NAVORD REPORT 4866

NAVAL ORDNANCE COMPUTATION CENTER
U.S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE

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FOREWORD

This publication announces the addition of the Naval Ordnance Research Calculator (NORC) to the equipment available at the Naval Ordnance Computation Center, at the Naval Proving Ground, Dahlgren, Virginia. It also describes other calculating equipment and services available at that establishment.

For large scientific problems, the NORC with its high speed, large storage capacity, internal checking, and unusual flexibility of operation, greatly exceeds the effectiveness of any other calculator presently in use. Many problems, the calculation of which was impracticable on previous machines because of economic or time considerations, can now be computed.

In addition to the NORC, the Naval Proving Ground operates two other large calculators, the Aiken Relay Calculator (ARC) and the Aiken Dahlgren Electronic Calculator (ADEC).

ABSTRACT

The equipment and capabilities of the Naval Ordnance Computation Center at the U. S. Naval Proving Ground, Dahlgren, Virginia, are described. Suitability of problems to digital computers are discussed, as well as the availability of mathematical and programming services.

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Section 1

COMPUTATION CENTER

GENERAL

The Naval Ordnance Computation Center at the U. S. Naval Proving Ground, Dahlgren, Virginia, has a coding and programming staff which uses high-speed calculators in the solution of various problems which arise in ordnance research and other fields. It also has a technical group which operates, maintains, and improves these calculators and related equipment.

The coding and programming group consists of applied mathematicians, mathematical programmers, and physicists who are responsible for analysis and preparation of problems to be computed by the calculators, and for research aimed at improving mathematical and computing techniques. In addition, they provide consulting services to outside agencies whose problems are being considered for solution at the Computation Center, to determine the feasibility of calculation on digital machines and to assist in analysis and formulation.

Technicians and engineers who operate and maintain the machines are supported by the electronic specialists who pursue a continuing development program aimed at improving component reliability and performance. This work includes studies of computer circuitry using transistors and storage methods such as magnetic core, cathode ray tube, and delay circuits.

Now in operation at the Computation Center are the Aiken Relay Calculator (ARC), the Aiken Dahlgren Electronic Calculator (ADEC), and auxiliary IBM equipment such as card-to-tape converters and printers. The Naval Ordnance Research Calculator (NORC), figure 1, is now in operation at the Computation Center. The NORC is the fastest and most powerful calculator yet developed. Its use will open new areas in the study of guided missiles, aerodynamics, hydrodynamics, high explosives, nuclear physics, and other fields. The ADEC, figure 2, is a somewhat slower machine, especially suited for solution of problems requiring a very large easy-access storage such as preparation of ballistics tables using equations of motion involving all degrees of freedom. The ARC, figure 3, is a relay type calculator with a limited storage. It is satisfactory for computation of particle trajectories, and for less complicated problems than are calculated by the other machines.

Following is a summary of specifications and capabilities of the calculators:

OPERATION TIME[1]:

NORC - 67 microseconds.
ADEC - 7100 microseconds.
ARC - 83,000 microseconds.

[1] Operation time is defined as the average of the time required for two additions plus one multiplication.

