any other single agency, possesses the personnel and experience to contribute a major effort to all of the areas involved.

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CNO Ltr, Ser 0204P37, Appendix No. 1. Development Characteristics No. AD-19401-1 NTDS. 24 April 1956.

CNO Serial 0286P34. Established as task priority *four* on ASW Operational Employment Study for NTDS by NEL. 7 June 1957.

OPNAVINST 003300.7. Enunciates a plan of application of tactical digital data systems which placed ASW fifth in chronological order after surveillance, air control, missile operations and electronic warfare. Amended in December 1958 to give ASW highest priority with air defense in NTDS development. 28 October 1957.

OPNAVINST 03300.9. Enunciates the intention to develop a general purpose Combat Direction System (NTDS) which will provide for command coordination and control of all major categories of naval warfare including ASW. 24 July 1958.

BUSHIPS Ltr, Ser 677-036 to CNO. Request to CNO for an Operational Evaluation Project Assignment for evaluation of NTDS. This request sets up the service test and defines to some extent the requirements for evaluation of ASW capabilities of the DLG's utilizing NTDS. 29 August 1958.

OPNAVINST 03360.2B. Requires emphasis on measures to improve coordination and control of our ASW operations (not held by NEL). 1 October 1958.

OP-345 CONFIDENTIAL MEMO No. 82-58. Describes possible future applications of NTDS to ASW. 14 November 1958.

NTDS COORDINATOR, CODE 2800, CONFIDENTIAL MEMO 2800-080-58. Local publication of the above in part. 22 December 1958.

CNO Ltr, Ser 0146P91 to COMOPDEVFOR AND BUSHIPS. Establishes a program for concurrent evaluations of the Naval Tactical Data System (NTDS). Includes requirements for operational evaluation of ASW NTDS capabilities in ASDEC and Service Test Ships. 6 March 1959.

Joint NEL/OPTEVFOR Proposed Project Plan for Concurrent Evaluation of the Naval Tactical Data System. Recommends objectives and schedules of tests for evaluation of NTDS including various aspects of ASW. 1 May 1959.

NTDS Service Test Instrumentation Volume I, DLG 10 and 11 (PURPLE BOOK). Contains functional description of Service Test Ship ASW positions and hardware. 18 May 1959.

APPENDIX. QUOTATIONS FROM OFFICIAL DIRECTIVES

A summary of requirements of the NTDS/ASW evaluation in the concurrent evaluation of NTDS has been prepared. These requirements are spelled out in the general objectives contained in the Joint NEL/OPTEVFOR Proposed Project Plan for Concurrent Evaluation of the Naval Tactical Data System (NTDS) published 1 May 1959. This bibliography begins with the CNO letter, Ser 0204-P-37 which contains the Development Characteristics of NTDS. Specific reference to ASW was as follows:

"(4) To provide information for the control and direction of traffic in air surface, ASW and amphibious operations."

During the following two-plus years NTDS development was linked in correspondence and directives with ASW in general terms.

In August 1958, BUSHIPS requested in BUSHIPS Ltr, Ser 677-036 to CNO that a project assignment be made to OPTEVFOR for the Operational Evaluation of NTDS. This document has become widely known locally as the "Service Test Letter." Here for the time specific shipboard NTDS/ASW requirements for the DLG were spelled out as evidenced by the following excerpts from that letter.

BUSHIPS Ltr to CNO, Ser 677-036, dated 29 August 1958

Subj: Naval Tactical Data System (NTDS) Operational Evaluation Project Assignment; request for

Encl: (3) Description of NTDS Equipment for Evaluation Aboard a DLG Class Ship

"B. Designated Tasks to be instrumented

"2. To operate defensively against submarines as a part of a coordinated ASW system.

a. Underwater Surveillance (active and passive)

(1) NTDS will provide a station for the sonar search operator to enter into storage the position and classification of observed sonar contacts.

(2) NTDS will provide a station for the Underwater Battery Control Officer to review sonar contacts and surface tracks generated locally and received from other ships to assist him in appraisal of sonar contacts for designation to a MK-5 attack plotter.

(3) NTDS will provide a station for the entry from the surface search radar. NTDS will up-date and compute velocity on these tracks.

(4) Computer capacity and space shall be reserved for future inclusion of an automatic high speed data transmission circuit for short ranges for further implementation of ASW functions.

(5) NTDS will prepare for transmission to other ships and receive for storage and display, surface target and sonar contact reports.

b. ASW Combat Direction

(1) NTDS will provide a station in surface operations which will permit display of stored information on sonar contacts and surface targets on a flat surface on which maneuvering board problems may be solved and various geographic overlays may be used. Note: "If this is not provided for during service test, a SPA 23 will be substituted."

Encl: (4) Page 2

"The two DLG's will demonstrate in addition:

a. Exchange of sonar surveillance data and integrated close support in ASW."

