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ACOUSTIC RANGE PREDICTION SYSTEM (ARPS).(U)
OCT 71 R.H ALLEN, K A FAUCHER, R MARUSICH
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ACOUSTIC RANGE PREDICTION SYSTEM (ARPS):

PROJECT SUMMARY – OCTOBER 1971

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PREFACE

This technical note describes the development status of a portable prototype sonar performance prediction system presently under development by Code 506, Naval Undersea Research and Development Center, San Diego. This note is not to be considered as an official NUC report. Its purpose is to be a working document to convey general information for the use of other persons for whom a need exists.

The work described in this technical note has been supported under NAVSHIPS Exploratory Development subproject SF11-111-500, tasks 14867 and 15558.

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ILLUSTRATIONS

ACOUSTIC RANGE PREDICTION SYSTEM (ARPS): PROJECT SUMMARY – OCTOBER 1971

I. INTRODUCTION

A. GENERAL DISCUSSION

This report summarizes on-board sonar performance prediction work being performed at the Naval Undersea Research and Development Center (NUC), and presents a plan for further work. Only summary information has been provided herein because this report is intended primarily as an introductory document. More extensive technical dissertations are presented in several of the references. Project details and status information are available from NUC (Code 506).

B. BACKGROUND

The performance of any sonar unit (e.g., maximum range at which a target can be detected) is strongly influenced by the characteristics of the ocean median. The ocean variables which govern the propagation of acoustic energy are extremely variable in both space and time dimensions, and, therefore, the performance of any sonar usually varies from place to place and hour to hour. The technical concepts used to predict sonar performance are:

1. ascertaining the numerical values of ocean variables for a specific geographic area during a particular time interval;
2. using these data to compute the acoustic transmission properties of the median; and, finally
3. applying this information to calculate sonar performance degradation or enhancement characteristics.

Accurate predictions of sonar performance are extremely difficult to accomplish, particularly in real-time, because of:

1. the large number of variables which must be considered (e.g., temperature, salinity, pressure, ocean depth in the area, sea surface roughness, bottom surface roughness, system maladjustments, etc.)

2. the large range over which most parameters vary and our lack of substantive data

3. the complexity of the computations necessary for processing the oceanographic and system data to attain meaningful results.

Because of these complexities and the general lack of systematic reference data, early work in the field centered on compiling and condensing test results in tabular formats for use by shipboard sonar operators (see reference 10). Extensive scientific research, over the period from the late 1940's to the early 1960's, provided a more complete understanding of acoustic propagation phenomena, and this, in turn, produced more complex methods for sonar performance prediction. Products developed during this period include the Key West TEVDET Method (reference 13) and various Sonar Detection Range Manuals published by the Naval Underwater Sound Laboratory (reference 2). During the 1960's, a variety of mechanical computation aids (slide rules, charts, nomographs, etc.) was introduced in order to simplify and speed up the on-board computation process. TACRAPS (see reference 7) is the most widely used mechanical aid resulting from these developments. Other typical slide rules are discussed in references 17 and 18.

The availability of large-scale, general-purpose digital computers during this decade provided the means to rapidly solve the complete propagation equations which, heretofore, was impractical. Previous methods were based on approximations and simplifications and, therefore, were capable of only limited accuracy and completeness. Two alternate approaches employing digital computers emerged during the period:

1. One approach combined remote oceanographic data collection stations, naval communication networks and large, shore-based computers. The shore-based computer sites use synoptic oceanographic data, both measured data received from field sites and calculated forecasts, to compute performance predictions for various sonar equipment types. The resulting sonar performance predictions are transmitted to fleet users in much the same manner as weather information. The SHARPS method is representative (see references 8 and 9).

2. The second approach sought to provide a self-contained capability on board individual ships by either sharing the use of an installed shipboard computer or by providing a separate small computer. This method has been investigated by NUC, SUBDEVGRU TWO and others. It is the concept discussed in the remainder of this report and is known by the acronym ARPS (Acoustic Range Prediction Systems). For a more complete description and history of various methods and techniques, see reference 12.

