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R-TR-76-046

**AUTOMATIC TARGETING DEVICE
IN SUPPORT OF THE
XM188/XM230 DATA ACQUISITION TEST (DAT)**

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**DENNIS D. HELSTROM
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NOVEMBER 1976

FINAL REPORT



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report covers the development and operating procedure for a computer operated automatic targeting device. This device automatically obtains and outputs both dispersion coordinates and velocities for an automatic weapon in bursts up to 60 rounds. The chronological order of rounds is maintained. Statistics on dispersion and accuracy, if point of aim is input to the computer, is also output. Accuracy of this system, with 50% probability, is within $\pm 1/2$ inch from actual location at 1,000 inches firing 20 rounds.		

DD FORM 1473

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Edward R. Lindquist

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ABSTRACT

This report covers the development and operating procedures for a computer operated automatic targeting device. The device consists of (16) ballistic screens, (3) chronographs, a teletype, and a PDP 8/E computer. The ballistic screens are ordered in parallel and present a 6 x 6 ft. area and 4 planes to the projectile. With these four planes, the X and Y position and velocity of each round is obtained by trigonometry. Further computer calculations obtain statistics on the dispersion. The same statistics can be obtained for accuracy, if a point of aim is input to the computer. Listing of the coordinates of each round, in chronological order, can be obtained from any reference point, the default point being the center of impact. A graphical plot of the rounds may also be printed on the teletype. The high, low, and average velocity may be output from the computer program, or each individual round may be obtained on command. Due to the 8K core computer limitation, the present program will handle a maximum of 60 rounds per burst. The program is written in Digital Equipment Corporation's (DEC) FOCAL-8 language with PAL III assembly language overlay. This program may be operated in automatic or interactive command mode.

This device was developed in support of the XM188/XM230 Data Acquisition Test. As such, the system accuracy can only be stated with respect to 30MM rounds. The round position for a 20 round burst is within $\pm 1/2$ inch at 1,000 inches. This accuracy is stated at a

50% confidence level. Erroneous ballistic screen outputs are usually of large magnitude. The program will trap these errors and delete the respective rounds from its computations. This input error is dependent on ballistic screen adjustment and sensitivity; however, under existing conditions this correctable error averages only 3 to 4 rounds per 300 rounds fired.

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I. OBJECTIVE

The objective of this effort was to reduce the time required in determining accuracy and dispersion of automatic weapons during engineering tests. The task was to be accomplished using as much existing equipment as possible and to computerize the process so that tabular and graphical data would be available after each burst.

II. GENERAL

A Digital Equipment Corporation PDP 8/E computer, 3 chronographs, teletype (Figure 1), and 16 ballistic screens (Figure 2) were used to accomplish the objective. A detailed list of equipment used is contained in Appendix D. The PDP 8/E was selected because it was in inventory, and relatively easy to interface. The velocity screens were chosen over other methods because of existing ballistic screen technology. The screens were arranged in a particular geometric pattern to enable measurement of both velocities and dispersion of the rounds fired from weapons being tested. The screens were positioned downrange from the test weapon as shown in Figure 3. Computer printed circuit boards were procured and modified to provide the capability desired. An external ballistic program (See Appendix A page A-15) was used to calculate an effective muzzle velocity from the velocity received downrange.



