NRL Report 6247

Toward the Elimination of Ocean Environment Variations in Integrated Detection, Localization, and Attack Systems

[UNCLASSIFIED TITLE]

R. H. Mathes and L. C. Ricalzone

Techniques Branch
Sound Division

May 3, 1965

U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

ABSTRACT

The current trend of lower frequency, higher power sonar systems with longer detection range capability has resulted in increased location errors caused by both ocean environment variations and inherent equipment errors. This report presents the philosophy of an integrated systems concept, which greatly reduces both of these errors at the extended range of detection. The adaptation of any existing sonar to such a system is shown to be possible with existing components and simple accessories to the sonar display. Existing hardware suitable for use with most U.S. sonars is described, and a simple method of determining overall system localization performance is discussed.

Simulator studies and field operations have shown a precision localization and attack capability. An advantage accruing from precise location is in classification, where it is now possible to place high-probability classification devices close enough to the unknown contact to effectively eliminate the medium transmission anomalies.

PROBLEM STATUS

This is an interim report on one phase of the problem. Work on the problem is continuing.

AUTHORIZATION

NRL Problem S02-09
Project SF-001-03-19-8137 (BuShips)

Manuscript submitted January 25, 1965.

TOWARD THE ELIMINATION OF OCEAN ENVIRONMENT VARIATIONS IN INTEGRATED DETECTION, LOCALIZATION, AND ATTACK SYSTEMS
[Unclassified Title]

The trend in detection sonar design has been toward lower frequency and higher power to produce longer ranges. This trend started with H. L. Saxton's 10-kc experiments after World War II and may well have reached its endpoint in Project Artemis at 400 cycles. Initially, it was considered by most that this was all that was required, that we could "blast" our way to long detection ranges. However, it soon became apparent to most that this was not so; the physics of the sea directed otherwise. There must be a reasonable acoustic path between sonar and target before there is some assurance of a detection. Three major acoustic paths are now being exploited in experiments and by various equipments. These are the surface bounded duct, the bottom bounce path, and the convergence zone. In detection we have learned our lesson and are trying to live with our oceanographic environment as it is.

After a target is detected, it must be localized and attacked. As the sonar ranges are increased, more stringent requirements are placed on range and bearing accuracy for sonar equipments in order to produce a given location accuracy. This problem is illustrated in Fig. 1, which is a log-log plot of percentage range error and the corresponding degrees bearing error versus range for a given location error or requirement. The solid diagonal line is the 500-yard location requirement, which may be used to determine for a given range either the range accuracy required to be within 500 yards of the target along the line of sight or the bearing accuracy required to be within 500 yards at right angles to the line of sight. Also the 300 and 1000 yard lines are dashed in. The caption under this plot identifies the number labels of some equipment errors, some oceanographic errors, and some overall attack errors.

The data obtained by the Loreli technique is the main subject of this paper. This is live field data of attacks against an evading submarine or simulator data as explained in the figure caption. It is not static location accuracy data or medium-induced-error data. It is interesting to compare this with the other data on the plot. The following paragraphs describe the Loreli program, which produced this data.

In February 1955 work started under Bureau of Ships sponsorship to provide high-quality acoustic information for fire-control purposes at long ranges. These ranges already had been experimentally demonstrated by existing equipments and were expected to become characteristic of future equipments. After examining many possible approaches, it was decided to use the idea of placing an acoustic transponder in the vicinity of the target. This transponder would then be used as a reference point from which to pinpoint the target.

A transponder is a simple acoustic device which, upon receipt of a sonar pulse, immediately transmits an acoustic pulse of its own. This pulse is received by the sonar and indicates the position of the transponder on the sonar display. A vector can then be read from the transponder to the target and used to correct a fire-control system for a

---

Note: This report was a paper presented by Mr. A. J. Hiller in October 1964 to the Tripartite Seminar on Oceanographic Instrumentation for Military Forces, Whitehall, London. The proceedings of the seminar will be published and will include the recommendations of the various working groups as well as the complete texts of all papers presented.