C. DEVELOPMENT CONCEPT

The development integrates several on-going research projects and orients the results for fleet application. The development combines currently accepted mathematical models of acoustic processes in the ocean, an extensive oceanographic data base, a library of threat information and modern information processing and storage techniques to provide the basic sonar prediction method. The basic method is then adapted to the specific requirements of the individual platform by considering such items as:

1. sonar equipment complement (existing and planned)
2. ship missions, tactics and scenario
3. combat system compatibility
4. human factors impact (particularly on controls and displays).

Automated on-board sonar performance prediction systems for the fleet are anticipated to fall into two general categories characterized by the implementation method. These are identified as the "stand-alone" approach and the "integrated" approach. The "stand-alone" approach provides a separate means of accomplishing sonar performance predictions and is typified by NUC's ARPS-1 demonstration equipment (see reference 1). It is capable of installation on any ship but is most appropriate for use on older ships which do not have an extensive digital computer capability (e.g., DEs, DDs, CVAs, SSNs, etc.). The "integrated" approach views sonar performance prediction as being an integral element of the ship's combat system and, therefore, is primarily applicable to newer ship designs (e.g., ULMS, DD-963 Class, Advanced High Performance Nuclear Attack Submarine, etc.) which stress functional integration and contain moderate to extensive digital data processing capabilities.

D. SYNOPSIS OF NUC'S WORK

NUC's current work in the field of on-board acoustic range prediction systems was initiated at the 1968 Pacific Oceanographic Command Conference. A requirement evolved from the conference proceedings to review the computer equipment currently on-board SSBNs with the intention of using this equipment for real-time acoustic range prediction. It was hoped that hardware already aboard SSBNs had suitable characteristics and that system commitments would be such as to allow the use of this equipment. Computer programs could be developed as needed, but the expensive and time-consuming hardware development phase would be omitted thus providing on-board acoustic prediction capability within a short time frame. NUC began work on an unfunded basis in FY-69; NAVSHIPS 901 supported a continuation of this work at a two-man level during FY-70. The first task was a survey of all available on-board computer equipment and various range prediction models pertinent to submarine application. Only three computers then in fleet use appeared to have the necessary mechanical features, peripherals, and operational schedule. To gain further insight into the problem, a passive sonar performance prediction model which was already programmed and in use at NUC was modified and reduced in size to run on the AN/UYK-1 computer. The AN/UYK-1 is the computational component of the AN/BRN-3 satellite navigation system on board SSBNs. The resulting computer program with various display options was tested and demonstrated on the mock-up system at the Fleet Training Center at Ford Island, Hawaii. Display options included:

1. a plot of detection range versus own ship's speed
2. tables of propagation loss versus range and probability of detection
3. two-dimensional insonification plots for a given FOM
4. in-layer and across-layer detection ranges for each sonar mode, and
5. a table of depression/elevation (D/E) angle settings for optimum detection in each sonar mode.

No hardware modifications were necessary. Real-time environmental data were entered into the computer via the IBM Selectric typewriter in a conversational process. The computer would type out a question and the operator would type back his response. When all questions had been answered the computer would then proceed with the computation and print out the selected display. All tests were successful and well accepted by Fleet personnel who participated in or observed them (see reference 16). However, a request for additional tests on board an FBM submarine was denied by SP-24, and, therefore, work on the FBM application came to a halt. NAVSHIPS 901 authorized continuation of work through FY-70 under a three phase approach:

1. continue the FBM effort, if possible
2. extend the scope of work to include surface ships and work cooperatively with Fleet vessels using whatever computers might be made available; and
3. develop a separate hardware system to support studies and simulations.

Extending the scope of work to include surface ships caused a major reorientation of the study – active sonar equipment and mathematical models, ASW surface ship tactics and different types of computers became additional topics for investigation. A brief survey of available shipboard computers indicated that a large variety of hardware is available at different times and that many of these were special purpose mil-spec computers. After some initial work, it became clear that programming would be an extremely difficult and prohibitively expensive process unless some standards were defined and adhered to.

