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FINAL REPORT

LRAPP DATA COLLECTION (U)

Submitted to
Long Range Acoustic
Propagation Project
Office of Naval Research
Department of the Navy
Arlington, Virginia 22217
Attn: Code 102-OS/469

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31 August 1971

Approved:

Wendell C. Murray
Director
Ocean Technology Division

Submitted:

Hugh Larsen
Project
Director

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ABSTRACT

The Long Range Acoustic Propagation Project (LRAPP) includes within its charter the requirement to provide accustic predictions in support of design concept formulation, system development and operational aspects of passive sonar surveillance systems for the U.S. Navy. In meeting this responsibility, LRAPP has initiated a program including a series of environmental acoustic experiments to be conducted in the Atlantic Ocean and adjacent waters during FY 72 and FY 73. These experiments are intended to furnish information which is urgently needed for the engineering support of existing ASW system developments. (FOUO)

Specific recommendations are presented for (a) the improvement of the exercise planning; (b) identification of equipment and data collection problems and solutions therefore; (c) an assessment of the data analysis to be conducted at the conclusion of the exercise; and (d) a program leading to the generation of a data package in support of development programs for surveillance systems. (FOUO)

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

TABLE OF CONTENTS

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

TABLE OF CONTENTS (CONTINUED)

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

LIST OF TABLES

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

1.0 INTRODUCTION

1.1 General

(U) This report is the result of an engineering survey of specific deep ocean acoustic measuring equipments to be deployed in the Mediterranean and an analysis of the data processing and reduction related thereto. All services were supplied during the period 23 June 1971 through 31 August 1971 under Contract N00014-71-C-0438, Office of Naval Research.

1.2 Background

(C) The Long Range Acoustic Propagation Project (LRAPP) includes within its charter the requirement to provide acoustic information in support of design concept formulation, system development and operational aspects of passive sonar surveillance systems for the U.S. Navy. In meeting this responsibility, LRAPP has initiated a program including a series of environmental acoustic experiments to be conducted in the Atlantic Ocean and adjacent waters during FY 72 and FY 73. These experiments are intended to furnish information which is urgently needed for the engineering support of existing and similar ASW system developments.

(C) The first major operation of these series of experiments is scheduled to be conducted in the Ionian region of the Mediterranean during the month of November 1971. The choice of this location was motivated by geographical priorities established by the MSS project (Mediterranean Sea), low availability of

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archival environmental data associated with the Ionian Basin, the existence of a compressed sound channel during the fall for this region, and a prevailing shipping density which gives rise to noise levels which are high for the Mediterranean.

(C) The most immediate objective of the IOMED Exercise will be to furnish information on the directionality and depth dependence of low frequency acoustic signals and ambient noise which will effect design decisions on MSS and DPS. In addition, the data will also be used in support of optimum deployment assessments for ITASS. To accomplish these objectives, LRAPP has enlisted six government organizations who will employ a variety of measurement equipments for the collection of the required data. The anticipated quantity of data is voluminous and dictates stringent management of its collection, reduction, analysis and presentation to insure productive results. Present planning requires each participant to perform limited data processing at sea and to submit these data together with copies of analog and/or digital recordings of the raw data to the Director of LRAPP at the conclusion of sea operations. Additional data reduction and analysis by the separate organizations is also planned as "in-house" efforts.

2.0 PURPOSE

(C) The purpose of this effort is to provide advisory services to the LRAPP Director for the following:

(a) An evaluation of the IOMED operations planning in terms of the exercises objectives, aimed at providing recommendations for the improvement of the data collection.

50 EVERGREEN PLACE / EAST ORANGE NEW JERSEY 07018

(b) Identification of equipment and data collection problems and to provide recommended solutions.

(c) An assessment of the data reduction and analysis to be conducted at the conclusion of the sea operation by each participating organization.

(d) The development of specific recommendations for a LRAPP data reduction and analysis program leading to the generation of a data package which will support MSS, DPS and ITASS. Additionally, the package should be appropriate for the support of other surveillance system developments yet not defined.

(U) The included recommendations associated with 2.0 (d) above, outline a data program which is essentially a two phase effort, e.g., near-term and long-term. The near-term effort is designed to be specifically responsive to the concept formulation needs of the MSS program. The long-term phase has been developed to meet the general requirements of LRAPP.

(C) The near-term recommendations are consistent with a target date of 31 March 1972 and are considered to be realistic and cost effective provided that the following constraints can be instituted and maintained:

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(a) Detail data planning to start no later than 1 October 1971. This effort to include preliminary computer programming required for post-exercise data reduction and analysis; concurrent with IOMED Exercise.

(b) IOMED Exercise schedule to hold firm.

(c) Raw data available for reduction during the first week of January 1972.

3.0 PROJECT APPROACH

(U) The approach used in the establishment of the included recommendations was:

(a) Summary of available information on data collection equipment and Exercise planning.

(b) Assessment of the required data.

(c) Formulation of data reduction and presentation form based on the present "state-of-the-art".

(U) Visits and conferences with each participating organization were held for the purpose of defining all aspects of the IOMED Exercise. In addition, conferences and briefings were also held with others where available information appeared to be pertinent. The following is a listing of these additional conferences:

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

- NAVSTIC - Analysis Branch
  Briefing on acoustic signals which are known to prevail within the Ionian - the emissions of which can be attributed to activities of other governments.

- NAVAIR - MSS Program
  Briefing on the status of the MSS procurement and a review of the initial environmental acoustic data requirements.

- ONR - Prediction Computer Models
  Technical discussions on the status of Navy prediction models and the data requirements thereof.

- NAVOCEANO - Oceanographic Data
  A review of available archival data collected within the Ionian region.

- TRACOR - DPS Program
  A review of environmental data requirements.

- NUSC - Vertical ITASS
  Discussions relating to ITASS design changes the anticipated problems.

4.0 IOMED EXERCISE

(U) At the date of this report, details associated with the exercise remain in flux. Only major items of concern

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are reported herein and are so classified due to the potential impact (which in each case is identified) on the success of the program

4.1 Operation Planning

(C) Planning for the exercise is considered to be inadequate in the following areas:

4.1.1 Equipment Calibration

(C) IOMED will deploy twelve (exclusive of VLAM) separate ambient noise measurement systems, the calibration of which is left to the discretion of the supplying organization. In addition, sonobuoys and associated receivers are also to be utilized.