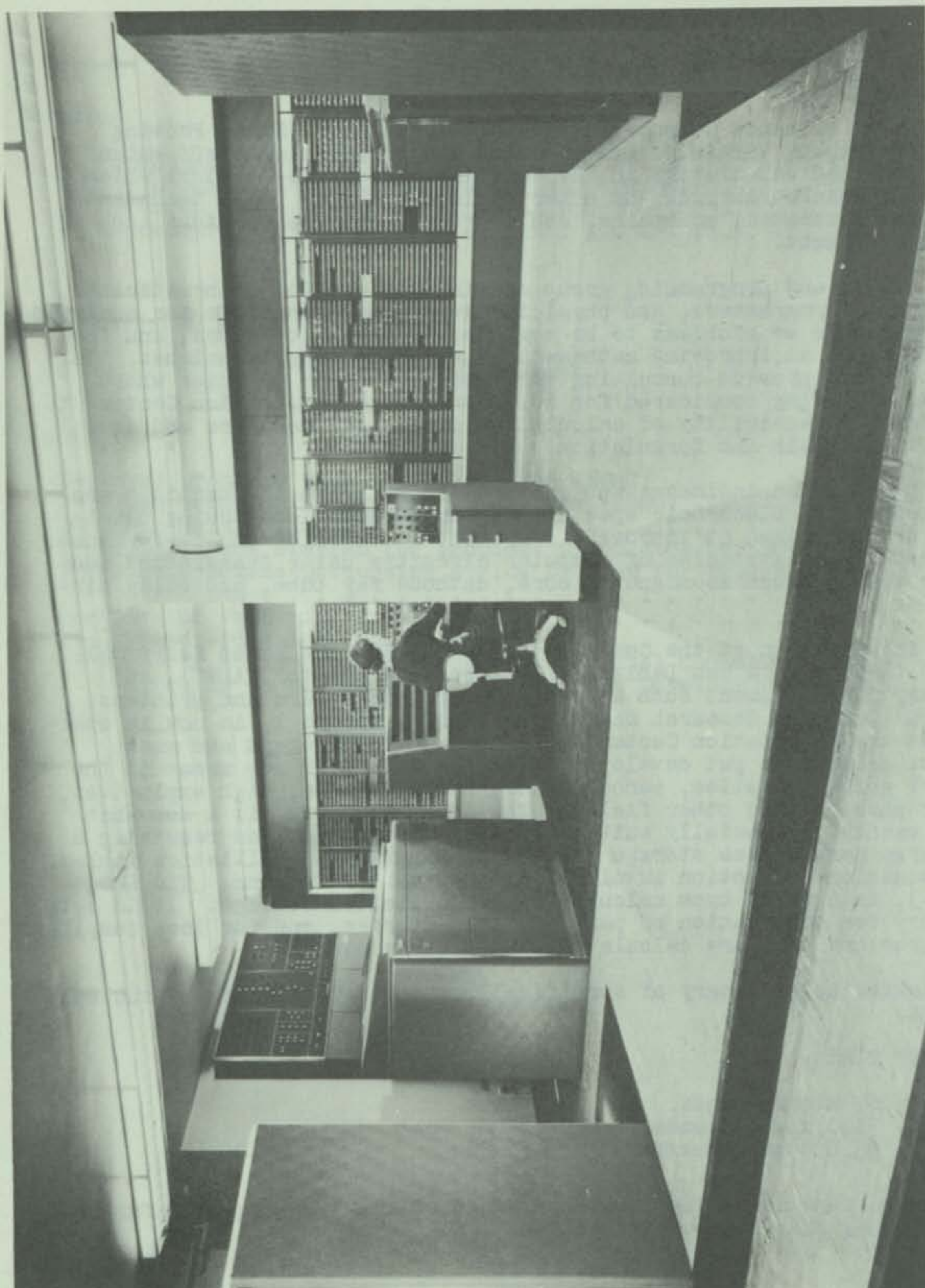

Figure 1—Naval Ordnance Research Calculator (NORC).

Figure 2—Aiken Dahlgren Electronic Calculator (ADEC).