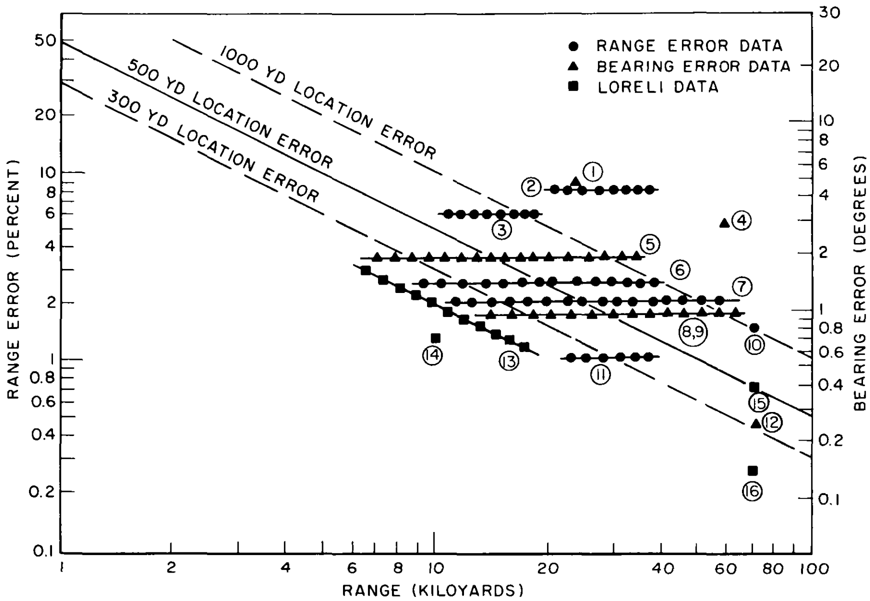


Fig. 1 - Various data on equipment errors, oceanographic errors, and overall attack errors plotted on a graph which, as a function of range, relates the error (or required accuracy) in range or in bearing with a given error (or required accuracy) in location: (1) an oceanographic bearing error of 5 degrees or 1 mile in 12 due to horizontal gradients (see Ref. 1); (2) the SQS-23 range accuracy (8% equipment error) when set on the 40-kyd scale (see Ref. 2); (3) the SQS-23 range accuracy (6% equipment error) when set on the 20-kyd scale (see Ref. 3); (4) an oceanographic bearing error of 2.9 degrees or 1.5 miles in 30 due to the effect of a 50-ft internal wave on the BQQ-2 (see Ref. 1); (5) an SQS-23 bearing accuracy of 2 degrees as determined by OPTEVFOR tests (see Ref. 4); (6) an SQS-23 range accuracy of 2-1/2% as determined by OPTEVFOR tests (see Ref. 4); (7) the predicted SQS-23 range accuracy of 2% (see Ref. 4); (8) the predicted SQS-23 bearing accuracy of 1 degree (see Ref. 4); (9) the BuShips requirement of an SQS-23 bearing accuracy of 1 degree (see Ref. 3); (10) a range error of 1 kyd at the convergence zone as measured by J. Cybulski of NRL; (11) the BuShips requirement of an SQS-23 range accuracy of 1% (see Ref. 2); (12) a bearing error of 0.25 degree at the convergence zone as measured with the Lorad (see Ref. 6); (13) Loreli field data with the SQS-23 sonar of the overall attack error on an evading target; (14) Loreli simulator data assuming a 60-knot towed transponder against a 17.5-knot evasive guppy submarine and assuming noise blanking above 30 knots; (15) Loreli simulator data for the first convergence zone assuming a 600-knot aircraft which is vectored from ASW ship to contact, where it drops a Posit buoy, and then is vectored at 120 knots and assuming the submarine zigzags through the zone at 25 knots; (16) Loreli simulator data for the first convergence zone assuming a 600-knot aircraft which is vectored from ASW ship to contact, where it drops a Posit buoy, and then is vectored at 120 knots and assuming the submarine runs straight at 25 knots.

missile shot or to direct a weapon carrier from the transponder to the target (Fig. 2). This is analogous to the method used in naval gunnery where one shot is fired, the error or "miss distance" noted, a correction made, and another shot or salvo fired to hit.

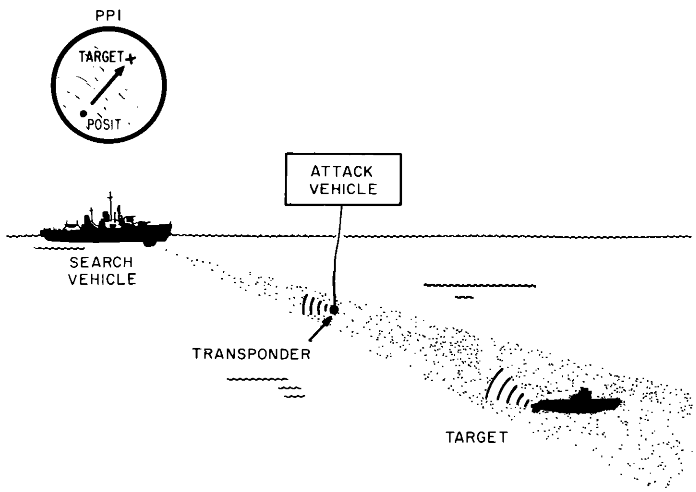
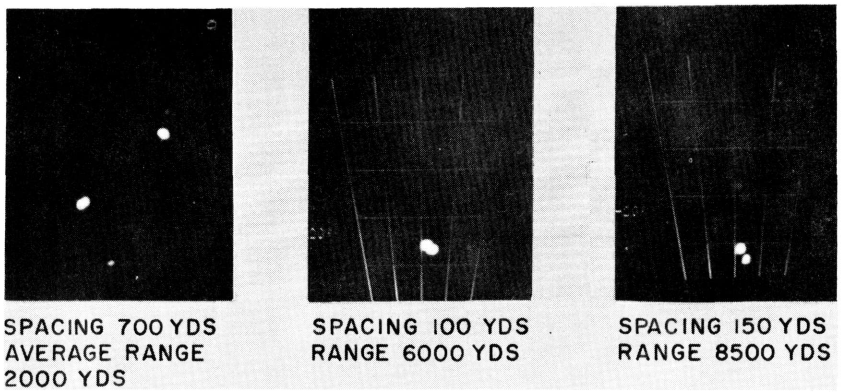


Fig. 2 - Loreli attack technique

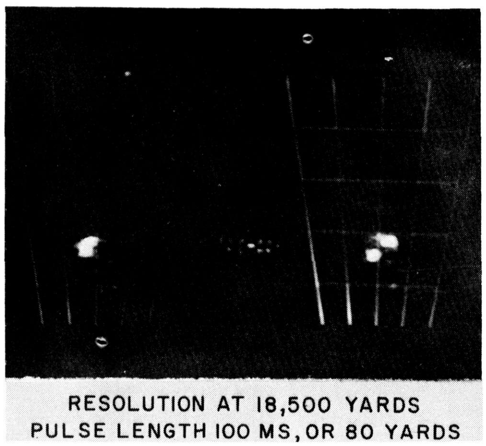
In this approach the equipment requirements are considerably relaxed, and indeed much equipment is eliminated entirely, as will be seen later on. There is no longer a requirement for high absolute accuracy or long-term stability in the series of components that make up the attack system. Instead the requirement is for a reasonable resolving power of the sonar equipment, short-term stability only, and a low dispersion in any long-range missile that might be used. What happens is that the errors are essentially subtracted out. The range and bearing errors to both the transponder and the target are about the same, whatever they may be, so that the vector from the transponder to the target is accurate. This, of course, is also true of the unknown errors of the acoustic medium produced by such things as horizontal thermal gradients, internal waves, or the bottom bounce path over unknown oceanographic topography.