(C) TRACOR considers the lack of a unified calibration plan for IOMED the most serious weakness of the exercise. Inaccurate measurements render the collected data useless when means for its correction is unavailable. Further, correction (if required) when included within the data reduction process can be costly and time consuming.

(C) A comparison of simultaneous measurements at sites Alpha and Bravo are indicated. At best, these measurements will be relative in nature and will require additional calibration if the data is to be useful. The standard used for the above two comparitive measurements will be Autobuoy-3 as supplied by NUSC and transported by the supply boat. This unit is scheduled for use in Bermuda and planning indicates that it will remain

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

on board the supply boat for transit to the Mediterranean.

(C) In effect, the following is a status of the planned level of calibration for IOMED.

(a) Relative measurements to be made at sites Alpha and Bravo; ACODAC and MABS plus ANB-1 and 2 thus checked.

(b) Relative measurements not planned at site Charlie; ANB-3 and 4 thus not checked.

(c) Comparison of measurements taken by sonodiver, sonobuoys with Autobuoy-3 not planned.

(d) Simultaneous measurements of noise by ACODAC, MABS and Autobuoy-3 most unlikely due to the difference in sampling time of each system;

- MABS on 25 sec. each ½-hour;
- ACODAC on 1.0 min each 15 min;
- Autobuoy on for 20 min at each programmed depth.

The problem of coordination is obvious and essentially voids even a relative calibration capability for IOMED.

(C) Two ANBs will be deployed at Site Charlie. A relative measurement here is possible due to continuous recording of noise by ANB, however, planning does not include Autobuoy-3 measurements at this site.

30 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

4.1.1.1 (C) Recommended Action

(a) Provide for calibration of Autobuoy-3 prior to departure for IOMED.

(b) Supply backup calibration for Autobuoy-3 in the event it becomes inoperative or lost.

(c) Deploy Autobuoy-3 at Site Charlie.

(d) Devise scheme of deployment which will insure simultaneous measurements between Autobuoy-3 and systems having discrete sampling times.

(e) Provide for recalibration of Autobuoy-3 at the conclusion of IOMED.

(f) Require Autobuoy-3 calibration measurements (absolute and relative) delivery to LRAPP at exercise conclusion.

4.1.2 Shipping Surveillance

(C) Ambient noise at the lower frequencies (10 to 500 Hz) in the Ionian basin will be dominated by contributions from shipping traffic. Use of data gathered in the basin for development and validation of computer models of ambient noise requires a complete understanding of all noise sources if the model is to be other than a summation of the statistics of all available measurements. In particular, characterizing the effects of shipping noise statistically with probability density approaches may not be feasible because of the highly temporal and geographical variations in the ambient noise field that result from shipping.[1] An alternative approach to modeling ambient noise is to consider the shipping noise contribution as a temporal composite resulting from individual sources (the number of sources will depend upon the desired scenario) with specified geographical locations and propagation conditions. Developing and validating models of this nature from measured data requires precise knowledge of the shipping sources contributing to the measured noise field. The shipping surveillance currently planned for IOMED will not provide this knowledge.

(C) Surveillance of shipping traffic in the Ionian Basin is scheduled on a semi-daily basis (3 consecutive days out of each 5). Present plans indicate that surveillance will be primarily radar siting of larger vessels by the aircraft. This data will be displayed on a small chart (8" x 6") of the Ionian Sea. This level and form of presentation is considered inadequate due to the shipping density anticipated and inherent inaccuracies in location due to the size of the plot chart.

4.1.2.1 Recommended Action

(C) The following are recommended action items for the improvement of shipping surveillance planning:

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1 Caldorone, M.A., NEL, "Probability Density Analysis of Ocean Ambient and Ship Noise," November 1964.

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(a) Provide for a backup aircraft to supply surveillance services in the event fleet support is withdrawn.

(b) Schedule daily flights and patterns for the collection of data on location, heading and speed (if possible) of all surface ships.

(c) Include rigging checks (estimate of size and type) for all major vessels within 100 N miles of stations A,B and C.

(d) Obtain signature (source spectrum levels) of all major merchant vessels and warships observed within 100 N. miles of the three stations. Ideally, the signature should be obtained by having the surveillance aircraft drop a calibrated sonobuoy (AN/SSQ-57) near (within 1000 yards) the ship. Recordings of the signature aboard the aircraft should be annotated with a voice track giving data on time, position, heading, speed and rigging data. If for reasons of cost or aircraft availability, signature data cannot be obtained on all ships as suggested above, an attempt should be made to obtain signatures of a representative sample of ships at various ranges from the stations.

30 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(e) Establish an agency and individual with responsibility for coordination, processing and reporting of the surveillance data collected during and after the exercise.

4.1.3 Environmental Data Collection

(U) Coupled with the need for better shipping surveillance is the need for more comprehensive collection of environmental data. The same reason prevails--use of measured data for validation of models of the acoustic environment requires very detailed knowledge of the factors which contribute to the observed propagation conditions and ambient noise field. In addition, sources other than shipping must be identified and the manner in which these sources contribute to the total noise field defined. As was pointed out in TRACOR's interim report, we feel that the IOMED exercise, as presently planned, does not sufficiently emphasize the importance of environmental data of all types. A recent report (IMP Final Report(S), dtd., Aug. 71) included statements which attack the basic validity of previous attempts to model the acoustic environment of the Mediterranean.

(U) "Ideally, one should be able to compute, with reasonable accuracy, values for such quantities as propagation loss and reverberation level from measurements of sound velocity, sea state, bottom characteristics and density of biotics. In actual practice this can only be done with confidence when

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

the values for these measured variables lie within the range of values used in deriving the basic equations. In other words, the models are reliable only when environmental conditions are nearly the same as those used to formulate the models."

(U) "As has been pointed out, the Mediterranean is significantly different from the "average" ocean in the feature of greatest importance to acoustic sensor performance, the sound velocity profile. Other differences exist and, while they may not have an effect of the same magnitude as the sound velocity structure of the water columns, nevertheless they cumulatively comprise a range of environmental conditions that constitute a substantial departure from the conditions upon which most prediction models are based. In short, there is good reason to suggest that the mathematical models applicable to a large part of the world should not be used to predict sonar performance in the Mediterranean and that direct measurements of environmentally dependent parameters are necessary."