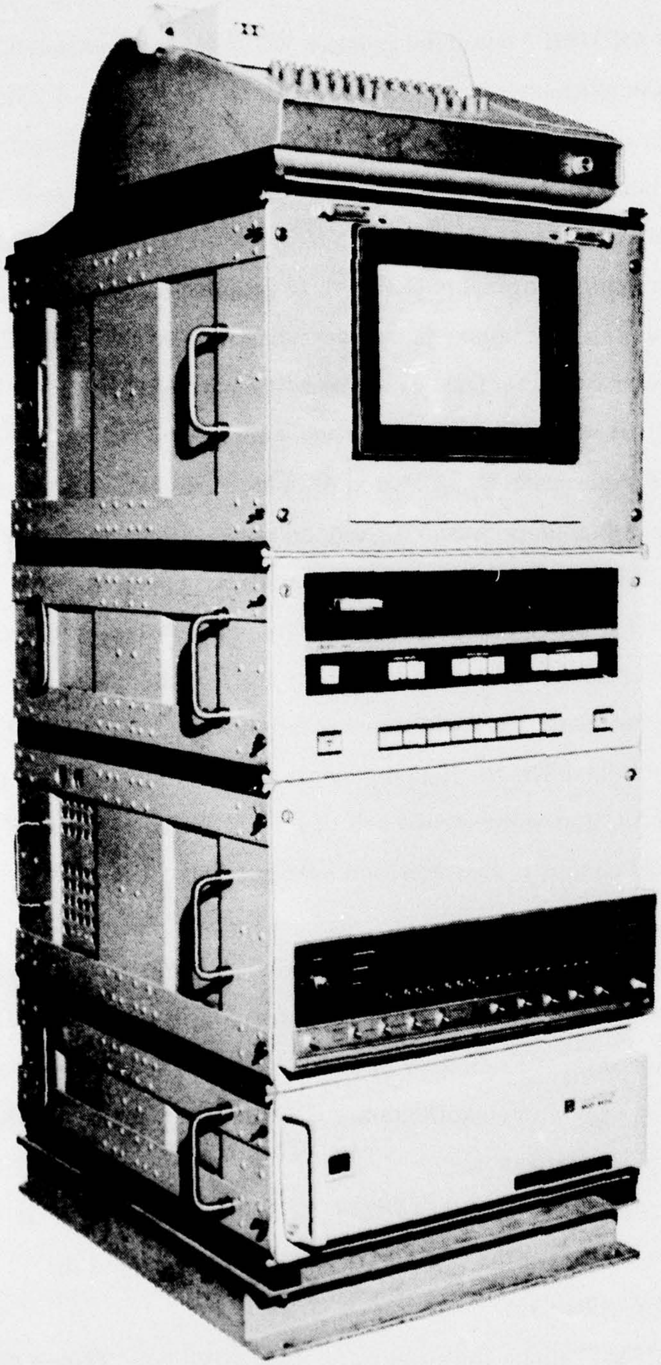
Because of the limited funding, the AN/UYK-1 computer program was developed in machine language rather than a more universal programming language (e.g., FORTRAN). The process of trying to adapt the AN/UYK-1 computer program for use by another computer with different characteristics and, therefore, a different machine language was difficult and time-consuming. Because of the variety of available shipboard computers, this type of translation was expected to be a frequent operation. The technical problems and cost of working primarily in machine language appeared to be prohibitive, and an alternate approach was needed. The basic programming standard that resulted was a requirement for FORTRAN compatibility in candidate shipboard computers. All programs would be written in FORTRAN and thus be capable of implementation on any computer which included a reasonably complete FORTRAN compiler in its software package. Unfortunately, this requirement eliminated most mil-spec shipboard computers from consideration, and the range of potential candidates was drastically reduced – from "too many" to "too few". Work-around tactics were investigated, but no suitable combination was apparent.

The lowest cost development approach – when tests on a wide variety of naval ships were included – was to develop a relatively small, transportable computer system specifically for acoustic range prediction computations. In response to these conclusions, design of ARPS demonstration equipment (ARPS-1) was conducted in the second half of FY-70. Purchase orders for all components were placed by the end of FY-70, and the equipment was received at NUC during the second half of FY-71. System integration, checkout and verification of interim acoustic model computer programs, and initial operator displays were implemented by the end of FY-71.

