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Quarterly Report, Contract N5ori-06002,

October through December 1950

Project NR 232-001

Submitted to

Office of Naval Research

Report by
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SUBJECT: QUARTERLY REPORT, Contract N5ori-06002, October through December 1950.

To: Head, Computer Branch, Office of Naval Research

From: R. A. Nelson

Abstract: This report describes work performed during October, November, and December 1950 on Contract N5ori-06002, covering research in digital techniques in naval anti-aircraft fire control. Programming of the Mark 47 equations for digital solution was nearly completed. Gun mount characteristics were studied. Work on fitting surfaces to firing table data and work on prediction of target position were started. Future work should include studies of data smoothing, gun-mount and radar characteristics, digital and analog methods, demonstration, tactical considerations, multiple-target considerations, adequacy of computer solution, and simulation of the fire-control problem. The first few of these will be accomplished during the present contract and the latter could form a basis for continued work beyond June 1951.

1. INTRODUCTION

This is the second quarterly report submitted under Contract N5ori-06002, covering research performed during October, November, and December 1950 in digital techniques in naval anti-aircraft fire control. The specific tasks prescribed in the contract are listed in the first quarterly report, Memorandum M-1118 of the Electronic Computer Division of the Servomechanisms Laboratory. The personnel are the same as mentioned in M-1118.

2. STATUS

2.1 Technical Status.

Work during the first quarter was basically orientation. During the second quarter, in addition to increasing our background knowledge to the point where we felt prepared to plan our future work more definitely than previously, we made progress in some of the explicit tasks set forth in the contract.

The bulk of the Mark 47 coding was accomplished. The chief result of this work is to demonstrate that the solution of the single-target anti-aircraft problem can be obtained by a digital computer of the capacity and speed of Whirlwind. We estimate now that about 1325 storage registers will be required (obtainable with present storage methods) and about 1500 operations must be performed for one complete calculation of gun orders, so that Whirlwind I with its present speed (an average of 60 μs per operation) could generate gun orders at a rate of 11 per second. (These estimates do not include solution initiation, which is performed in Mark 47 by the set-up computer, or any additional computations possibly required to tie in satisfactorily with radar and guns.) We adhered as closely as possible to the analog solution, determining what equations are solved by Mark 47 and then coding them or their difference equivalents. The remaining work in this problem is to check and improve the code, explain it in a general way, state and consider the effects of necessary restrictions and deviations from the Mark 47 solution, and draw conclusions.

At the same time a study was started of the characteristics of representative conventional gun mounts and power drives in order to determine how the guns would behave if orders were supplied at discrete intervals instead of continuously. One important fact discovered was that gun mounts have a resonant frequency of 8-10 cycles

per second, so that there may be stability problems if gun orders are furnished at about the same frequency. This and the corresponding problem for aided tracking orders to the radar require additional work, although a complete investigation is beyond the scope of our study. Two extremes of solutions are possible: (1) have the digital computer do all the stabilization of radar and guns, and perhaps even any servo compensation necessary; and (2) use only analog equipment to stabilize the radar and guns, freeing the computer for other problems. Some consideration will be given to each of these viewpoints and possible variations between them.

One phase of the general problem of making firing-table data available has been nearly completed. Differencing the table of superelevation (a function of predicted range and predicted elevation) for the 5"-38 gun showed that the data could probably be adequately represented by an expression of the type

$$f(R2, E2) = f_1(R2) + f_2(R2)f_3(E2),$$

where f_1 and f_2 are third-degree polynomials and f_3, a second-degree polynomial. The required coefficients were calculated by the solution of a twelfth-order determinant, resulting from normalizing 40 equations based on a grid of 40 evenly spaced points of the table. This work is still in process. It will be followed by sufficient examination of the other tables to show what degree polynomials are necessary. Later some thought will be given to the possibility of storing the firing table information in some sort of external storage and making appropriate sections of it available to the computer during the course of an engagement.

Work has been started on the problem of predicting the target's future position. The most important questions to consider are (1) the balance between the advantages of different prediction laws and the difficulty of coding them, and (2) the feasibility of shifting from one type of prediction to another as tactical conditions warrant. To start, helical prediction as developed by the Mark 65 project was considered, and first results indicate that the calculation of the necessary constants is rather involved. More study still has to be given to prediction. As the work proceeds, it will be wise in a practical sense to tie prediction more closely to the problem of smoothing, which has not yet been attacked seriously.