(U) The above statements serve well to indicate the degree of frustration experienced by those in need of model

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

predictions. TRACOR is of the opinion that the conclusion drawn is invalid and that the problem stems from a continuing lack of adequate archival environmental data.

(U) Again, increased emphasis in the area of environmental data collection is required if ambient noise and propagation measurements are to effectively support model validation and prediction.

(U) The following comments and recommendations relate to increased environmental data collection:

4.1.3.1 Sound Velocity Profiles

(C) The number of XBTs and AXBTs should be increased. Considerable variation in salinity along the CW and ITASS tow tracks could exist due to the current structure in the basin. For this reason salinity measurements via Nansen casts should be obtained to complement the XBT and AXBT deployments;accurate calculation of SVP is thus assured.

(C) All sonobuoy deployments by aircraft or surface ships should be accompanied with AXBT or XBT deployments. In addition, the surveillance aircraft should deploy AXBTs in a systematic pattern throughout the basin to measure the horizontal variability of SVP. The suggested pattern consists of parallel North/South tracks separated by no more than 50 N. miles with AXBT drops at 50 N. mile intervals along each track. This measurement should be carried out at least three times during the exercise.

50 EVERGREEN PLACE / EAST ORANGE NEW JERSEY 07018

(U) Where possible direct velocimeter measurements should also be increased at each station. In addition to the normal x-y plot of the profile, it is recommended that sing-around frequencies and depth be digitally or punch tape recorded as well. All commercial velocimeters provide for easy assess of these frequencies or a digital output of the sound velocity as a function of depth.

(C) ITASS ships should also deploy XBTs at frequent intervals. Present planning does not identify the source or responsibility for such drops.

4.1.3.2 Weather Data

(U) In addition to weather data collected by each participating ship, all navy ships operating in the basin should be requested to provide copies of their normal daily reports to the operations control center. These should be scanned for unusual conditions (squals, high local winds, etc.) which might affect the ambient noise measurements. All significant data from this source should be included in the oceanographic report.

4.1.3.3 Bottom Data

(U) A preliminary review of the available bottom loss data for the Ionian indicates a gross insufficiency. This information will be critically required for propagation loss model predictions. Without this information, improvement in the ability to predict ambient noise levels associated with distant shipping cannot be expected.

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(C) As a minimum effort, it is recommended that bottom loss measurements be conducted in the near vicinity of each IOMED site; explosive techniques could be used for this purpose. Grazing angles of approximately 20 degrees would be preferable.

4.2 Measuring Equipment and Processing

(U) With the exception of VLAM, all measurement systems planned for deployment during IOMED have been reviewed. These systems are briefly summarized in Table 4-1. The following sections present details relative to each system which are considered to be potential problem areas:

4.2.1 MABS/NUSC

(U) The mechanical design of MABS essentially incorporates typical features of classical bottom-moored vertical systems. An attempt to reduce self noise by means of cable farings have been incorporated, thereby, reducing strumming due to water currents. Two additional system elements, however, could contribute significantly to a high system mechanical noise. The contribution of each will be a function of the system dynamics.

(a) Miller Swivel

(U) Two swivels are used; one at a depth of 2030 ft and the other close to the bottom. Swivels are used to prevent cable destruction during

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

installation and are effective when used with low anchor weights. This infers that the MAB swivels will work, e.g., rotate when torsional forces exceed the static frictional force induced by the positive buoyancy of the main supporting buoy. Rotating swivels generate noise and should be avoided in the design of noise measuring systems.

(b) Chain

(U) MAB is designed with a 3000 lb. anchor clump, attached to a steel cable by means of 3/4 inch chain. Again, chain is an element which generates high noise levels and should be avoided in the design of noise measuring systems.

(U) The data collection features of MAB have several drawbacks, one of which is common to all systems scheduled for IOMED, e.g., inadequate tape recorder. The general feeling is that the MAB recorder is one of the better commercially available units, however, figures for wow and flutter were not available. On 31 Aug 71, it was reported that these measurements were being conducted at NUSC. On 7 July 71 it was reported that the recorder for MAB induced a discrete signal of 800 Hz into the measuring system. If this condition is not corrected, the 800 Hz signal must be filtered during data reduction.

(C) The quantity of data to be realized from MAB is lowest of all systems scheduled for IOMED. Although MAB will be installed at Bravo for 9 days, the maximum cumulative ambient noise recording at each depth for the entire period will be 3 hours. The data obtained from a single Sonodiver drop is equivalent to a 24 hour data collection period for each MAB hydrophone.

(C) Due to the short sampling time (25 sec.) and duty cycle (2 samples per hour) it is TRACOR's opinion that the data collected will have limited usefulness if the noise field is found to vary significantly within a 1/2 hour period.

4.2.2 Autobuoy/NUSC

(C) Autobuoy has the advantage of being flexible due to its size, weight and free diving capability. Reduced performance is the cost of this flexibility and again is the direct result of the tape recorder. A flutter of 2½ percent has been reported for the NUSC Autobuoy unit. This is a serious limitation and is the basis for even greater concern in light of its intended use as a secondary calibration standard for IOMED.

4.2.3 ANB/NRL

(C) Four ANB systems will be deployed during IOMED; two each at Bravo and Charlie sites. Again, it is anticipated that data analysis will be limited by the capability of the recorders. ANB will make use of modified Nutmeg recorders, having a tape speed of 30/160 inch per sec, and recorded on

1/4 inch tape. The extremely low speed of these machines accounts for the capability of continuous recording for seven days. After recovery, the data is rerecorded on 1/2 inch tape at a speed ratio of 80:1. Playback for analysis is then run at 1/4 speed resulting in a 16:1 speed ratio, referred to the original recording.

(C) NRL has reported that the modified Nutmeg machines have a resolution better than 1 Hz in the 20 to 600 Hz band. This degree of stability for a small machine is excellent and would allow for narrow band analysis of the collected data. The procedure of rerecording and subsequent playback at 1/4 speed could result in an increase in the overall flutter. The quality of the 16:1 data will depend on the stability of the rerecording at 80:1 and the absence of additional noise introduced during this process.