The ARPS-1 system, shown in figure 1, is an extremely flexible multi-application system designed for developmental work. System components were modularly repackaged off-the-shelf units which can be cabled together in various geometries as required for submarine or surface ship applications. In general, ARPS-1 is a general purpose mini-computer system with great flexibility in input/output options. The hardware specifications are discussed in detail in reference 1.

In early FY-72 (July-August, 1971), ARPS-1 commenced a year of extensive testing with its participation in the SQUEEZE PLAY exercise on board the USS BROWNSON (DD-868), and the UPTIDE exercise on board the USS SCULPIN (SSN-590).

The study program was continued in FY-71 under the auspices of NAVSHIPS 901. During the early part of FY-71, the development of an active sonar model was begun. As in the passive model case, the active model was adapted from a computer program used by NUC for study and simulation of various types of active sonars. Separate passive and active sonar prediction models were written in FORTRAN and debugged using commercial grade time-shared computer terminals (Tymshare Corporation).



Teletypewriter unit Model 33
Teletype

Video Display unit Model 611
Tektronics Video portion of Model
4002 Tektronics

Tape cassetts unit Model 344
Dicom

Multipurpose Switch

General Purpose Computer Model
Nova Data General

Interface, Control and Character
Generator. Portion of Model 4002
Tektronics.

Figure 1. The ARPS System Assembled as a Single Unit by Stacking the Components Vertically

In addition, the passive sonar model together with modified displays and data input routines was compiled on a Hewlett-Packard minicomputer (HP-2115) in order to:

1. identify potential programming problem areas which might be encountered with the Data General minicomputer specified for ARPS-1, and

2. participate in upcoming fleet exercises and tests.

The HP-2115 program (passive sonar model only) was used during the first half of FY-71 to support the PRE-LAMPS Exercise on board the USS TICONDEROGA (CVS-14) and the AN/BQS-13 TECHEVAL on board the USS BERGALL (SSN-677) (see reference 11). The program provided useful data during both at-sea periods and provided considerable experience in programming minicomputers using FORTRAN. Work with the HP-2115 computer program was terminated prior to receipt of ARPS-1.

Near the end of FY-71, authorization to procure major components for another demonstration system (ARPS-2) was received. ARPS-2 will be used to support computer program development work at NUC. If need be, ARPS-2 can be cannabilized for long-lead items should such components fail in ARPS-1 (Note: Very few spare parts have been purchased for ARPS-1 support).

II. WORK PLAN

A. GENERAL

The scope of work required to develop and implement ARPS concepts is interrelated with several other Navy RDT&E programs. The work structure contained herein reflects these relationships by segregrating tasks into technical study and product categories. Technical study tasks pertain to mathematical analyses, computational processes and input data which are necessary regardless of the specific user. These study tasks are principally centered on oceanographic data and the processing and modeling thereof. Product tasks are oriented to the particular needs of each major user group and include such activities as: the development of specific sonar equipment models; system integration efforts encompassing mechanical, electrical, thermal and human factors considerations; preparation of equipment specifications; etc.

B. WORK BREAKDOWN STRUCTURE

A project summary work breakdown structure (WBS) is shown in figure 2. Numbers assigned to individual work elements are for identification purposes and indicate the work element level. Several level 4 work elements are included to illustrate the development of specific computer programs. The WBS will be modified and/or expanded to reflect the status of related programs as well as the attainment of project milestones.

C. NEAR TERM OBJECTIVES AND TASKS

Tasks for the near term (FY-72 and early FY-73) center on the test and evaluation of ARPS concepts in an operational environment. Exploratory development work to date has provided:

1. insight and understanding of the total problem and its component parts
2. test hardware suitable for limited at-sea use (commercial grade components used throughout)
3. an interim passive and active sonar simulation model in a computer program, and
4. a tentative approach for software development and system implementation.