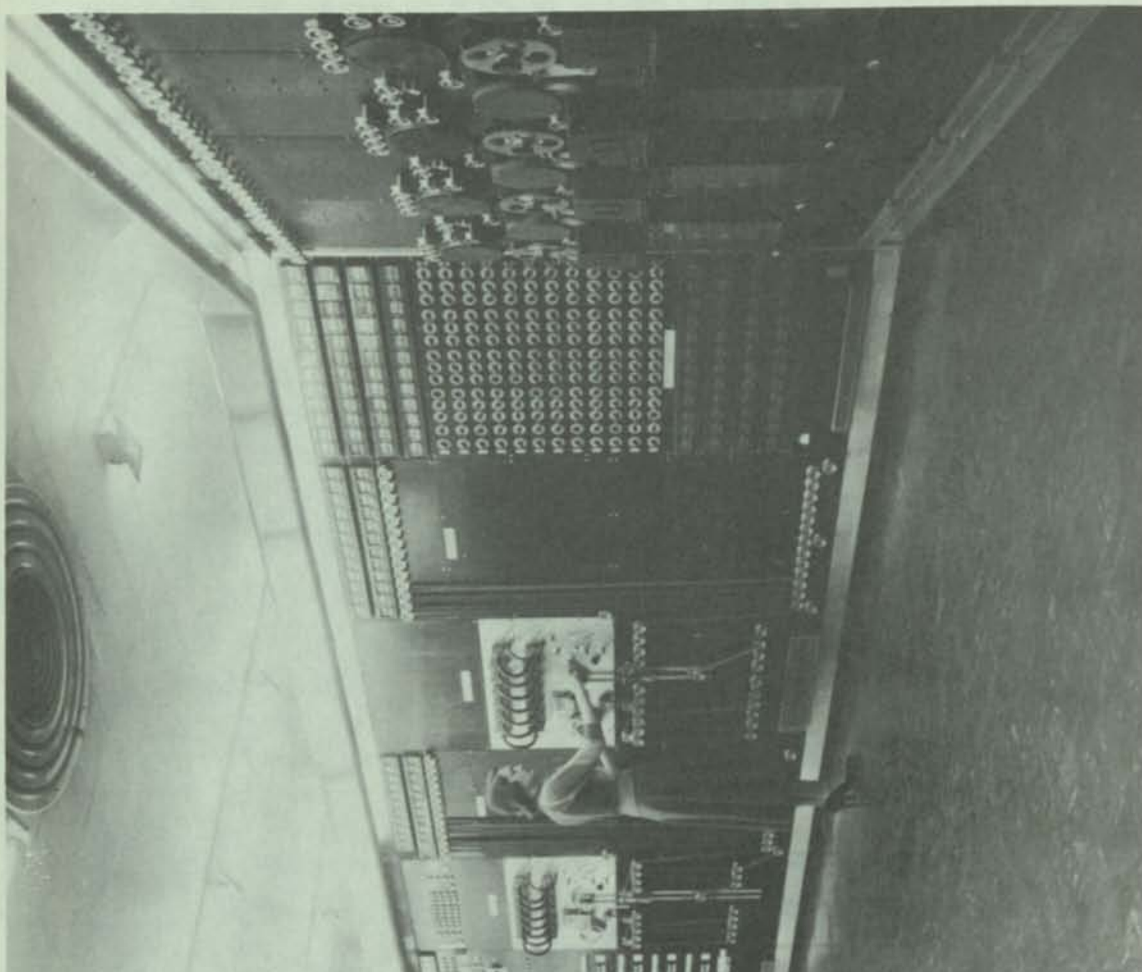

Figure 3—Aiken Relay Calculator (ARC).

NUMBER SYSTEM:

NORC - coded decimal employing 1, 2, 4, 8 representation.
ADEC - coded decimal employing 1, 2, 4, 2* representation[2].
ARC - coded decimal employing 1, 2, 4, 8 representation.

WORD SIZE[3]:

NORC - 16 decimal digits plus a check digit.
ADEC - 16 decimal digits plus sign.
ARC - 10 decimal digits plus exponent and sign.

STORAGE:

NORC - 2000 sixteen-decimal digit words in electrostatic storage. Approximately 3,000,000 words on eight high-speed magnetic tape mechanisms which can read at speeds up to 4000 words per second.
ADEC - 4350 sixteen-decimal digit numbers on magnetic drums. 4000 three-address instructions on magnetic drums.
ARC - 100 ten-decimal digit numbers in relays. Program storage is on punched paper tape.