(U) If these degrading factors can be avoided, the ANB systems would provide adequate recordings of ambient noise appropriate for narrow band analysis. TRACOR considers the achievement of this data quality to be optimistic.

(U) Self induced noise is an additional potential problem area for the ANB system. The cable used for connecting hydrophones to the recording system is a single shielded coaxial cable (RG-58/U). This cable is known to generate microphonic d.c. noise at millivolt levels. Frequency components also exist and could render erroneous spectrum levels within the recorded data. The major contributing cable element to microphonic noise is the 36 AWG tinned copper braided shield wire. Electrically unb[illegible]ced cables (coaxial) should be avoided in noise measuring

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

systems or modified so as to prevent noise generation.

4.2.4 ACODAC/WHOI

(U) The ACODAC system also has a potential recording stability problem. Wow and flutter for the machine to be used is reported to be less than 1/4 percent. This figure will be a function of tape skewing and surface wearing at the record head. Speed stability will be significantly effected by tape thickness. ACODAC machines are presently using 1/2 mil tapes which will result in speed instability due to stretching. Recording heads should be new if flutter of 1/4 percent is to be achieved.

(U) Recording explosive data will be a problem due to the dynamic range of the signal. Although the system is quoted to have a dynamic range of 81 db, it is achieved by selection of gain settings, monitored once each minute and is therefore not continuous.

(U) Signal levels are monitored once each minute and the gain is switched in the event saturation is detected. Thus, periods up to one minute could exist during which time the amplifiers would be in overload, thus loss of data.

4.2.5 Sonodiver/NUC

(U) Sonodiver is limited to one depth per dive and would require a minimum of two dives in order to compare noise signal levels with other systems used during IOMED.

TRACOR 50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(U) NUC reports that the stability of the Sonodiver recorder is adequate for 1 Hz data resolution, however, figures of wow, flutter and speed stability were not available.

4.2.6 Recommended Action

(U) TRACOR submits the following action items which consider time constraints established by IOMED present schedules.

(a) Eliminate chain and swivels from all systems where possible.

(b) NRL should reassess the contribution of RG-58/U to the ambient noise recordings of ANB and replace with an electrically balanced cable if found to be appreciable.

(c) Acoustic bottom loss experiments are recommended , using explosive sources and receivers at sites Bravo and Charlie. Impulse response can be computed for different angles of incidence. At a minimum, the experiment should consider angles of 20 and 45 degrees.[2]

(d) Request measurements of wow, flutter and speed stability for all magnetic tape recorders used for IOMED.

[2] Hastrup, O.F., JASA, "Digital Analysis of Acoustic Reflectivity in the Tyrrhenian Abyssal Plain".

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(e) Request sensitivity calibration for all hydrophones at pressures equal to the scheduled installation depth.

(f) If AXB systems are to be used for future experiments, request direct recordings on 1/2 inch tape, thus eliminating the necessity for re-cording.

(g) All systems should use high quality tapes; TRACOR recommends Ampex 771, Ampex 761 or equivalent.

(h) Each organization should provide adequate mechanical and magnetic protection for all analog recording tapes before and after IOMED Exercise.

(i) All tape heads should be checked for alignment and wear prior to IOMED.

(j) Use only virgin tapes for IOMED; erased tapes should not be considered.

4.3 Participating Organizations Processing and Analysis

(U) Table 4.2 briefly summarizes the data processing

SYSTEM [illegible]	COGNIZANT LABORATORY	HYDROPHONE DEPTHS FT.	LENGTH OF DEPLOYMENT AND STATION	RECORDING DATA AND STABILITY
[illegible] Subsurface moored buoy [illegible] 2500 Hz	NUSC	200', 450', 700', 1000', 2000'	9 days at Station B 25 sec. sample from each hydrophone every 30 min.	1 7/8"/sec., 7 track tape 3600' reel 1/2" tape Stated to be adequate for 5 Hz resoluti[illegible] spectral analysis
[illegible]BOOMY Free diving vehicle [illegible] Hz	NUSC	Selectable 5 depths/dive	various points 20 minute sample at each depth	1 7/8"/sec., 7 track 1/2" tape Not obtained
VERTICAL TASS Vertically suspended from surface ship	NUSC	Various depths to 7000 ft.	Current plans not firm. Simultaneous recordings of individual hydrophone outputs	Not specified high quality multi-track instrumentati[illegible] recorder Not known
ARB Subsurface moored buoy 0-300 Hz	NRL	4 to be deployed, 2 hydrophones per system. Station B: ARB1, 2000', 6500' ARB2, 4200', Bottom Station C: ARB3',450', 6500' ARB4', 4200', Bottom	7 days at B and C Continuous recording	30/160"/sec. 4 track, 1/4" tape ± 1 Hz RMS
[illegible]ODIVER Free diving vehicle [illegible] 5000 Hz	RUC	Selectable 1 depth per dive	various points 20 minute sample at selected depth	3 3/4"/sec. 7 track 1/2" tape Not obtained but stated to be adequate for 1 Hz resolution spectra analysis
ACODAC Subsurface moored buoy 15-300 Hz	WHOI	7 hydrophones per system ACODAC-A: 90', 450', 4000', 4200', 6500', Bottom	2 systems at Station A for 17 days 7 minute sample each 14 minutes a [illegible]	15/160"/sec. 7 tracks + time code edg[illegible] track, 7200' reel 1/2" tape Not obtained