The goal for FY-72 is to refine and upgrade the ARPS concept so that engineering development of specific user-related products can commence. In other words, FY-72 is viewed as a period wherein technical risk shall be significantly reduced. The work plan has two major components:

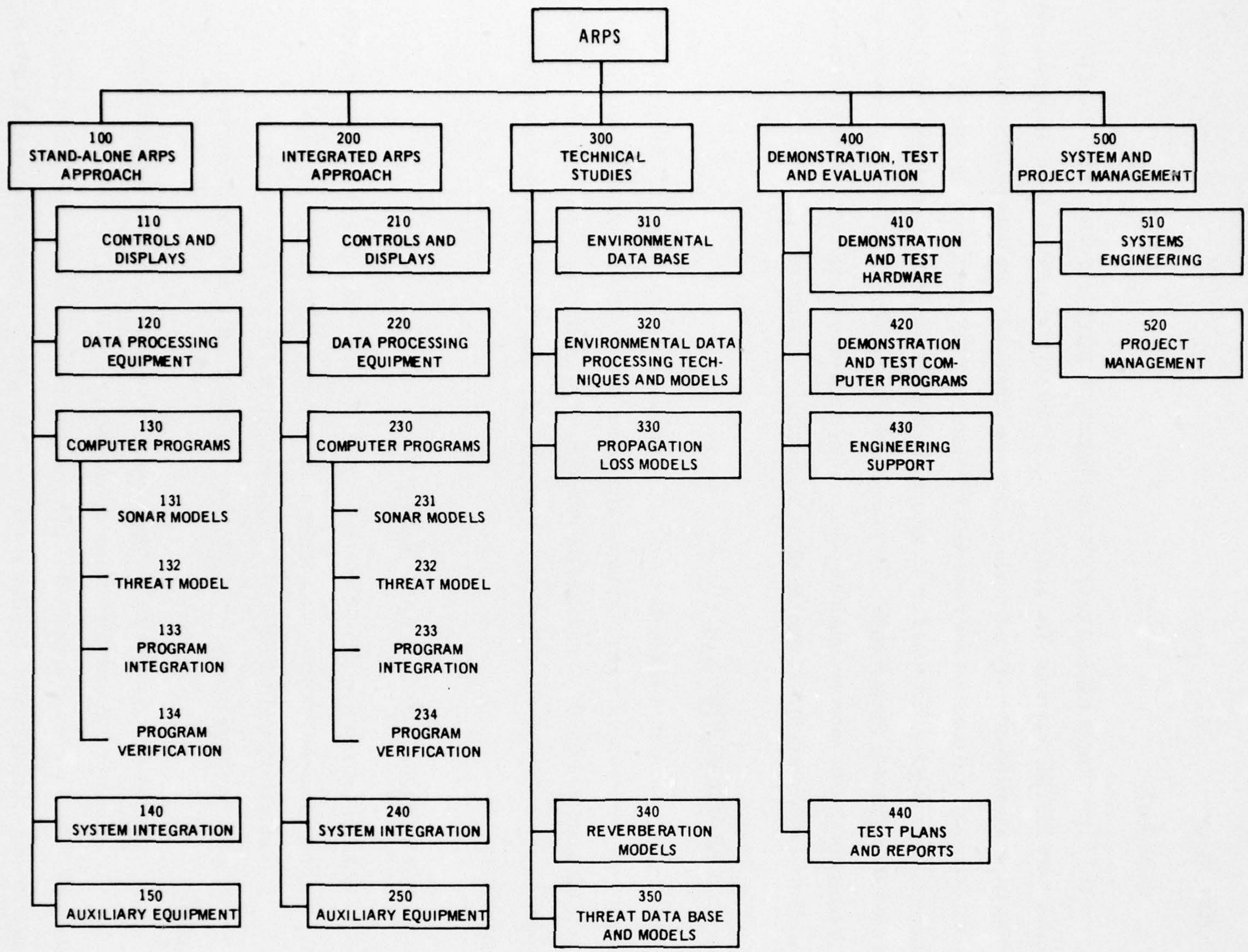


Figure 2. ARPS Work Breakdown Structure

1. demonstration, test and evaluation of ARPS concepts at sea, and

2. continued software development at NUC.

However, a significant reduction of technical risk is attainable only by the concurrent prosecution of both work components.

The scope of work during the at-sea demonstration, test and evaluation of ARPS concepts is to:

1. develop and evaluate basic displays for surface ASW ships and submarines

2. identify and document specific operational requirements and constraints on the design approach imposed by tactical usage within various operating areas in a shipboard environment

3. evaluate the suitability of demonstration hardware for naval use

4. identify and, where feasible, specify critical design and interface characteristics (e.g., size, weight, electrical input power, thermal environment, etc.)