A great many errors must be considered if a rigorous examination of ASW fire-control problems is made. Some of these are: sonar-equipment alignment errors, readout errors, target-tracking and prediction errors, errors due to dead time, attack-vehicle or missile-control errors, the acoustic medium error already mentioned, and the temporal variance of all these errors. Because of the complexity of this problem and, more important, because of the lack of sufficient numerical information about most of the errors, especially with regard to the medium, it was decided to take a direct experimental approach and measure the sum of all the errors. Two kinds of data have been collected: from the Loreli attack simulator, and from actual field trials using presently available sonar and weapon-delivery methods.

Since the key to the Loreli philosophy appeared to lie in sufficient resolving power, measurements were conducted on several occasions using two transponders as targets. By varying the transponder spacing, the resolution of various equipments and displays could be measured. Some examples are shown in Fig. 3.



(a) Short-range data



(b) Long-range data

Fig. 3 - Some experimental resolution studies

Resolving power is only one factor affecting the accuracy of vectoring, and since a vector is taken from the center of one echo to the center of the other, the accuracy is better than might be thought from a consideration of the resolving power alone.

At the time that the resolution experiments were being conducted, a dynamic attack simulator was developed and built to study the problem with simulated long-range sonar and high-speed submarines. This simulator generated a real time plot of a Loreli attack, with appropriate sonar time delays for the Loreli operator. Helicopters, hydrofoil boats, and fixed-wing aircraft have been simulated as attack vehicles against a variety of submarines operating at ranges out to the first convergence zone. Most targets have been fully evasive, and in many of the runs the submarine "skippers" have been allowed to watch the attack as it was generated and to hear the commands the Loreli operator gave the attacking vehicle.

The advantage of a short dead time for weapon delivery was demonstrated in the simulator runs. In the case of Loreli with a helicopter as the attack vehicle the total weapon delivery dead time consists of the time for the echo to travel from the submarine to the sonar plus the time to read and report the latest vector plus the time between the last vector report and the weapon drop. Since the attack vehicle is under continuous control, this last term can be quite small. However, as long as sonars are used, there is not much that can be done about the time for the echo to travel from the submarine to the sonar, which in a well-run, long-range attack is the largest component of dead time. During the simulator runs it was discovered that when the speed of the attack vehicle was more than 2.5 times that of the target, evasion became futile. Things happened so fast that the target appeared to be stationary.

Another interesting and very important fact demonstrated in the simulator work, and later in the field, was that there is little training required to produce Loreli operators—a learning curve does not apply. Naval officers and some types of enlisted men already have sufficient knowledge of vectoring techniques and do very well after only brief familiarization. In fact, naval officers consistently outperformed the NRL scientists on the simulator. In the field, however, we had a slight "untraining" problem; it was difficult to convince people on the ships that information did not have to be passed about in the ship or plotted anywhere.

Most of the time when vectoring, the operator has only to aim at the last target echo. Occasionally there is a need to lead the target to compensate for sonar time delay and target motion. This can be explained by pointing out that when the next echo of a series is received, the target is already further ahead along its track, by about one-half the spacing between the last two echos. Any person who has fired a gun at a moving target has a feel for leading the target.

The main difficulty in the conduct of the Loreli work has lain in collecting scientifically and operationally valid data. One problem has been the precise measurement of the miss distance when a simulated weapon is dropped on a maneuvering submarine. A distance-measuring equipment (DME) was developed to do this.

Some experimental work was done vectoring a hydrofoil boat (Fig. 4) to a stationary target. The boat was tracked out to 10,000 yards with an AN/SQS-4 sonar and produced the attack data shown in Fig. 5.

However, it soon became apparent that the best presently available vehicle for collecting data was the helicopter, vectored by a surface ship and carrying a droppable transponder. The transponder also had to be developed, and has been called the Posit buoy. Figure 6 shows the original NRL buoy and overlay. Figure 7 shows the production Posit buoy (AN/SQQ-18 transponder buoy), and Fig. 8 shows the production model overlay. This constitutes the total fire control hardware requirement for the Loreli technique as used by NRL.

The attack sequence is shown in Fig. 9. The target shows up as a "pip" on the ships display as seen in the upper left in Fig. 9(a). A helicopter is sent to the vicinity of the target on a bearing and to a range from the ship as read from the sonar display. When it arrives at this point, a transponder is dropped. Figure 9(b) shows in the upper left the ships sonar presentation of the transponder and target pip. It now remains to read a final vector range and bearing from the transponder buoy to the target using the overlay and radio this to the helicopter, which flies this vector and drops the weapon. This is a basic attack; however, several possibilities might exist. If, for instance, the transponder was dropped more than 1000 yards from the target, it might be advisable to give the helicopter a second vector from his first drop to the target, where upon he would drop a second transponder. Also, on occasion, it has been found that correction while on the final vector often helps to improve the accuracy of the weapon drop.