	LENGTH OF DEPLOYMENT AND STATION	RECORDING DATA AND STABILITY	DYNAMIC RANGE	REMARKS
',	9 days at Station B 25 sec. sample from each hydrophone every 30 min.	1 7/8"/sec., 7 track tape, 3600' reel 1/2" tape Stated to be adequate for 5 Hz resolution spectral analysis	30 dB at 10 Hz	Calibration and time code included in sample of Ambient noise. Fixed gain on hydrophones.
ive	various points 20 minute sample at each depth	1 7/8"/sec., 7 track 1/2" tape Not obtained	30 dB at 10 Hz	Two hydrophones 1 fixed gain 1 variable gain in 3 steps, also records rate of descent, depth and time code.
dio .	Cases & plans not firm. Simultaneous recordings of individual hydrophone outputs	Not specified high quality multi-track instrumentation recorder Not known	Not known	Current plans uncertain as to deployment during TOMED.
- s . ', ', , 0',	7 days at B and C Continuous recording	30/160"/sec. 4 track, 1/4" tape ± 1 Hz RMS	34-35 dB	Current strings also deployed at each ANB site to measure currents at depths hydrophones.
	various points 20 minute sample at selected depth	3 3/4"/sec. 7 track 1/2" tape Not obtained but stated to be adequate for 1 Hz resolution spectra analysis	30 dB	System also includes a [illegible] phone sus[illegible] from spa[illegible] used to m[illegible] noise fie[illegible] sonodiver [illegible] water.
ones n ,00',	2 systems at Station A for 17 days 7 minute sample each 14 minutes a 1 minute	15/160"/sec. 7 tracks + time code edge track, 7200' reel 1/2" tape Not obtained	27 dB per attenuation step, 3 steps available	Gain settings (3) automatically selected to keep record level within range of tape. Hydrophone dynamic range about 80 dB. In-situ calibration every 6 hours

2

			hydrophone every 30 min.	[illegible] adequate fo 5 Hz resolu spectral analysis
[illegible] Free diving vehicle [illegible] Hz	[illegible]SC	Selectable 5 depths/dive	various points 20 minute sample at each depth	1 7/8"/sec. 7 track 1/2" tape Not obtaine
V[illegible] TASS [illegible]ically [illegible]ed from [illegible] ship	[illegible]SC	Various depths to 7000 ft.	Current plans not firm. Simultaneous recordings of individual hydrophone outputs	Not specif high qualit multi-track instrumenta recorder Not known
[illegible]RB Subsurface moored buoy [illegible]-300 Hz	[illegible]	4 to be deployed, 2 hydrophones per system. Station B: AR[illegible], 2000', 6500' AR62, 4200', Bottom Station C: AR63',450', 6500' AR64', 4200', Bottom	7 days at B and C Continuous recording	30/160"/sec 4 track, 1/4" tape ± 1 Hz RMS
[illegible]ORDIVER Free diving vehicle [illegible]-5000 Hz	NUC	Selectable 1 depth per dive	various points 20 minute sample at selected depth	3 3/4"/sec. 7 track 1/2" tape Not obtaine but stated be adequate for 1 Hz resolution spectra analysis
ACODAC Subsurface moored buoy 15-300 Hz	WHOI	7 hydrophones per system ACODAC-A: 90', 450', 4000', 4200', 6500', Bottom ACODAC-B: 3600', 3800', 4000', 4200', 4400', 4600', 4800'	2 systems at Station A for 17 days 7 minute sample each 14 minutes a 1 minute sample each 15 minutes	15/160"/sec 7 tracks + time code track, 7200 reel 1/2" tape Not obtain

TABLE 4-1 SUMMARY OF MEASUREMENT Systems to be used in IOMED

		spectral analysis		
ble s/dive	various points 20 minute sample at each depth	1 7/8"/sec., 7 track 1/2" tape Not obtained	30 dB at 10 Hz	Two hydrophones 1 fixed gain 1 variable gain in 3 steps, also records rate of descent, depth and time code.
depths ft.	Current plans not firm. Simultaneous recordings of individual hydrophone outputs	Not specified high quality multi-track instrumentation recorder Not known	Not known	Current plans uncertain as to deployment during IOMED.
de- 2 ones tem. B: 000', 200', C: 50', 4200',	7 days at B and C Continuous recording	30/160"/sec. 4 track, 1/4" tape ± 1 Hz RMS	34-35 dB	Current strings also deployed at each ANB site to measure currents at depths hydrophones.
ble e	various points 20 minute sample at selected depth	3 3/4"/sec. 7 track 1/2" tape Not obtained but stated to be adequate for 1 Hz resolution spectra analysis	30 dB	System also includes a hydrophone suspended from spar bouy - used to monitor noise field while sonodiver is in water.
phones tem A: 0', 4200', B: 3800', 4200', 4600',	2 systems at Station A for 17 days 7 minute sample each 14 minutes a 1 minute sample each 15 minutes	15/16"/sec. 7 tracks + time code edge track, 7200' reel 1/2" tape Not obtained	27 dB per attenuation step, 3 steps available	Gain settings (3) automatically selected to keep record level within range of tape. Hydrophone dynamic range about 80 dB. In-situ calibration every 6 hours

TABLE 4-1 SUMMARY OF MEASUREMENT Systems to be used in IOMED

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and analysis plans of each of the laboratories (with the exception of NADC) involved in the IOMED exercise. In the cases where plans are not shown, indications were given TRACOR that the analytic efforts were either not sufficiently defined or that key personnel with definite knowledge of the plans were unavailable. In general, each laboratory has been made responsible for processing and analyzing only that data which will be collected by the systems deployed by that laboratory. Central control of all analysis has apparently been limited to broad guidance on the goals of the exercise and specification of the general formats in which the preliminary data is to be reported. As might be expected, there are considerable differences in the data processing techniques to be used, and more important, in the aspects of the acoustic environment which have been chosen for analysis by each laboratory.

(U) This approach, while making use of the considerable facilities and expertise existing in the laboratories to produce, in some cases, well planned individual analytic efforts, has several disadvantages which may seriously degrade the usefulness of the data for LRAPP. These include:

(C) (a) There is no apparent effort to develop a comprehensive description of the acoustic environment in the Ionian Sea by combining results from the individual measurements in IOMED with previous data. We feel that this description, in summary form, is most urgently needed by LRAPP for support of ITASS and MSS.

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(U) (b) The measurements will not necessarily be analyzed in ways which fulfill specific needs of LRAPP. In particular, the analytic parameters and reporting formats do not stress applicability of the results to the problems of surveillance systems.

(C) (c) The efforts planned (and funded) will not provide all data that could be extracted for use in development and validation of models of the acoustic environment. For example, among other items, the very important analysis of shipping effects is lacking, and an analysis of the effects of spectral line components in the ambient noise background is needed for future (and current) surveillance systems.

(U) (d) The differences in processing parameters such as sampling and averaging periods, frequency bands, regression parameters, etc., will make the task of melding the results of individual analyses into a comprehensive description of the acoustic environment very difficult to achieve. In addition, evaluating the effectiveness of the various ocean measurement techniques will be nearly impossible to accomplish in a meaningful, objective manner.