5. evaluate and improve software organization and comprehensiveness

6. demonstrate additional capabilities provided by ARPS and propose improvements to existing operating procedures which utilize ARPS features and capabilities

7. develop and evaluate methods of automating cumbersome functions now performed by sonar operators and ASW personnel.

The ability to incorporate recommendations made by fleet users and evaluate the modifications on a short turn-around cycle is essential to the ARPS development process.

In addition to modifications resulting from the at-sea tests, changes to the system will result from supporting technical studies conducted at NUC and elsewhere. The majority of these changes are expected to deal with data processing techniques and algorithms and, in part, will provide solutions of known problem areas and deficiencies (e.g., overall computation speeds, excessive storage requirements for certain software modules, etc.). Particularly, it is the ernest intent of NUC that all sonar model algorithms and acoustic transmission expressions be those propagated by the Navy "standard models" effort.

Supporting work will also include the collection and organization of data for:

1. validation of system performance

2. specification of physical, electrical and human interfaces, and

3. preparation of required software modules which heretofore have not been developed (e.g., sonar operating control settings and system mode recommendations, threat characteristics, equipment self-test and checkout procedures, etc.).

D. FAR TERM OBJECTIVES

A long-term development plan for on-board sonar performance prediction systems is implicit in the planning information contained herein. The required work is that shown in the project summary WBS; the proposed schedule is illustrated in Section III and discussed in the remainder of this paragraph.

Far term work focuses on engineering development of ARPS systems for specific weapon systems or classes of navy platforms. Work during FY-73 addresses the design and specification of two implementation concepts. These are envisioned as:

1. a "stand-alone" ARPS suitable for use on surface ships equipped with AN/SQS-26 and AN/SQS-35 type sonars, and

2. an "integrated" ARPS suitable for use on various submarine and surface ship platforms.

It is also noted that an exploratory development effort must be concurrently maintained to develop system mode operating criteria and algorithms for various environments.

A separate advanced development model for the "stand-alone" ARPS concept is not believed to be necessary due to the extensive test program and the nature of the system. Therefore, engineering development of a "stand-alone" ARPS will commence in early FY-73 with delivery of the first engineering model targeted for late FY-73 or early FY-74. It is anticipated that approximately five engineering models will be fabricated for technical evaluation. The TECHEVAL is anticipated to be performed in mid FY-74 and would be conducted simultaneously on ships which are widely dispersed geographically. Such a method would minimize the calendar time needed to accomplish TECHEVAL and yet ensure that the equipment was evaluated under a full range of service conditions.

Engineering development of the "integrated" ARPS concept is largely dependent on other navy development programs which require sonar performance prediction capabilities. Inasmuch as the principal products to be developed are system and computer program specifications, the development time requirements are expected to be minimal; interfaces and system compatibility considerations are anticipated as the dominant technical problems. A comprehensive set of specifications, incorporating all pertinent recommendations from the test program and supporting studies, could be available as early as mid FY-73; however, they have been tentatively scheduled for late FY-73 in order to minimize peak demands on engineering resources.

Subsequent tasks encompass the full range of design, development and evaluation work necessary to commence and support the production of operational hardware as well as the continued development and refinement of the basic techniques and methods.

III. SCHEDULE

A. MILESTONES PLAN

A milestone plan for continued ARPS development is presented in figure 3. The plan is constrained by the delivery date for engineering models of the "stand-alone" ARPS concept (early FY-74). To meet this key milestone, advanced development must be completed during FY-72 and engineering design must be completed by mid FY-73. Work elements correspond to those identified in the Work Breakdown Structure.

B. DEMONSTRATION, TEST AND EVALUATION PLAN

The current plan for ARPS-1 demonstration and test activities is given in figure 4.