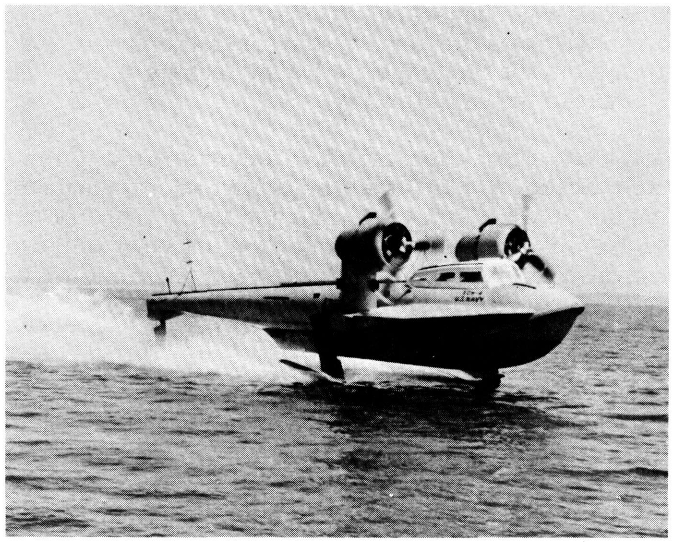


Fig. 4 - Hydrofoil boat (XCH-4) used in some experimental vectoring operations

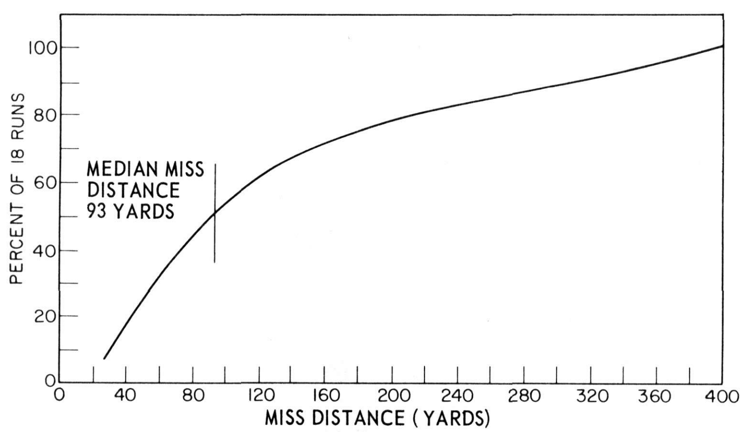


Fig. 5 - Vectoring performance of the hydrofoil boat of Fig. 4 operating at 50 mph against a stationary target at a range of 3200 to 6200 yards

Fig. 6 - The original Posit buoy and the PPI overlay

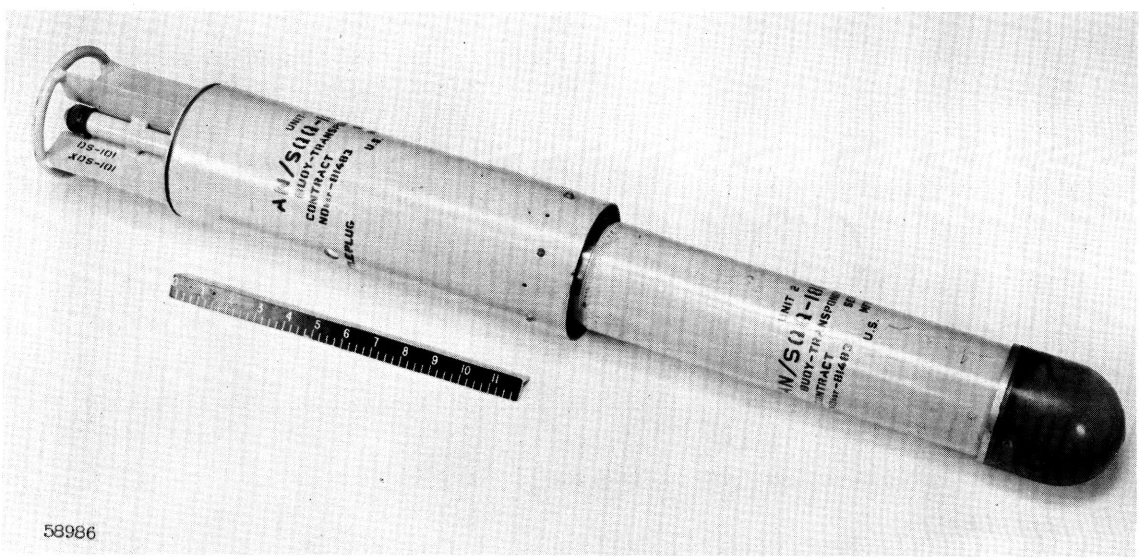


Fig. 7 - The production Posit buoy (AN/SQQ-18 transponder buoy)

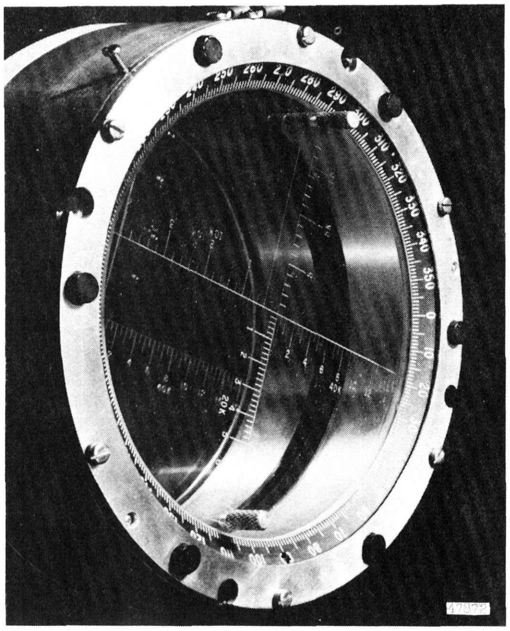


Fig. 8 - The production overlay for the PPI

However, for data collection purposes, instead of dropping a live torpedo as shown or mentioned previously, a distance-measuring-equipment or DME buoy was utilized. This buoy is physically and electronically similar to the transponder buoy used for the first vector. Prior to the exercise, the target submarine is instrumented with a small echo ranging system using a chart paper recorder as its display (Fig. 10). It presents 1600 yards across its 7-1/2-inch width, and range can be read to plus or minus 5 yards. This equipment is energized at the start of the exercise. At the time of weapon drop, the

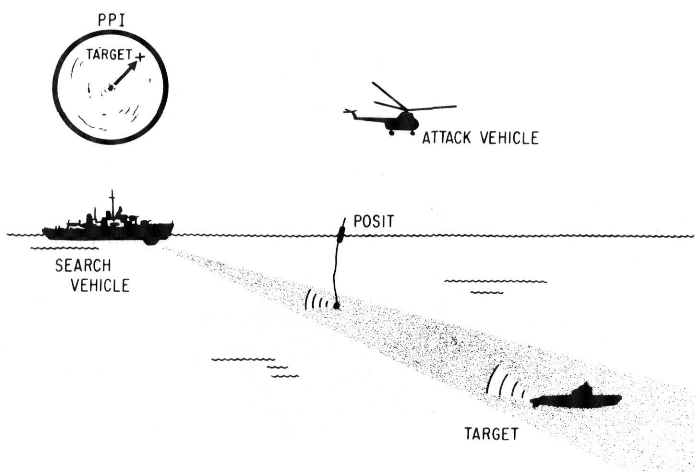


Fig. 9(a) - The basic Loreli technique--use of the first vector in dropping the transponder buoy

