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A TH: DD 254
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Date: 12/2/59

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SUBJECT: BI-WEEKLY REPORT, PROJECT 6782, February 2, 1951

To: J. W. Forrester

1. GENERAL

(R. A. Nelson)

Those of the NDRC Division 7 (Fire Control) reports that we are not keeping will be kept by the Vail Library.

A first draft of the second quarterly report has been written and is being revised.

2. THE FIRE CONTROL PROBLEM

2.1 Data Smoothing and Target Position Prediction

(R. A. Nelson)

To provide a concrete example of how a digital computer might select an optimum prediction law for particular tactical conditions, I have been considering the combination helical-linear prediction mentioned in the Mark 65 reports; I have previously found how the helical constants could be determined either from smoothed position readings at three different instants of time or from smoothed position, velocity, and acceleration readings at one instant. I am now thinking about the switch from helical to linear prediction. The Mark 65 reports include a graph showing when the change should be made, as a function of target inherent flight roughness, target maneuver, lethal radius (dependent on both target and projectile characteristics) and range to target. Since the curves would be difficult for the computer to use exactly, and since much of the information would not be available to the computer, some approximation must be sought that greater kill probability for most cases than either helical or linear prediction alone, and at not too great a cost in computer facilities. It appears at first that a single change-over range is not worth very much, but this conclusion will have to be better substantiated by consideration of the actual kill probabilities involved. The next likely possibility is to use a criterion of switch-over

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2.1 Data Smoothing and Target Position Prediction (continued)

range as a function of the target's intentional maneuver alone, assuming inherent unsteadiness and lethal radius to be constants; this may be necessary anyway, since insufficient information is available to the computer to determine these quantities.

(J. M. Dodd)

Several reports having to do with data smoothing and prediction have been read. At present I am looking at "Data Smoothing and Prediction in Fire Control Systems" by Blackman, Bode, and Shannon and "A Simplified Derivation of Linear Least Square Smoothing and Prediction Theory" by Bode and Shannon.

Based on the linear prediction function

$$y = b + mt,$$

one report by the Eastman Kodak Company derives expressions for the values of b and m giving the best fit based on the least-square-error criterion. For a prediction formula based on the last n values of y , these are:

$$n(n+1)b_n = 2(2n-1) \sum_0^{n-1} y_1 - 6 \sum_0^{n-1} iy_1$$

$$n(n^2-1)m_n = 6(n-1) \sum_0^{n-1} y_1 - 12 \sum_0^{n-1} iy_1$$

For example in the case $n = 5$, these would be:

$$10b_5 = 6y_0 + 4y_1 + 2y_2 - 2y_4$$

$$10m_5 = 2y_0 + y_1 - y_3 - 2y_4$$

Values of b_n , m_n have been computed in terms of y_1 for

$n = 2, 3, \dots, 9.$

Some time has been spent extending this approach

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2.1 Data Smoothing and Target Position Prediction (continued)

(J. M. Dodd) (continued)

to prediction based on a parabolic function

$$y = b + mt + at^2$$

In this case the "best fit" values of b, m, and a are given by considerably more complicated expressions:

$$P_5 b_n = P_4 \sum_0^{n-1} y_1 + P_3 \sum_0^{n-1} i y_1 + P_2 \sum_0^{n-1} i^2 y_1$$

$$P_5 m_n = P_3 \sum_0^{n-1} y_1 + P_2 \sum_0^{n-1} i y_1 + P_1 \sum_0^{n-1} i^2 y_1$$

$$P_5 a_n = P_2 \sum_0^{n-1} y_1 + P_1 \sum_0^{n-1} i y_1 + P_0 \sum_0^{n-1} i^2 y_1$$

where P_k is a k^{th} degree polynomial in n.

2.2 Ballistic Consideration

(A. Katz)

During the past bi-weekly period, I continued my efforts toward obtaining a more satisfactory surface to approximate the superelevation (Vfn) function. Some weeks ago I obtained a twelve term least-squares polynomial which gave a fairly good representation for Vfn as a function of ballistic range (R2) and ballistic position angle. By fitting a two term least-squares polynomial to the resultant residual surface and adding these two new correction coefficients, I was able to reduce the residual errors over the entire Vfn surface. This proves that a good approximating surface can be obtained with relatively few terms and a consequently short program.

I have begun a first draft of a final report on the ballistic tables and methods for storing them. Work on this draft will be done concurrently with an investigation of the possibility of using magnetic drums to store the tables.

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3.0 CODING

(J. M. Dodd)

Except for the ballistic section, the Mark 47 coded program has been typed. Both the equations and the code (without notes) are now completed.

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