100 Stand-Alone ARPS (AN/SQS-26 and -35)
Engineering Design and Specifications
Engineering Models Delivered
TECHEVAL

200 Integrated ARPS
Engineering Design and Specifications

300 Technical Studies
- 310 Environmental Data Base
  - 311 Data Base for T & E Computer Program – Mod II
  - 312 Process Specifications – Stand-Alone and Integrated ARPS Concepts
  - 313 TECHEVAL Data Base
- 320 Environmental Data Processing
  - 321 T & E Computer Program – Mod II
  - 322 Process Specifications – Stand-Alone and Integrated ARPS Concepts
  - 323 Design Support
- 330 Propagation Loss Models
  - 331 Process Specifications – Stand-Alone and Integrated ARPS Concepts
  - 332 Design Support
- 340 Reverberation Models
  - 341 Process Specifications – Stand-Alone and Integrated ARPS Concepts
  - 342 Design Support
- 350 Threat Data Base and Models
  - 351 Process Specifications – Stand-Alone and Integrated ARPS Concepts
  - 352 Design Support

400 Demonstration, Test and Evaluation
- 410 Demonstration and Test Hardware
  - 411 ARPS-1 Demonstration, Test and Evaluation
  - 412 ARPS-2 Delivered
- 420 Demonstration and Text Computer Programs
  - 421 T & E Computer Program – Mod II
- 430 Engineering Support
- 440 Test Plans
- 450 Reports