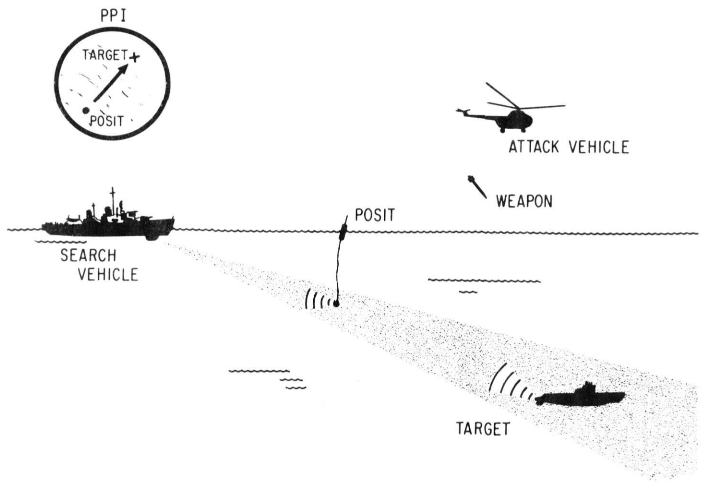


Fig. 9(b) - The basic Loreli technique--use of the second vector in dropping the weapon

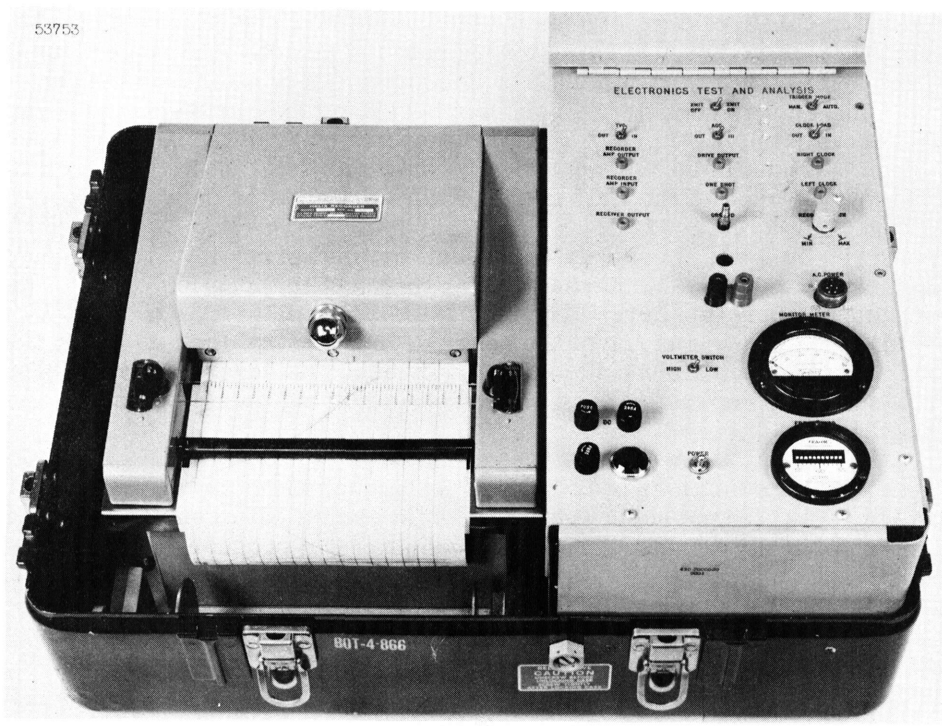


Fig. 10 - Recorder for an echo ranging system used aboard the target submarine to give the slant range of the DME buoy dropped to represent the weapon

helicopter drops the DME buoy, which is interrogated immediately upon water entry. The buoy returns cause marks on the chart paper at a range which is the slant range from the buoy to the target, or miss distance of the attack. Knowing the depth of the submarine and buoy, the slant range can be quickly converted to horizontal range. If more precision is required, the ranges can be corrected for sound velocity as well. Also, the actual position of the buoy can be found by relating the DME ranges from the trace to the corresponding times on the DRT plot of the submarine (Fig. 11). If arcs with radii equal to the DME ranges for the given times are drawn for several points, then the intersection of these arcs will give the position of the buoy with respect to the submarine track. This system has been found to give accuracy in bearing for any point along the trace of plus or minus 5 degrees.

Since time limitations in conducting the experiment required getting in as many runs as possible, certain restrictions were put on the field exercises. The submarine was restricted in depth in order to maintain the longest possible sonar contact range. At the start of the exercise, the submarine would proceed at maximum contact range at 3 to 6 knots. As the helicopter flew by and dropped the Posit buoy, the submarine was ordered to take full azimuth evasive action. After the DME buoy had been dropped, the submarine reverted to the original conditions while an assessment of the miss distance was made. These actions simulated the situation of a submarine trying to sneak through a screen and only evading under attack. It was assumed that the submarine was always alerted and knew the method of attack, which in practice is not true.

Figure 12 summarizes most of the NRL Loreli data collected to date, both on the attack simulator and in field experiments. Median miss distances are plotted against a logarithmic scale of the spread of sonar ranges to the target. Also shown are the 40-, 20-, 10-, and 5-mil error curves for a ready comparison of the results in these terms. Each set of data, or experiment, has been numbered and may be identified from Table 1. A generally accepted requirement for the location accuracy of surface ship sonar is 30 mils. A 30-mil dashed line has been added to show this relation to the Loreli data. Inspection shows that most of the field data and all the simulator data fall below this line.