In October 1958 CNO issued OPNAVINST 03360.2B requiring added emphasis on measures to improve the ASW situation. ASW priority in NTDS development was upped to a co-equal status with air defense. OP 345 (later OP 348), Office of CNO published a Memo dated 14 November 1958.

CNO ltr, Ser 0146P91, dated 6 March 1959 to BUSHIPS and COMOPDEVFOR established the concurrent evaluation of NTDS and is the basic document upon which the Proposed Project Plan was based. The scope of the tests of NTDS/ASW capabilities are stated. Pertinent excerpts are as follows:

CNO ltr to COMOPDEVFOR and BUSHIPS, Ser 0146P91, 6 March 1959

Subj: Establishment of Program for Concurrent Evaluation of the Naval Tactical Data System (NTDS)

States scope of Operational Tests at NEL under *task 2* "shall include but not necessarily be limited to determination of the following."

"b. Capability of NTDS in processing, display and dissemination of tactical information."

"c. Operability of the NTDS Unit Computer in the processing of synthetic ASW information."

Scope of tests under Task 4 (Service Test) includes the determination of the following:

a. "The capability of the NTDS equipped ship in the collection, processing, display and dissemination of air defense and ASW information."

d. "The effectiveness in NTDS in ASW combat direction and coordination in multi-ship operation."

g. "The effectiveness of the exchange of information afforded by the NTDS high frequency digital data link."

h. "The effectiveness and flexibility of NTDS in the display of information."

i. "The effectiveness and flexibility of NTDS in computer programming."

Under phase 3 — "When sufficient members of NTDS equipped ships become available it is anticipated that further evaluation of NTDS will be undertaken as part of Fleet operations and will emphasize ASW, Strike and Assault and Amphibious employment of NTDS."

All of the broad CNO objectives are reflected in the proposed project plan as follows:

Proposed Project Plan for Concurrent Evaluation of the Naval Tactical Data System, 1 May 1959.

A2a. (2) *Task Two* — Operational Tests

"Establish by operational tests and observations of the developmental NTDS under controlled environmental conditions and imposed conditions of interference:

(a) The capability of NTDS to:

2 Process synthetic ASW

3 Provide evaluated tactical information in suitable form to controllers and directing officers for the purpose of combat direction control and coordination of air defense and ASW."

A2b. (2) *Task Four* — Operational Evaluation

"Establish, by operational tests and observations of the NTDS under conditions representative of service employment:

(a) The capability and limitations of the NTDS to:

1 Collect, accept, process, display, disseminate, and exchange air defense and ASW information.

2 Provide evaluated tactical information in suitable form to controllers, directing officers, and command for the purpose of single and multiple ship combat direction, control and coordination of air defense and ASW including air intercept, weapon assignment and ECM."

Under specific objectives *Task 1* of Concurrent Evaluation Plan, Page F5, 6.

Objective 1.1, 2.1 — System Performance. "Determine the capacity, accuracy and adequacy with which the system performs the following functions:

(e) Utilization of ASW information.

Objective 1.8, 2.8 — Compatibility. Determine the compatibility of the system with associated equipments and systems including:

(d) Sonar Set AN/SQS-4

Objectives 1.10, 2.10 — NTDS — Non NTDS Operation

Objectives 1.15, 2.15 — Adequacy of Support Equipments

Task Two

a. *Major Objectives*:

"Establish by operational tests and observations of the developmental NTDS under controlled environmental conditions and imposed conditions of interference:

(1) The capability and limitations of NTDS to:

(b) Process synthetic ASW and ECM information."

Objective 2.1 — System Performance (same as 1.1)

Objective 2.8 — Compatibility (same as 1.8)

Task Four

a. *Major objectives*:

"Establish by operational tests and observations of the NTDS under conditions representative of service employment:

(1) The capabilities and limitations of NTDS to:

(a) Collect, accept, process, display, disseminate and exchange air defense and ASW information.

(b) Provide evaluated tactical information in suitable form to controllers, directing officers and command for the purpose of single and multiple ship air defense and ASW combat direction, control and coordination, including air-intercept, weapon assignment and ECM."

b. *Specific Objectives*

Objective 4.1 — System performance. Determine the degree of capacity, accuracy, and effectiveness with which the systems perform the following functions:

(i) Intraship dissemination and display of tactical information including status and orders.

(j) Intership exchange of tactical information

(k) ASW Operations

The following scheduled tests deal specifically with ASW evaluation.

1.9, 2.9	NEL System — ASW	April, May 1960
1.24, 2.24	NEL System — Multi-mission	Feb, Mar, Apr, May 1960

Navy Electronics Laboratory
Report 948

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Report summarizes papers presented during the NTDS/USW symposium at the Navy Electronics Laboratory on 25 September 1959. The procedures given are not doctrine, and are subject to change as new knowledge dictates.

1. NTDS
2. Data processing systems

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