500 System and Project Management
- 510 Systems Engineering
- 520 Project Management

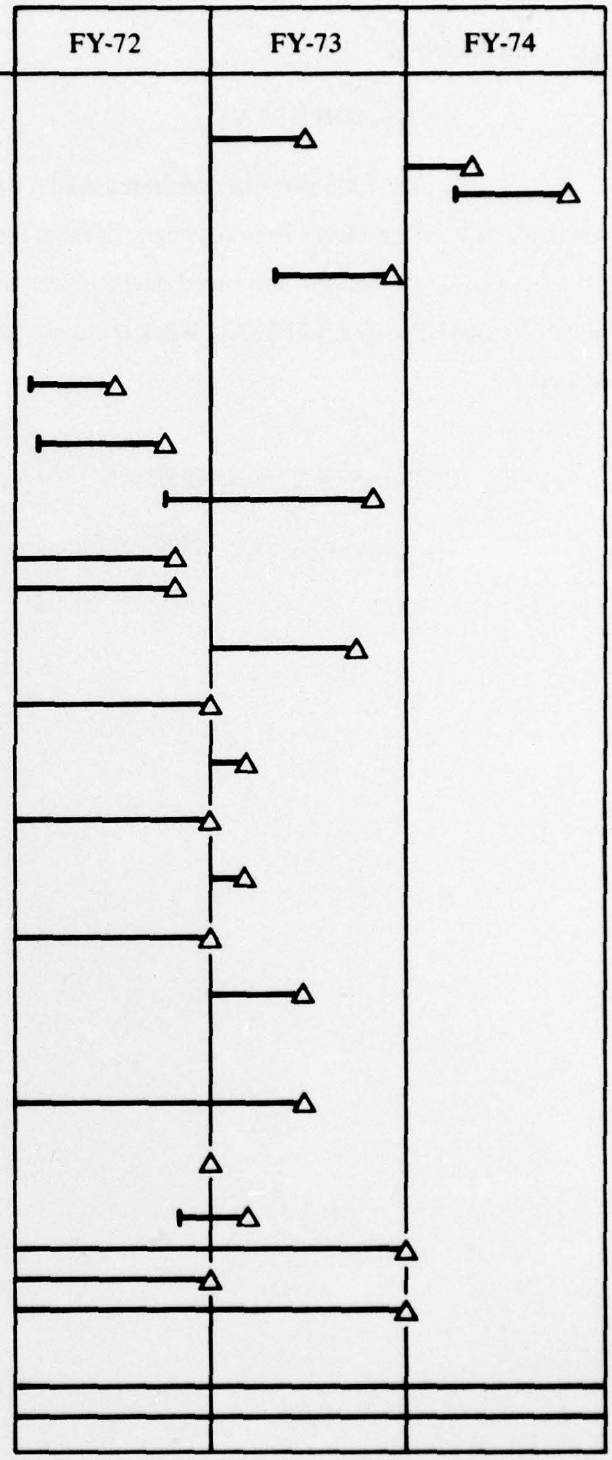
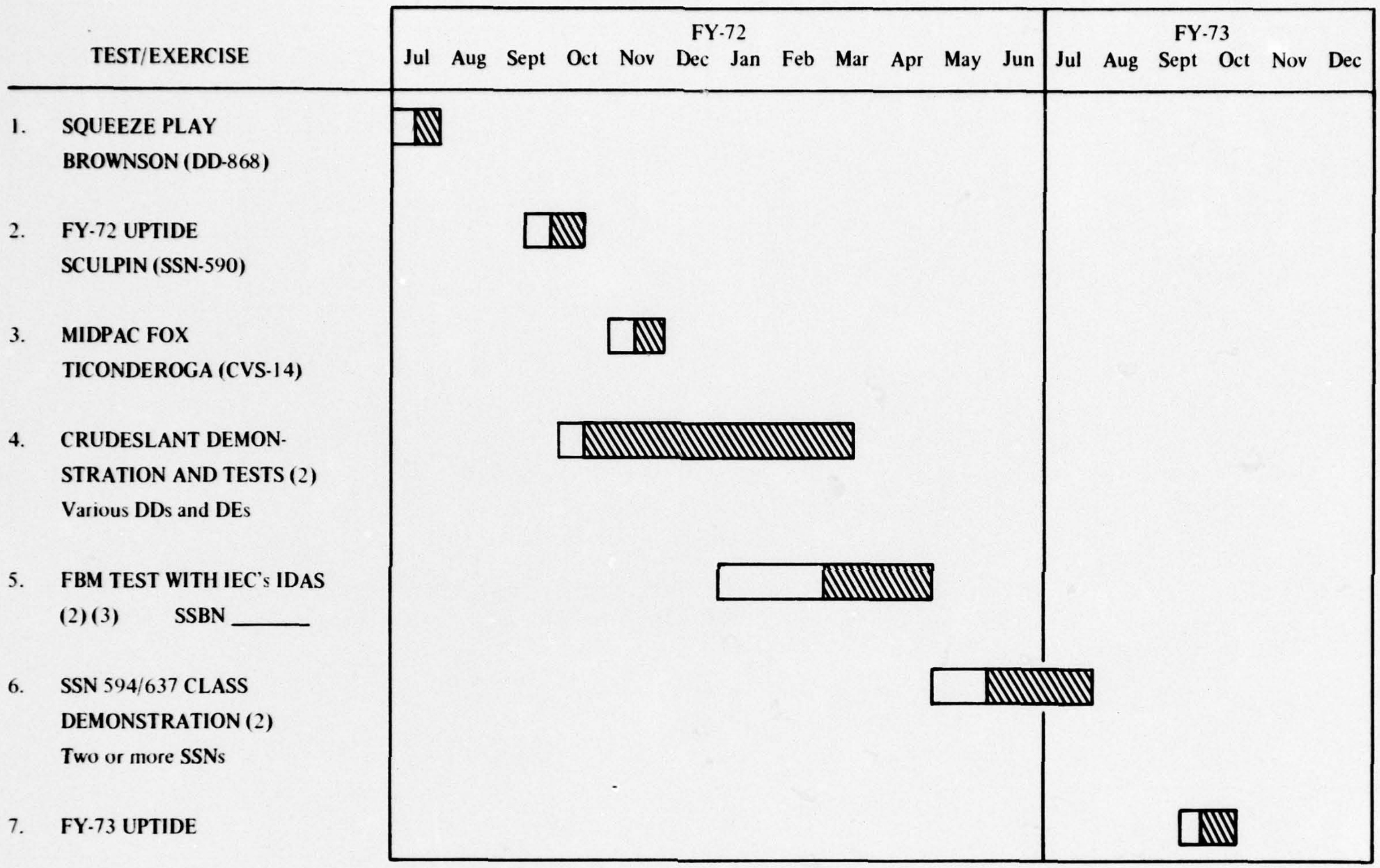


Figure 3. ARPS Milestone Schedule



NOTES:

1. Legend:

   Preparation

   At Sea

2. Tentative test platforms and schedule.

3. ARPS functions may be programmed in IEC's IDAS Computer instead of using ARPS-1.

Figure 4. ARPS-1 Test Schedule

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