It should be noted that these data represent the total error involved in delivering a weapon on top of an evading submarine, rather than just the location error of the sonar equipment. Indeed, using the Loreli technique, it is possible to have the overall attack error less than the location error of the sonar used to control the attack. It is not certain whether this happened, since the sonar equipment was never really calibrated prior to any NRL-run Loreli operation, and since next to nothing was known about the oceanographic conditions.

Of the several applications of the Loreli technique, one is in the area of classification. The presently planned surface-ship acoustic classification methods rely almost entirely on good-quality sound transmission conditions to preserve sufficient target detail to classify. These conditions seldom exist on initial detection, and sometimes do not exist until the range is closed considerably. A Loreli-vectored vehicle with remote sensors for classification and weapons for the kill can be sent out to do both jobs. If the classification is negative, nothing is wasted, but if the classification is positive, the fire control problem is in hand.

There are two ideas stemming from this philosophy that we have worked on. Both make use of the Loreli vector initially to aim something at the target, thereby reducing or eliminating reacquisition time. Figure 13 shows a torpedo-on-a-string experiment in which a modified Mk 43 was physically steered to hold contact with a passing submarine. The torpedo was controlled in both the horizontal and vertical directions. High resolution

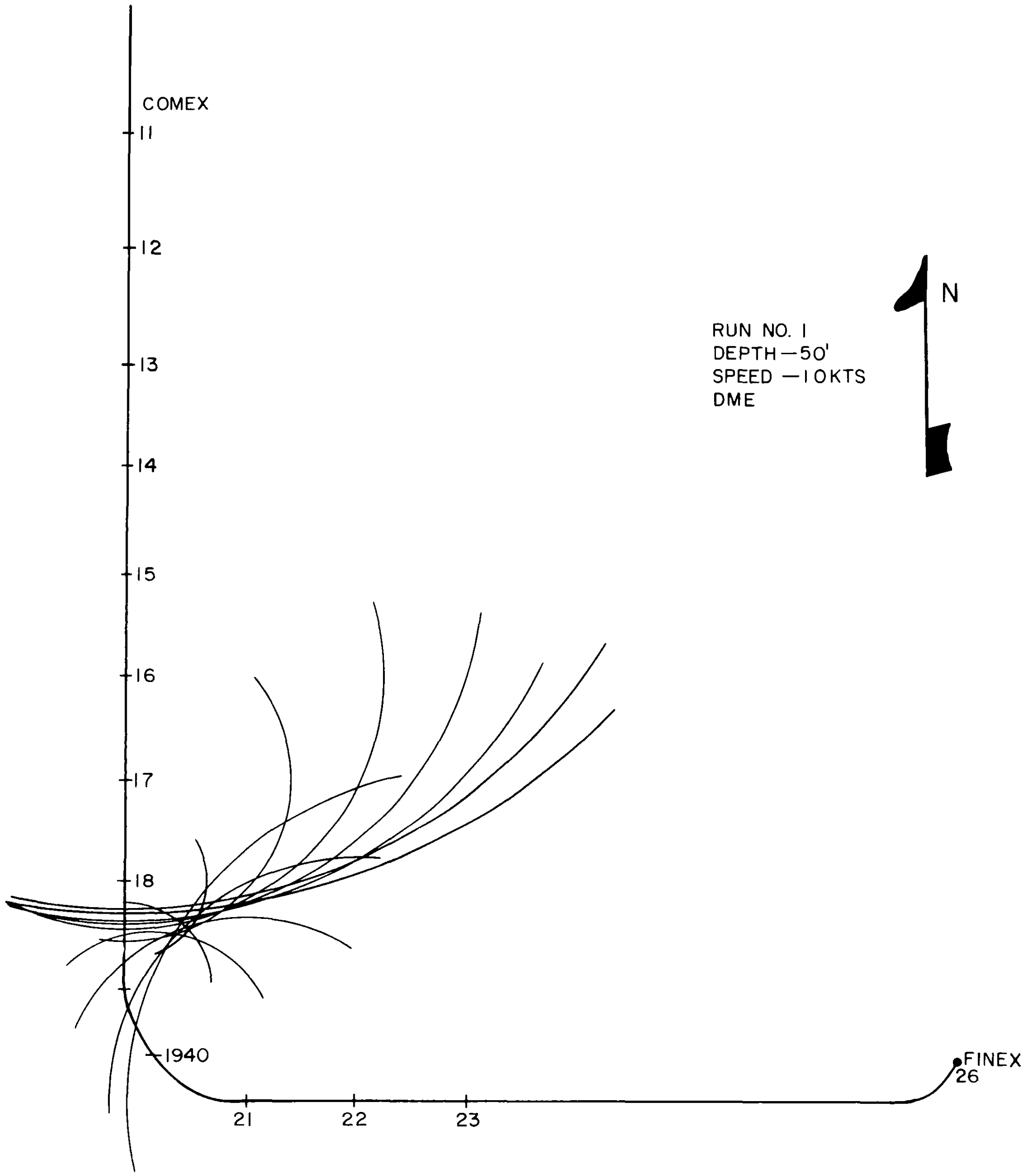


Fig. 11 - DME ranges as related to a DRT plot of a submarine

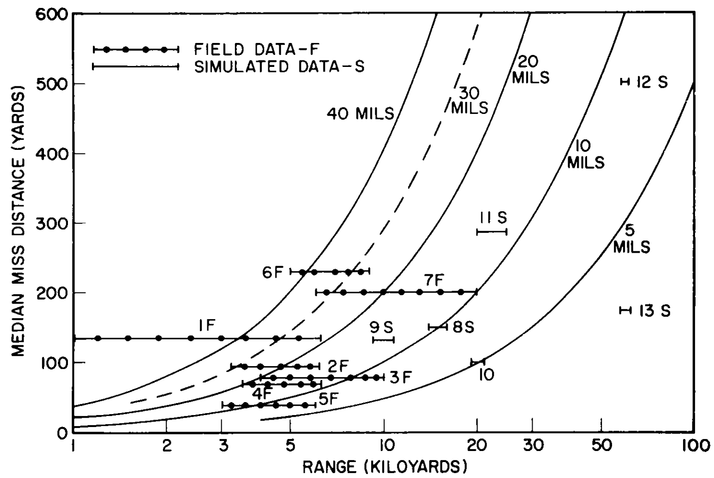


Fig. 12 - Summary of Loreli data. The labels on the data give the run numbers as identified in Table 1, with F and S indicating field and simulator data, respectively.

