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QUARTERLY REPORT, Contract N5ori-06002, July to
September 1950.

To: Head, Computer Branch, Office of Naval Research

From: R. A. Nelson

Abstract: This report describes work performed during July, August, and September 1950 on Contract N5ori-06002, covering research in digital techniques in naval anti-aircraft fire control. Three persons are engaged in the project. An initial schedule was set up to allocate the amount of effort going into the different phases of the work. Considerable time was spent in reading to provide background for the problem. The functions performed by the Mk 47 fire control system are being coded for a digital computer, and this will serve as a measure of speed and storage requirements for solving the problem digitally. Investigations will be carried on to see how the results might be advantageously modified. Studies will be made of smoothing and prediction methods and of the requirements imposed by the gun-fire control problem on analog-digital and digital-analog conversion equipment.

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1. INTRODUCTION

Contract N5ori-06002 calls for conducting "research in digital techniques in fire control to include, but not necessarily be limited to, the following:

- (1) The coding of typical mathematical functions and equations solved by an existing representative anti-aircraft computer, and establishing the speed and capacity requirements for digital equipment suitable for use against a high-speed target;
- (2) Determine whether it is more advantageous to compute ballistic data as needed, or to store the tables and search for the particular data desired;
- (3) Recommend where, in the process, conversions to and from digital information should take place;
- (4) Determine if it is possible to make provision for several types of prediction, and to have the computer use the one most suitable for the particular target maneuver;
- (5) Estimate the type of data smoothing to be employed and the magnitude of smoothing time necessary; and
- (6) Proceed as far as possible with the simulation of a digital fire-control system using the Whirlwind computer. This would include a plan for a suitable demonstration, coding of sequences for the computer, and preliminary tests."

2. PERSONNEL

This study is being supervised by Mr. Robert A. Nelson under the general direction of Mr. Robert R. Everett.

Robert A. Nelson, S.B. in Physics, MIT 1943, military radar, S.M., MIT 1948, two years with Project Whirlwind.

John M. Dodd, Jr., B.S. in Electrical Engineering, Stanford University, 1950.

Abraham Katz, S.B. in Electrical Engineering, MIT 1950.

3. PLANNING

In July a preliminary planning schedule was drawn up for two persons to work for 12 months each, and a third, starting in October, for 9 months. This schedule called for about 30% of the total effort

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to go into work on coding and investigating ways to obtain tabular data (by table look-up with interpolation or by function generation); and about 20% on smoothing problems and the possibility of selecting prediction methods. The rest would be divided among orientation, data-conversion requirements, a demonstration, liaison with other relevant activities, and report writing. This division of work still appears suitable.

4. STATUS

Work performed through August was mostly orientation. The basic reading consisted of Chapters 15, 16, and 17 of Naval Ordnance and Gunnery (NavPers 16116), concerned with the naval anti-aircraft fire control problem and the way it is solved by the system using the Mk 37 director, the Mk 6 stable element, and the Mk 1 computer (this is similar in many respects to the Mk 47 system, whose equations are being coded). Three important benefits resulted from this reading: it introduced standard Navy definitions of fire-control terms and provided us with practice in using them; it outlined the theory involved and often gave an indication of what simplifying approximations were made; and it explained how one proved system operates. Additional background information was obtained from some study of the report Gunsight Mk 15 for the Control of Short-and-Medium-Range AA Fire from Naval Vessels, Vol. I, issued by the Instrumentation Laboratory of MIT, and excerpts from some of its appendices. Other introductory reading about fire control has included parts of reports on Mk 50, Mk 56, Mk 63 and Mk 65; two books on exterior ballistics; and the monograph of Blackman, Bode, and Shannon, Data-Smoothing and Prediction in Fire Control Systems.

In July Nelson visited Washington for three days, where he talked with representatives of the Computer and Armament Branches of ONR, the Bureau of Ordnance (Section Re4c), Naval Research Laboratory, and Operations Evaluation Group. These conferences added to the list of reports thought to be of value to our Project, and in addition resulted in a decision to study especially the Mk 47 system.

Actual work on the fire control problem itself started during August in the derivation of the exact expression for deck-tilt correction in terms of level, cross-level, and director train. Only an approximation of the exact expression is solved by the Mk 1 computer, and no indication of its adequacy is given in Naval Ordnance and Gunnery. Although the evaluation of the exact expression is rather lengthy, the practical limitations on the magnitudes of level and cross-level angles permit an approximation which considerably simplifies computer procedure and at the same time gives better accuracy than the Mk 1 approximation.

At the end of August we obtained a copy of the Engineering Report on Computer Mk 47 Mod A (NavOrd Report 493). First attempts at codes have been written for several of the equations given in that report.

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These preliminary codes have used subroutines for the evaluation of sines and cosines that were developed as part of the training in coding. It has been assumed so far that the ballistic functions of two variables can be written as relatively easily computed functions of algebraic polynomials.

Some thought has been given to smoothing by a digital computer. Exponential smoothing appears not difficult to code; but if the influence of data of more than some particular age is to be cut off sharply, storage may be a problem.

5. FUTURE WORK

At present the effort of one man is being devoted to coding the Mk 47 equations for digital solution. This work will necessarily introduce the question of how firing-table data is to be made available to the computer, problem (2) of the contract as quoted in Section 1 of this report. The coding of the Mk 47 equations will serve as a basis for determining the requirements for speed and storage capacity of a digital computer for fire control purposes. It will also serve as a point of departure for modifications of the method to take better advantage of the characteristics of a digital computer.

In connection with this latter phase will come the questions of prediction and smoothing of various kinds. Also relevant are the problems of converting between analog and digital forms of information and supplying orders to the guns at discrete intervals of time. Some consideration will be given to various possible methods of converting data, particularly with respect to their integration with a digital computer and power-driven guns. A demonstration of the digital solution of the fire-control problem will depend on the results of the other work.

Throughout all our studies we shall keep in mind the fact that the small scale of this effort will probably produce only an indication of the usefulness of digital techniques in fire control. We should look for a reasonable balance of analog and digital equipment most suitable for the job. We should also keep in mind the possible extension of all our results from the single-target to the multiple-target problem.

Signed

R. A. Nelson

R. A. Nelson

Approved

R. R. Everett

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