(U) (e) The reporting schedules vary considerably among the laboratories. This fragmented availability of the data will compound the difficulties of any additional analyses or interpretation of the data which might be required for system applications in the near future.

(U) These disadvantages result primarily from the lack of central control for the processing and analysis of IOMED data. In general terms, an analysis plan of this nature should contain the LRAPP requirements for data specified in detail. In addition, the plan should specify, where possible, standard processing parameters as well as reporting formats to insure compatibility among the results. Ease of application of the results to surveillance systems problems should be stressed in developing these standards. LRAPP has the responsibility and should initiate schedules and assignments for tasking the various participants to conduct well defined portions of the analysis. Finally, only LRAPP should be responsible for assimilating the results from the participants and developing a series of reports in a timely fashion to meet the various ASW system data requirement milestones.

(U) At this late date, we feel that any immediate reorganization or re-direction of the participants' efforts in post-exercise data analysis will very likely result in further delays in achieving the desired results.

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(U) We suggest, therefore, that no further data processing and analysis tasks be assigned to any of the participants until an overall plan for this work has been developed and close, centralized control of all efforts established. Additional discussion relative to these points are presented in Section 5.0.

4.3.1 Discussion of Laboratory Processing

(C) The most comprehensive analysis of all data to be collected during IOMED appears to be that of WHOI. These data relate only to ambient noise exclusive of propagation however. The statistical analysis of the data includes many higher moment parameters including variance,skewness and kurtosis. These parameters are useful for a quick assessment of the possible normality of the noise distribution from which samples were taken. The data is also useful in determining departures from specific data distributions which are presently known. The usefulness, therefore, of these statistics is limited and not really significant in terms of MSS requirements. If ambient noise is to have utility toward the solution of problems in the design of MSS, analysis must treat not only stationary random distributions but more important, nonstationary random and non-random noise fields. Classical statistical analysis will not provide an appropriate assessment of the data. One can arbitrarily treat shipping noise as a stationary random or non-random phenomenon for short time periods. MSS must have the capability of effective surveillance on a continuous base, the noise fields which will not be stationary.

ORGANIZATION and SYSTEM	INITIAL ON-BOARD PROCESSING	POST EXERCISE PROCESSING
[illegible]	1/3 octave filtering and strip chart recordings for quick-look assessment of experiment. Also plot selected lofargrams.	Digitize and format data Derive average spectral density Plot band levels vs. time and depth Propagation loss vs. range and depth Statistical analysis Auto-correlation for each hydrophone Correlations in levels and wind speeds
[illegible]	Recording of individual hydrophones	A/D conversion Beamforming via cross correlations among hydrophones, derive beam output levels versus frequency, direction and depth. Plot contour plots of above.
[illegible]	1/3 octave filtering, A/D conversion, digital tape recording and plotting	On-board during return transit: Statistical Analysis - mean level, standard deviation, other moments, test for normal distribution, plot histograms. Laboratory processing not specified - possibly narrow band analysis.
[illegible]	1/3 octave filtering A/D conversion, plotting and recording on digital paper tape	Not definite at time of contact with NRL. Some consideration being given to narrow band analysis, other analysis similar to that by WHOI.
[illegible]	1/3 octave filtering plotting on strip chart recorder	Not specified

(a) [illegible], A.J. "Ambient-Noise Spectrum Levels as a Function of Water Depth" J.Acoust. Soc. Amer. 48, 362-370, (1970)

(b) Arase, E. M., and Arase, T., "Ambient Noise in the Deep and Shallow Ocean" J.Acoust. Soc. Amer. 42, 73-77, (1967)

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TABLE 4-2 BRIEF SUMMARY OF PROCESSING PLANNED BY IOMED PARTICIPANTS

POST EXERCISE PROCESSING	ANALYSIS CURRENTLY PLANNED
Digitize and format data Derive average spectral density Plot band levels vs. time and depth Propagation loss vs. range and depth Statistical analysis Auto-correlation for each hydrophone Correlations in levels and wind speeds	1. Propagation loss vs. range with depth. 2. Ambient noise dependence on depth and windspeed. 3. Periodicity of ambient noise via auto-correlations. 4. Ambient noise statistics. (Standard deviations) Analysis is extension of Perrones' (a) work.
A/D conversion Beamforming via cross correlations among hydrophones, derive beam output levels versus frequency, direction and depth. Plot contour plots of above.	Plans are indefinite. Decision to deploy during IOMED not definite. Most likely analysis will be vertical directivity versus depth and frequency associations with surface conditions and shipping distribution.
On-board during return transit: Statistical Analysis - mean level, standard deviation, other moments, test for normal distribution, plot histograms. Laboratory processing not specified - possibly narrow band analysis.	(b) Said to be extension of Arase paper, ambient noise dependence on wind speed and depth, ambient noise statistics.
Not definite at time of contact with NRL. Some consideration being given to narrow band analysis, other analysis similar to that by SACLANTCEN.	Ambient noise, 1/3 octave band levels versus time at each depth. 24 hour histograms for each band and depth
Not specified	Ambient noise level versus time at each depth measured. Average spectral density Comparison with measurements by suspended systems.

TABLE 4-2 BRIEF SUMMARY OF PROCESSING PLANNED BY IOMED PARTICIPANTS

2

(C) All participants plan 1/3-octave analysis at present. The evils of calculating spectrum levels for 1 Hz bands are well known but is the basis for most published ambient noise data. MSS will ultimately require 1 Hz analysis which must be a minimum LRAPP objective for data processing of ambient noise.

5.0 RECOMMENDED LRAPP POST-EXERCISE DATA PROCESSING AND ANALYSIS

5.1 Data Management

(U) As illustrated in Section 4-3, currently planned analyses of the IOMED data are considerably less than optimum due to the lack of an overall plan which defines and controls these efforts Development of such a plan is urgently required but more important to the longer range success of LRAPP, there is the need to develop the capbility for such planning within the LRAP Program. We recommend, therefore, that the LRAP Program Office acquire the capability for detailed technical planning and control of all data processing and analysis required for support of LRAPP.