Table 1
Summary of Loreli Data

Run No.	Type of Study	Kind of Run and Vehicles Used	Median Miss (yd)
1	Field	USS SARSFIELD with SQS-4 sonar. USS AMBERJACK. Helicopter-dropped Posit buoy.	135
2	Field	XCH-4 hydrofoil boat towing a transponder at 45 knots. Stationary target.	93
3	Field	12-knot towed transponder. Stationary target.	80
4	Field	Data from Run 1 beyond a 2500-yard range.	70
5	Field	Helicopter-dropped Posit. Stationary target.	39
6	Field	USS NORFOLK with SQS-23 sonar. USS CHOPPER and USS BLENNY. Helicopter-dropped Posit.	230
7	Field	USS BARRY with SQS-23 sonar. USS THREADFIN. Helicopter-dropped Posit.	200
8	Simulator	PCH towing a transponder at 45 knots against the USS SKIPJACK.	150
9	Simulator	60-knot towed transponder against a 17.5-knot evasive guppy. Also, noise blanking above 30 knots was assumed.	130
10	—	Dash Loreli derived from NUOS report.	100
11	Simulator	20-kyd helicopter-dropped Posit. USS ALBACORE.	285
12	Simulator	First convergence zone. 600-knot aircraft vectored from ASW ship on contact. Drops Posit. Then vectored at 120 knots. Sub zigzags through zone at 25 knots.	500
13	Simulator	Same as Run 12 with straight-running, 25-knot target.	175

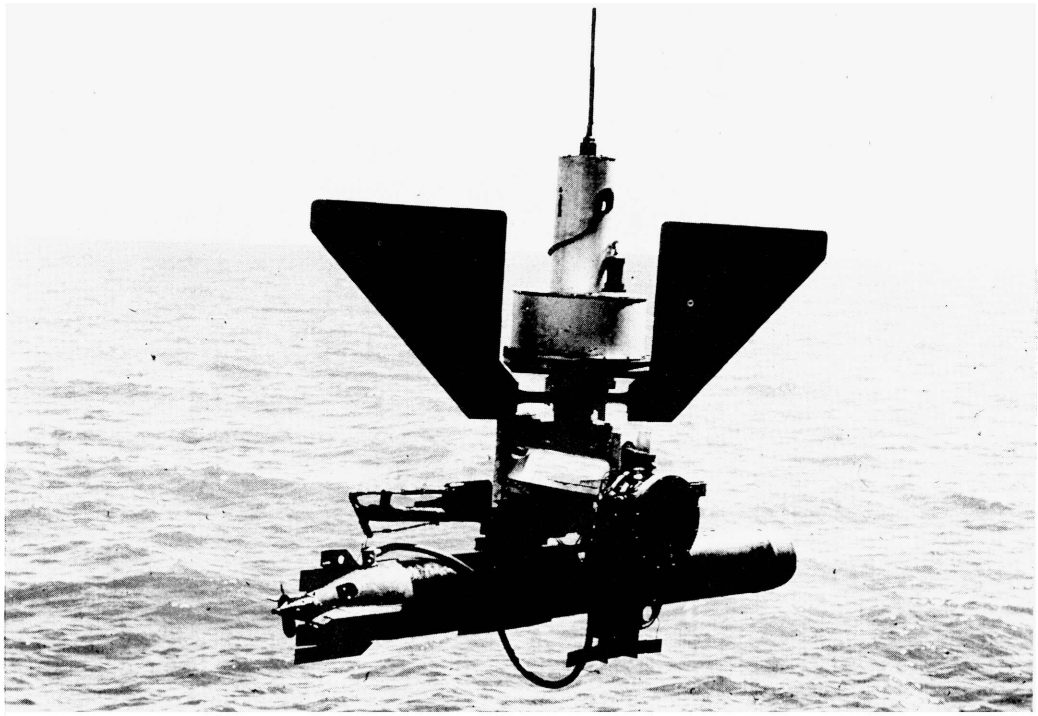


Fig. 13 - CAATS training and tilting mechanism holding a modified Mk 43 torpedo

displays were furnished for an operator for aiming and short-range classification. After the torpedo was locked on the target, it was fired for a straight run. Figure 14 shows a small 100-knot underwater rocket which is tracked by the high-resolution classification sonar. Several would be placed in a pod similar to the torpedo housing; one unit would be fired and tracked, and then step corrections made for additional firings. Figure 15 shows a rocket track on the high-resolution-sonar screen during a rocket test firing. Here again equipment and acoustic medium errors are greatly reduced. These ideas represent a second-step application of the Loreli in a remote vehicle for both classification and attack.

In general, some specific applications of Loreli in approximate order of their immediacy of applicability are as follows:

1. Use of manned helicopters and fixed wing aircraft. This can be done with existing ships, sonars, and Loreli hardware.

2. The Dash capability, which is under development.

3. Use of destroyer-based small manned helicopters. This could easily be developed around existing hardware and backfitted to present ships.