Various miscellaneous subjects have occupied part of our time. A fair amount of the Mark 65 reports (up through the Second Supplement to the Report on Task 2) have been gone over. These are especially useful since they treat the fire-control problem as a whole, and our work should be to use what others have learned of fire control. Smoothing has been considered a little. Some thought has been given to using

Whirlwind I to check some of the coding by actually going through it and displaying the solution. Possible future work was considered and outlined; this is discussed briefly in Section 3 below.

2.2 Financial Status.

At the end of December $9,350 had been spent of the $32,000 available. The rate will be somewhat higher during the remaining six months both because there will be three engineers working for the whole period, and because extra secretarial work will be required.

3. FUTURE WORK

We foresee at least the following topics as profitable areas for study. It is not possible to separate exactly the work of the next quarter from that of the second quarter of 1951 and possible work beyond. The Mark 47 coding will be completed very soon, and the work on firing-table data and prediction a little later.

a. Data Smoothing.

Study of data smoothing should include digital coding of various kinds of smoothing used in analog equipment as well as possible variations of these that might be performed conveniently by a digital computer. In evaluating the different possible methods and determining the effect of the choice of coordinate systems, the amount of smoothing necessary, and the time delay involved, we must consider the nature of the noise to be expected.

b. Gun-mount and radar considerations.

Work on gun mounts and radar will be an extension of that already done on the characteristics of present gun drives. It concerns making raw information available to the computer and making the processed information usefully available to the guns. Knowledge about the accuracy of observed data, the effects of data quantizing, possible conversion devices, and gun-order requirements is necessary. Stabilization against own ship's motion by various means may be considered.

c. Comparison of digital and analog methods.

Study of digital and analog methods is a separate topic in our planning, although most of the work on it will probably be incidental to other topics. The point is to consider which method best meets the requirements of each of the various aspects of the fire-control problem. It is possible that some combination of digital and analog equipment will do the job better than either kind alone.

d. Tactical considerations (single target only).

The ability of a digital computer to make decisions might make it useful in solving tactical problems. Some of the considerations brought out in the Mark 65 reports (when to open fire, synchronization of last rounds, desirable dispersion, etc.) should be studied.

e. Multiple-target considerations.

Background and criteria for work on the multiple target problem come from Mark 65 work and, possibly, from some Army Signal Corps work. Again, the ability of the digital computer to make decisions is the characteristic that would be used in evaluating target threat and deciding how to distribute fire and when to transfer fire. Tracking while scanning might be investigated.

f. Demonstration.

Various simple demonstrations of the application of digital computers to fire control might be arranged. Oscilloscope displays of digital data smoothing have already been accomplished by another project in the Laboratory and can be modified for our use. Some of the codes to be prepared for the topics listed above can be checked and their results displayed by the computer. In particular, some of the tactical and multiple-targe solutions might be demonstrated.

g. Adequacy of computer solution.

A doctoral thesis that may lead to practical methods of determining the adequacy of coded programs is now being written in the Laboratory under the sponsorship of another project. The results of this work may be of help in our study of sampling rates, of iterative procedures, and of digital methods of differentiation and smoothing, as all these affect the behavior of the solution.

h. Simulation for testing, training, etc.

It is possible that a digital computer could be effectively used in a simulation set-up that would aid in training personnel, testing equipment, etc. Canned courses or "live " inputs might be used. Various displays and controls would have to be provided. Any work on this problem in the near future would be on a very low level.

The first three of the topics discussed above, along with the completion of work currently being done, will roughly cover the next

quarter. Work on demonstration and report writing, and some study of topics d and e, will occupy the second quarter of 1951.

Work after the completion of the present contract (June 1951) might be divided into three categories: (1) topics d, e, g, and h (i.e., problems already outlined but not worked on sufficiently); (2) further work on topics a, b, c, and f, already considered (e.g. investigation of other possible numerical methods for representing firing-table data); (3) study of problems not mentioned previously. A proposal may later be submitted to cover an extension of the contract at about the same level as at present.

Signed: Robert A. Nelson
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Approved: R R Everett
R. R. Everett

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