ARITHMETIC OPERATIONS:

NORC - Floating- or fixed-decimal arithmetic, depending on a code for each operation. Floating arithmetic with 13 significant digits and exponent in the range of -30 to +30.
ADEC - Fixed-decimal arithmetic (sixteen-digit). Decimal may be pre-set at any one of seven locations.
ARC - Floating-decimal arithmetic (10 significant digits) with exponent range of -15 to +15.

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[2] With 2* notation, complement on nines (for subtraction) can be obtained by inversion of the voltages representing each digit.

[3] A "word" is a group of digits representing either a number or an instruction.

INSTRUCTION SYSTEM:

NORC - Three-address instructions in each word. 2000 words of electrostatic storage plus eight high-speed auxiliary magnetic tape mechanisms which may be used for instructions. Addition, subtraction, and shifting may be performed on instruction words. Unlimited program transfers are possible.

ADEC - Three-address instructions; 4000 on magnetic drum. Limited modification of addresses, depending on a computed quantity. Unlimited program transfers are possible.

ARC - Modified, fixed, single address. Instructions are led to the machine on four paper tapes. Limited modifications of addresses, depending on a computed quantity. Program transfers from one tape to another automatically.

INPUT:

NORC - Numbers recorded on magnetic tape can be read into the calculator at an average rate of 2500 numbers per second, using any one of eight tape mechanisms. Also, numbers from IBM cards can be transferred to magnetic tapes on a card-to-tape-to-card (CTC) machine.

ADEC - As many as ten numbers may be set in by manual switches. Also, numbers recorded on magnetic tape may be read into the calculator at an average rate of five numbers per second, using any one of eight tape mechanisms.

ARC - As many as 12 numbers may be set in by manual switches. Also, numbers punched in paper tape may be read into the calculator at the average rate of 1.5 seconds per number on any one of four reading mechanisms.

OUTPUT:

NORC - Two line printers are attached directly to the machine for utility printing. Eight magnetic tape mechanisms record results at the average rate of 2500 numbers per second. The results are then converted to IBM cards for printing on standard IBM equipment.

ADEC - Any one or all of the eight magnetic tape units records the output at the average rate of five numbers per second. These results are then printed, as a separate operation, on one of five electric typewriters, or are transferred to IBM cards by a tape-to-card converter.

ARC - Output is punched on paper tape or is printed directly by four modified teletypewriters. The tapes can be used to record results on IBM cards.

CHECKING FEATURES:

NORC - The arithmetic operations are checked automatically with a modulo-9 check on the operation. Transfers are checked with a bit count modulo-4, complement on 3. Tape operations, print operations, etc., are checked with a bit count modulo-4, complement on 3.

ADEC - Some automatic checking is provided in the sequencing and record system. Other checks are programmed mathematical or identity checks.

ARC - Two independent halves of the calculator automatically compare simultaneous results. See figures 4, 5, 6, 7, and 8.