4. Long-range torpedo guidance for both surface ships and submarines.

5. PCH or DDH with two vehicles or one vehicle and a vectoring buoy.

6. Error correction for Asroc or Subroc.

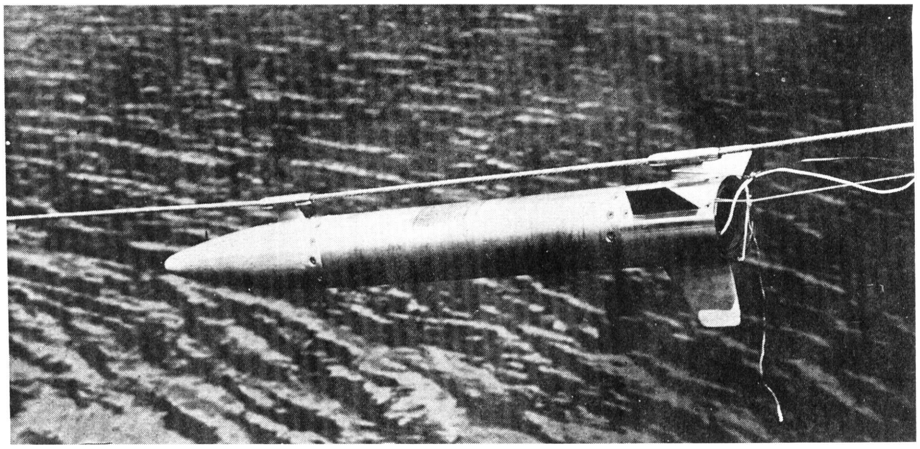


Fig. 14 - A small 100-knot underwater rocket which is tracked by high-resolution sonar

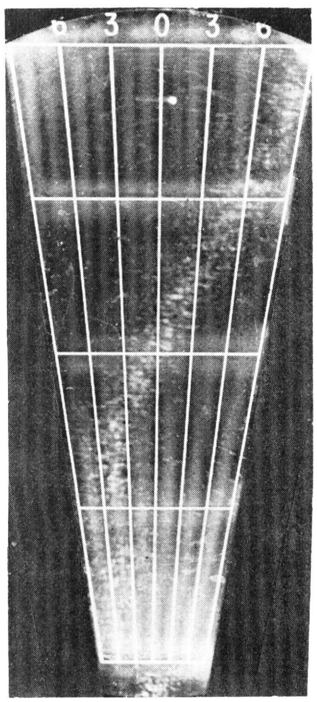


Fig. 15 - High-resolution-sonar screen showing the track of an underwater rocket such as the one in Fig. 14

7. Basis for missile systems using spin-stabilized missiles.

8. "Fire hose" application using many cheap missiles.

9. Use of bottom mounted sonars to vector ships, aircraft, or submarines to a long-range contact. In this application, the exact location of the sonar need not be known.

As stated at the beginning, we must learn to live with our environment, and in order to live with it we must know it. Gaining this knowledge is the purpose of military oceanography. We have not learned to live with our environment in the conventional approach to weapon systems design. Rather than specify the requirements for the accuracy of the medium in order to rationalize or justify a particular approach or system, we must accommodate or eliminate the effects of the ocean in our systems design. The conventional approach now being used requires high absolute accuracy on the part of all components in the system, which indeed does include an unrealistically detailed knowledge of the oceanographic conditions between the weapons controlling sonar and the target many miles away. In the Loreli approach to the problem, the need for this precision and complexity, with all it includes in the way of manpower, space and cost, is essentially eliminated. The problem is effectively converted from a long-range fire control problem requiring high absolute accuracy to a short-range fire control problem requiring only relative accuracy. We have learned to live with the ocean as it is, rather than as we would like it.

REFERENCES

1. Sullivan, LCdr R.H., "Submarines Are Not For Killing," Combat Readiness 10 (No. 3): 21 (July-Sept. 1962) (Confidential)

2. Parker, E.L., "The Effects of Calibration Accuracy on Basic Sonar Operations," Human Factors Research Inc. Technical Report 206-24 (Confidential Report, Unclassified Title), May 1964

3. Harbedian, A. and Mackie, R.R., "The Effects of Calibration Accuracy on Basic Sonar Operations," Human Factors Research Inc. Technical Report 206-23 (Confidential Report, Unclassified Title), June 1963

4. Chief of Naval Operations, Technical Analysis and Advisory Group, "Sonar Detection Probability and Accuracy," TAAG Monograph TC-1 (Secret), Nov. 1963

5. Yee, G.S., "Determination of Sonar Bearing Accuracy with the Mark II Lorad," Navy Electronics Laboratory Report 1069 (Confidential Report, Unclassified Title), Oct. 6, 1961

* * *

[redacted]ssification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U.S. Naval Research Laboratory	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP 3

3. REPORT TITLE

TOWARD THE ELIMINATION OF OCEAN ENVIRONMENT VARIATIONS IN INTEGRATED DETECTION, LOCALIZATION, AND ATTACK SYSTEMS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

An interim report on one phase of the problem.

5. AUTHOR(S) *(Last name, first name, initial)*

Mathes, R. H. and Ricalzone, L. C.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 3, 1965	19	5

8a. CONTRACT OR GRANT NO. NRL Problem S02-09 b. PROJECT NO. Project SF-001-03-19-8137 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 6247 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Department of the Navy (Bureau of Ships)

13. ABSTRACT

The current trend of lower frequency, higher power sonar systems with longer detection range capability has resulted in increased location errors caused by both ocean environment variations and inherent equipment errors. This report presents the philosophy of an integrated systems concept, which greatly reduces both of these errors at the extended range of detection. The adaptation of any existing sonar to such a system is shown to be possible with existing components and simple accessories to the sonar display. Existing hardware suitable for use with most U.S. sonars is described, and a simple method of determining overall system localization performance is discussed.

Simulator studies and field operations have shown a precision localization and attack capability. An advantage accruing from precise location is in classification, where it is now possible to place high-probability classification devices close enough to the unknown contact to effectively eliminate the medium transmission anomalies.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Weapon systems						
Sonar						
Antisubmarine warfare						
Antisubmarine defense systems						
Acoustic detectors						
Position finding						
Underwater object locators						
Underwater ordnance						
Underwater tracking						
Targets						
Antisubmarine fire control systems						
Military tactics						
Oceanology						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
____________________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
____________________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
____________________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.