(U) This capability should be established by the addition of the necessary personnel to the staff of the LRAPP director or by obtaining the services of a contractor. It is reasonable to expect that this capability could be provided by two or three well qualified individuals. Aside from relative costs, the primary considerations in establishing this capability are that the personnel assigned be fully qualified and that they be solely responsible to LRAPP. The general qualifications required, include the analytical ability to assess the continuing information needs of Navy surveillance projects and to specify, in detail, each processing and analytic effort required to fulfill specific needs as they are identified. Sole responsibility to LRAPP is necessary so that these data managers can objectively assess and recommend tasking, with realistic time and cost estimates.

(U) Planning the detailed analysis of the IOMED data will be the first task of this group. Their approach should be as follows:

(a) Determine the detailed data requirements of the modeling and system development activities supported by LRAPP.

(b) Assess the measurements made during IOMED for applicability to these requirements. Also determine, any other sources of data which might be applicable.

(c) Define the individual analytic efforts required to extract the desired information from the measurements or other sources. Detailed specification of processing parameters and reporting formats should be included in this definition. Trade-offs between the extent of the analysis, data requirements and time/cost requirements should also be performed by the data managers to assure that the requirements are met within realistic time and cost constraints.

50 EVERGREEN PLACE / EAST ORANGE, NEW JERSEY 07018

(d) Develop detailed task assignments for performance of the analysis, and recommend placement of the task to the best qualified laboratory or contractor.

(e) Supplement the results of individual analyses with the results of similar work done within other programs such as the Integrated Mediterranean Plan (IMP).

(U) This approach is also the general method that should be followed by the data management team throughout the life of LRAPP. We believe that centralized technical control of this type is absolutely necessary to the success of LRAPP and that immediate development of this capability is indicated.

5.2 Near Term Data Program

(C) In the near term period, IOMED data analysis must develop meaningful information design to support the early data requirements of the ITASS and MSS projects and must be accomplished within the time frame identified. Based on current acitivities in these projects, the data will be needed by the end of the first quarter of 1972.

(U) We believe that these initial data requirements can best be fulfilled with a descriptive summary of the acoustic environment in the Ionian Sea. This summary should be drawn from IOMED data as well as all other available measurements in the area. The intent of this summary will be to provide data which can be used in proposal evaluations and during the early stages of system development where the initial design choices are based on worst-case estimates. We believe that the most cost-effective way to fulfill these initial requirements is to present a representative summary of measurements in the Ionian Sea with less than a comprehensive analysis of the measurements.

(U) The work required to devise this summary is discussed in the following paragraphs. We feel that this work can be accomplished concurrently with the planning recommended in Section 5.1, and since the need for this information is urgent, we recommend that it be started as soon as possible. We further recommend that this work be done by a qualified contractor rather than one of the laboratories participating in IOMED so that the initial stages of the work can be done concurrently with IOMED without disrupting other aspects of the exercise.

(U) The general approach that should be followed in developing this descriptive summary is as follows:

(a) Obtain IOMED data in the form of raw or minimally processed analog tapes from each participant. Obtain environmental measurements and surveillance data in tabular or graphical forms.

It is recommended that the responsibility for all environmental data collection, reduction and presentation be assigned to NAVOCEANO. A quick summary of these data should be compiled within the first two weeks of January 1972. Formal presentation should be available no later than mid February. The early date should be used for preliminary propagation model runs based on actual environmental measurements exclusive of bottom loss measurements. These predictions should then be compared with propagation measurements collected by MABS and reduced by NUSC. An early evaluation of the capability of new Navy models to accurately predict propagation is desirable. Actual bottom loss measurements should be used for a second propagation model run to determine the degree of accuracy improvement.

(b) Obtain data from other measurements in tabular form.[3]

(c) Using appropriate A/D conversion, other I/O equipment, and a digital computer; categorize these data, process and plot the results.

[3] For example, Urick, R.J., and Bradley, D.L., "A Compilation of Ambient Noise Measurements in the Mediterranean Sea," NOLTR 70-191, 16 Sept 70, Confidential, have tabulated results from several pertinent experiments in the Ionian Sea.

(d) Publish the results in graphical form with sufficient annotation to describe all assumptions.

(U) We recommend three general categories of data to be included in this description. These are (a) Ambient noise, (b) Environmental data including weather, bathymetric and bottom parameters; sound velocity profiles; and propagation loss measurements; and (c) Shipping surveillance data. Although (a) and (c) are, of course, closely related, we feel that the importance of shipping effects in the Ionian Sea requires the emphasis of a separate section.

(C) We also recommend that for presentation of the data, the above categories each be divided into several sub-categories. These include:

(a) Five geographic areas of roughly equal size, having a central area, and four peripheral areas of the Ionian Sea.

(b) Four depth groups for ambient noise and propagation loss measurements, C to 1000 ft., 1000 ft. to 4000 ft., 4000 ft. to 6000 ft., and 6000 ft. to bottom.

(c) Two Seasons - May through October and November through April.

(C) The basic format for presentation of ambient noise should be average spectral level plots giving sound pressure levels in dB (re 10^{-6} Newtons/meter^2) versus frequency on a logarithmic scale within the range 10Hz to 10kHz. Averages for these plots should be derived from all measurements taken within each sub-category defined above. Since the systems used for these measurements vary widely, a common definition for a "measurement" should be developed. We suggest the following:

> For preliminary IOMED data, a "measurement"is defined as the average level in a 1/2 hour sample taken by any of the measurement systems. Where the system takes samples shorter than 1/2 hour, the average of the level during the actual sampling period should be termed a "measurement."

(U) For data other than IOMED, the averaging period for a "measurement" should be that used in reporting the data.

(C) Each curve on these plots will be the average of all "measurements" taken within each sub-category. Percentile points showing 5% and 90% levels (that is, 5% and 90% of the measurements exceeded these levels) should also be shown at the frequency steps of 10, 20, 50, 100, 200, 500, 1000, 2000 Hz. The total number of "measurement" taken at each step should also be shown. Where possible, however, frequency steps for determining the average curves should be to the resolutions, 10 Hz steps from 10 to 500 Hz, 50 Hz steps from 500 Hz to 2500 Hz.

(U) For conciseness, and to illustrate relationships, several curves within each sub-category can be included on each plot if it is done in a logical fashion without degrading the clarity of the plot.

(U) Propagation loss measurements should be shown, within the above sub-categories, as plots of propagation loss versus range. The tracks used for these measurements should be shown on a separate chart of the Ionian Sea.