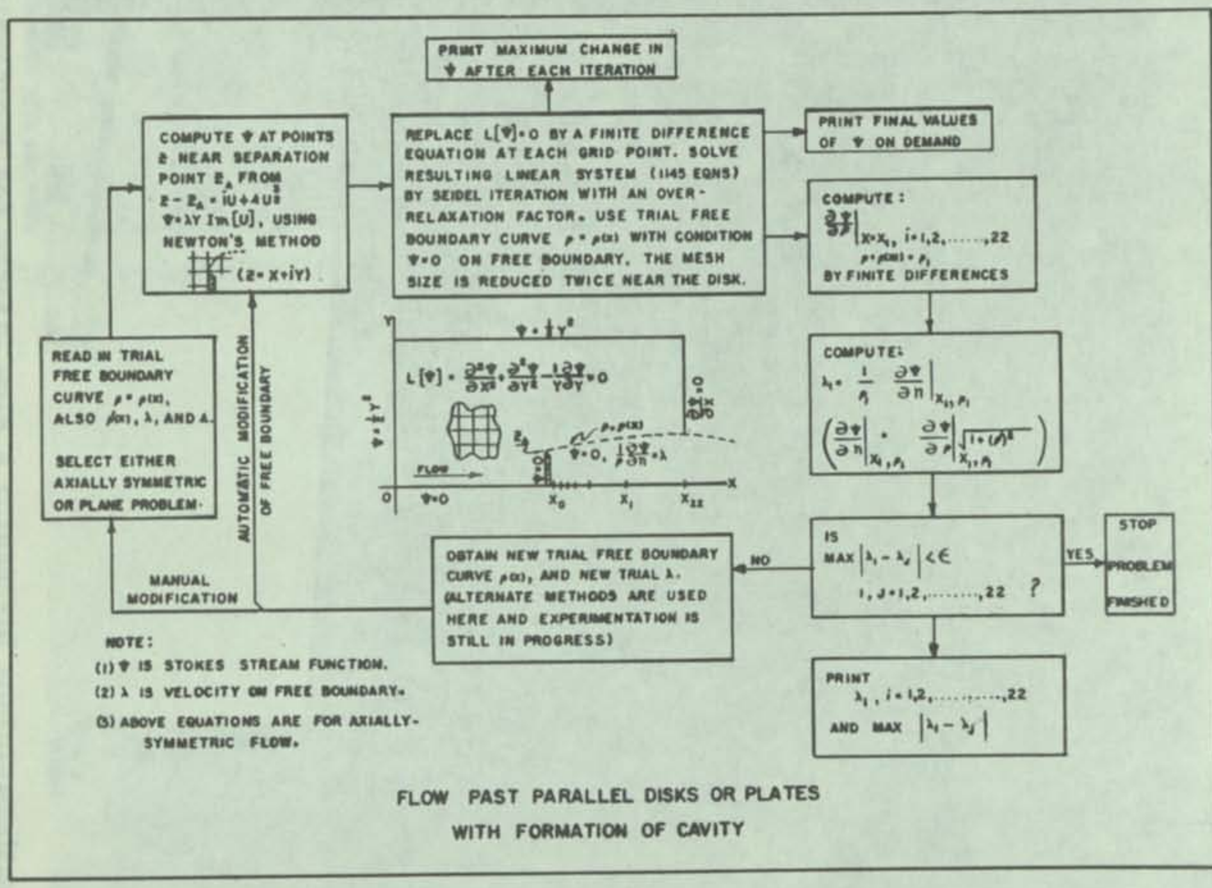

Figure 4—Typical Flow Diagram for Problems Calculated by the NORC.

Figure 5—Mathematicians Discussing a Flow Diagram for Programming a Problem.

Figure 6—Operator Preparing Input Tape for ADEC.

Figure 7—Operator Punching Input Tape for ARC.

Figure 8—Engineer Working on Development of Digital Computing Circuits in Computer Research and Development Branch.

Section 2

PROBLEMS SUITABLE FOR LARGE DIGITAL COMPUTERS

To be suitable for computation on a large scale digital calculator, a problem should call for either a large number of repetitions of a computing cycle, or a large number of manipulations of input data such as one may encounter in the fields of logistics and statistics, with only a relatively small number of arithmetic operations. Problems of the former type ordinarily include a larger number of cases corresponding to a range of parameters, each solvable by the same method. In any case, the problem should be of such magnitude that the use of manual computation is clearly impractical because of the excessive time required. It is essential that the problem should be capable of being broken up into sequences of arithmetical and logical operations. Because of its high speed and large storage capacity, the NORC can handle more complex problems than could be considered for computation on earlier machines.

When questions concerning the feasibility of solving a particular problem on a digital computer arise, it is advisable to discuss them with persons who are familiar with the techniques of numerical analysis and machine operations. Some of the types of problems which are adapted to computation on large-scale digital calculators are:

(a) <u>Evaluation and tabulation of functions defined by mathematical formulas such as integrals, power series, sequences, or recurrence relations.</u>

The results of such computations are normally needed for use in further calculations, and it is ordinarily easier for a machine to compute a function directly than to interpolate in a table of previously computed values. Therefore, machines are being used less frequently for computing tables. In most cases, a machine such as the ARC or ADEC would be adequate.