(U) Environmental data should be divided into the above sub-categories and shown as follows:

<u>Weather and Surface Conditions</u>: Average histograms of wind speeds and sea states.
<u>Sound Velocity Profiles</u>: Average profile plus 10% and 90% limits of measurements - 3 curves per plot.
<u>Bathymetric Data</u>: Track contours with separate chart showing tracks; Bottom loss and reflectivity measurements in tabular form and with indications on chart showing locations/tracks of measurements.

(U) Shipping surveillance data should be shown on charts of the five areas. We suggest three of each - one showing "typical" ship distribution on a particular day; two others showing a near minimum and a near maximum daily situation. These are to be used for illustrative purposes only. Attempting to describe shipping densities statistically is beyond the scope of this initial effort and should be considered as a separate effort. Associated ambient noise curves might also be included with these illustrative charts of shipping. These particular ambient noise curves should show, if possible, fine line spectra in the background noise. To do this, we suggest that they be taken from a single system (Autobuoy or Sonodiver) and at three or four specific depths. The data used should be taken on the same days that the three selected shipping distributions are taken. The averaging period for the data should be no longer than 1/2 hour, and the frequency resolution of the plot should be at least as fine as 5 Hz (1 Hz resolution would be better, but probably not achievable with the recording system being used). As with shipping plots, these curves are for illustrative purposes only. They are needed, however, to give system designers some indication of the ambient noise spectrum when it is highly resolved.

(U) The data processing efforts required to develop this description are rather extensive because of the large volume of data that must be handled and because of the wide variety of formats in which this data will become available. With the exception of IOMED data, this information will be taken largely from tabulated and plotted results of other experiments. In general, this data will be key punched onto IBM cards for entry to the computer. This will present no serious implementation problems beyond those associated with developing and debugging the programs required to organize the data for subsequent processing. These problems are usually straight forward and can be solved by competent programmers.

~~(U) Using IOMED data will require access to and process~~-ing of the raw data tapes from each measurement system. We suggest that the raw tapes be re-recorded onto a standard tape size and type - 1/2", 7 track, high quality instrumentation tape, and at either 7.5"/sec. or 15"/sec. The resulting shift in base frequencies due to speed differences is easily handled in the processing if the recording/playback ratios are known. (These suggestions are, of course, dependent on the flexibility of the equipments available for this work at both the participating laboratory and the contractor chosen for the data processing. Defining standardization of tape sizes and speeds should be done jointly and is one of the early tasks to be undertaken.) The tape playback and recording should be done on the highest quality equipment available.

(U) Once the raw data tapes have been digitized, they can be sampled according to the "measurement" criteria defined above. Combination and categorization of the measurements are relatively straight forward operations as are the tabulation and plotting of the results. Although the exact methods used will vary from contractor to contractor, most who are experienced in this type of data processing will have standard or easily adaptable programs available. This availability of programs should be a major factor in selection of the contractor.

(C) We believe that this summary description of the acoustic environment in the Ionian Sea could be made available by the end of the first quarter of 1972 if the effort to do so is started before October, 1971. Obtaining all data, both from IOMED and from other sources, will require a significant portion of the time allowed for this effort. The fact that much of this data collection can be done before the end of the IOMED exercise justifies an early start in the effort.

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5.3 Far Term Data Program

(C) The far-term data program should be devoted to a fine grain analysis of all aspects of the ambient noise field. The interrelationship between a definition of various sound sources, propagation and the composite ambient noise field must be established. Simply, surveillance systems must detect and classify. The major determinant toward an accomplishment of these objectives will unquestionably center about signal to noise ratios.

(C) TRACOR feels strongly that the success of programs such as MSS will depend on (a) cost, (b) ability to accomplish detection with acceptable false alarm rates, and design features which will reduce the requirement for specialized equipment versions dictated by deployment areas.

(U) The recommended far term program, as stated previously, will require detailed technical management of the data processing and analysis of IOMED and future experiments in order that extraction of the truly pertinent information is realized.

(U) Three major comprehensive analysis activities seem to logically follow:

(a) Assessment of shipping noise and its contribution to the composite noise field.

(b) Characterization of the composite noise field in a manner which will support signal to noise evaluations as a function of detection probability and false alarms.

(c) Additional model evaluations for validation and/or improvement in the prediction of composite noise field.

(U) Until models have demonstrated a prediction accuracy which meets the data requirements with high confidence, system designers must rely on engineering trade-offs of the information generated within (a) and (b).

(U) These long-range programs should start during the near-term reduction of IOMED data and should first emphasize noise field trends and their variability. This information is of particular importance to the surveillance system designer.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

The Long Range Acoustic Propagation Project (LRAPP) includes within its charter the requirement to provide acoustic predictions in support of design concept formulation, system development and operational aspects of passive sonar surveillance systems for the U.S. Navy. In meeting this responsibility, LRAPP has initiated a program including a series of environmental acoustic experiments to be conducted in the Atlantic Ocean and adjacent waters during FY 72 and FY 73. These experiments are intended to furnish information which is urgently needed for the engineering support of existing ASW system developments. (FOUO)

Specific recommendations are presented for (a) the improvement of the exercise planning; (b) identification of equipment and data collection problems and solutions therefore; (c) an assessment of the data analysis to be conducted at the conclusion of the exercise; and (d) a program leading to the generation of a data package in support of development programs for surveillance systems. (FOUO)

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T-71-NJ-4508-C	Larsen, H. L., et al.	LRAPP DATA COLLECTION (U)	Tracor, Inc.	710831	AD0517012; ND	U
Unavailable	Anderson, C. G., et al.	ADAPTIVE BEAMFORMING ANALYSIS FOR DIRECTIONALITY USING DATA FROM A VERTICAL ARRAY IN THE MEDITERRANEAN	Naval Undersea Research and Development Center	710901	AD0517696	U
MC PLAN 06	Unavailable	IOMEDEX LRAPP OPERATION ORDER (U)	Maury Center for Ocean Science	710924	ND	U
NRLFR7322	Lawson, W. M.	POSITION-DETERMINING SYSTEM FOR SEA-SPIDER HYDROPHONE ARRAYS	Naval Research Laboratory	711230	ND	U
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