(b) <u>Solutions of linear and non-linear equations and matrix problems.</u>

Such problems occur frequently in statistics, curve fitting, reduction of experimental data, economics, linear programming, and elsewhere. Matrix eigenvalue problems are important in the study of dynamic systems.

(c) <u>Solutions of systems of ordinary differential equations.</u>

These are used in many engineering and physical problems including particle trajectories, rigid body trajectories, fire control, boundary layer, and many others. Use of the NORC will permit the more accurate solution of initial value, boundary value, and characteristic value problems involving more dependent variables than has been possible previously.

(d) <u>Partial differential equations.</u>

Elliptic partial differential equations have applications to subsonic flow problems which may involve cavities, and to problems in elasticity and steady state heat conduction. Hitherto, the use of machines for these problems has been largely limited to boundary value problems involving Laplace's or Poisson's equation in two independent variables with simple boundaries and a relatively small number of net points. By use of the NORC, it will be possible to obtain greater accuracy by including more net points. Also, one may treat problems with more general differential equations in three independent variables with irregular shaped regions and mixed boundary conditions. The high speed of the NORC will greatly reduce the time necessary to evaluate and compute the numerical procedures.

Parabolic equations are important in transient heat conduction problems involving high explosives and propellants.

Hyperbolic equations occur in the study problems involving supersonic flow and shock waves. These are important in aerodynamics and in the design of missiles and explosives.

(e) Evaluation of integrals by probability methods ("Monte Carlo methods").

Many problems occurring in nuclear physics, operations analysis, and weapons systems evaluations are most efficiently treated by the use of "Monte Carlo methods." Previously, the size of the calculator has generally limited the complexity, and hence the realism, of the mathematical model. Although this limitation probably will not be eliminated by the use of the NORC, it should be much less restrictive.

Section 3

PROBLEM PREPARATION AND FORMULATION

In preposing a problem to be considered for calculation at the Computation Center, the basic equations should be complete, and the precision of results including the number of significant figures and density of tabulation should be specified. The following information is required by the programmers in order to prepare a problem for solution:

(a) A general statement of the problem, with definition of terms.

(b) A list of equations and derivations when feasible, plus any possible geometrical representation of the problem.

(c) A list of all tabulated functions in the problem, and approximations to these tabulated functions if they have been made.

(d) An indication of the range of various quantities, if known, and any machine stop orders to be included if certain conditions are not met.

(e) A desired arrangement of printed results, and alternatives or reduction in number of quantities to be printed if the desired arrangement is not feasible.

(f) A list of the quantities to be recorded, and the number of decimal places for each.

(g) A numerical example of a representative case, if available. In general, it is not considered desirable for the problem originator to attempt a detailed reduction of the problem to a finite difference form, or to prepare flow charts or other reduction. Similarly, it often is wasteful for the originator to attempt analytical transformations such as replacement of differential equations by quadratures, etc., although it may be desirable for him to mention any such possibilities of which he is aware. However, if the personnel of the problem originator are familiar with the calculators and have some knowledge of coding and programming, detailed suggestions are in order.

Section 4

PROCEDURES FOR OBTAINING SERVICES

The Computation Center is operated for and under the direction of the Bureau of Ordnance.

Computing time can be provided, depending on the current Bureau of Ordnance workload, to other government agencies and their contractors. Requests should be addressed to the Bureau of Ordnance (Attn: Re3-d), and should include a sufficiently detailed statement of the problem so that its suitability for computation on the calculators can be determined and a cost-time estimate made. The staff at the Computation Center at Dahlgren is available for consultation on proposed problems. Visits and clearances should be arranged through the Bureau of Ordnance. When a problem is accepted, a cost-time estimate will be forwarded to the requesting agency. Final charges will be based on costs for "good" machine time, plus costs for any coding, programming, or analysis services provided by personnel of the Computation Center. Payment will be effected in accordance with current practices.

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