FIGURE 1. TELETYPE, COMPUTER, AND CHRONOGRAPHS

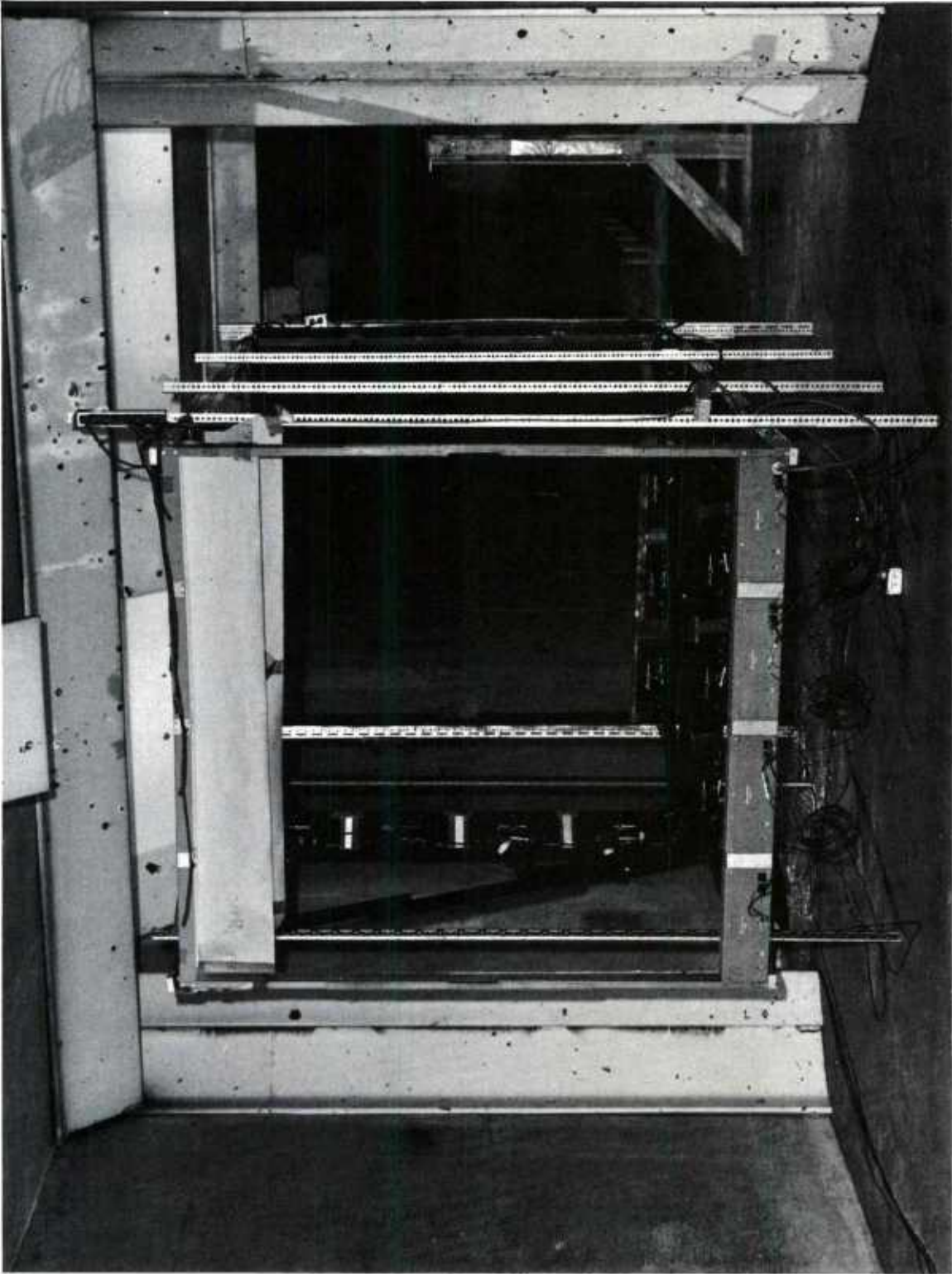


FIGURE 2. FRONT VIEW OF VELOCITY SCREENS

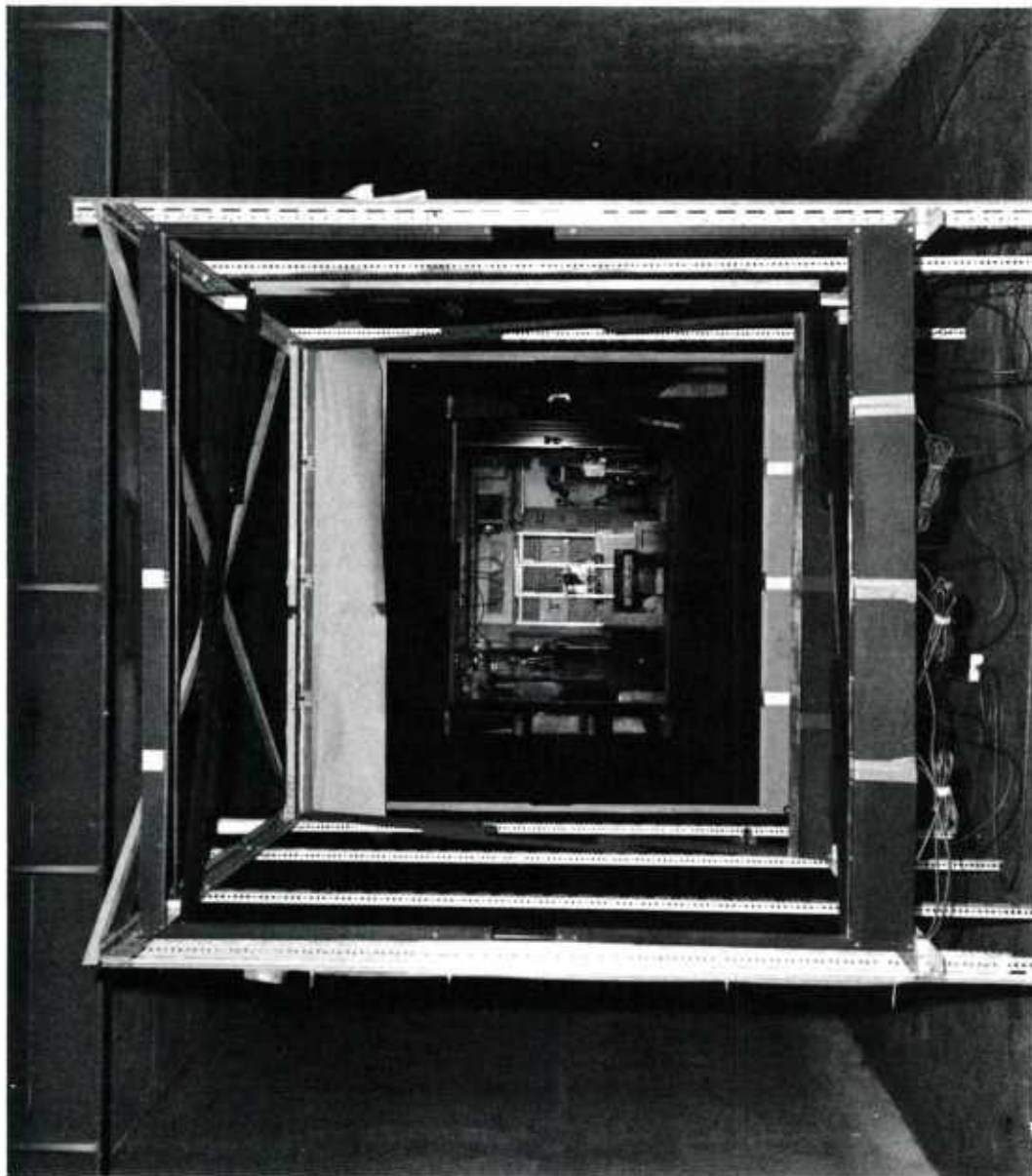


FIGURE 3. AFT VIEW OF VELOCITY SCREENS SET UP AT 1,000 INCHES

III. PRINCIPLE OF OPERATION

The 16 ballistic screens were oriented as shown in Figures 2 and 3 forming 30-60-90 degree triangles and four planes. As the projectiles decrease the light input to the light sensing diodes (Oehler model 55 ballistic screens), a 12v square wave with a rise time of 0.1 microsecond is produced. All four screens in one plane are connected in parallel to provide one output per plane. Screen one (first plane) starts all three chronographs and screens two, three, and four (remaining planes) stop their respective chronographs (See Figure 4).

The interface between the chronographs and the computer works in a hand-shake method. The chronographs sets a print line when its Binary Coded Decimal (BCD) data is stable telling the computer to read the BCD data from its respective two input/output devices. The computer then sends a read-down line signal to reset the chronograph. Two one-shot devices were required on the interface boards per chronograph to convert the normally high and low lines to pulses. A 112 nanosecond pulse was used for the print command and a 240 microsecond pulse was used for the read-done command to double-safe possible timing problems.

The computer continues in this method of dumping BCD data into core until a maximum of 60 rounds are fired or a programmable time between rounds is exceeded. Either the number of rounds in the burst, or an error message stating core has been exceeded, is then printed

(16) BALLISTIC SCREENS; (3) CHRONOGRAPHS; & COMPUTER
SET UP

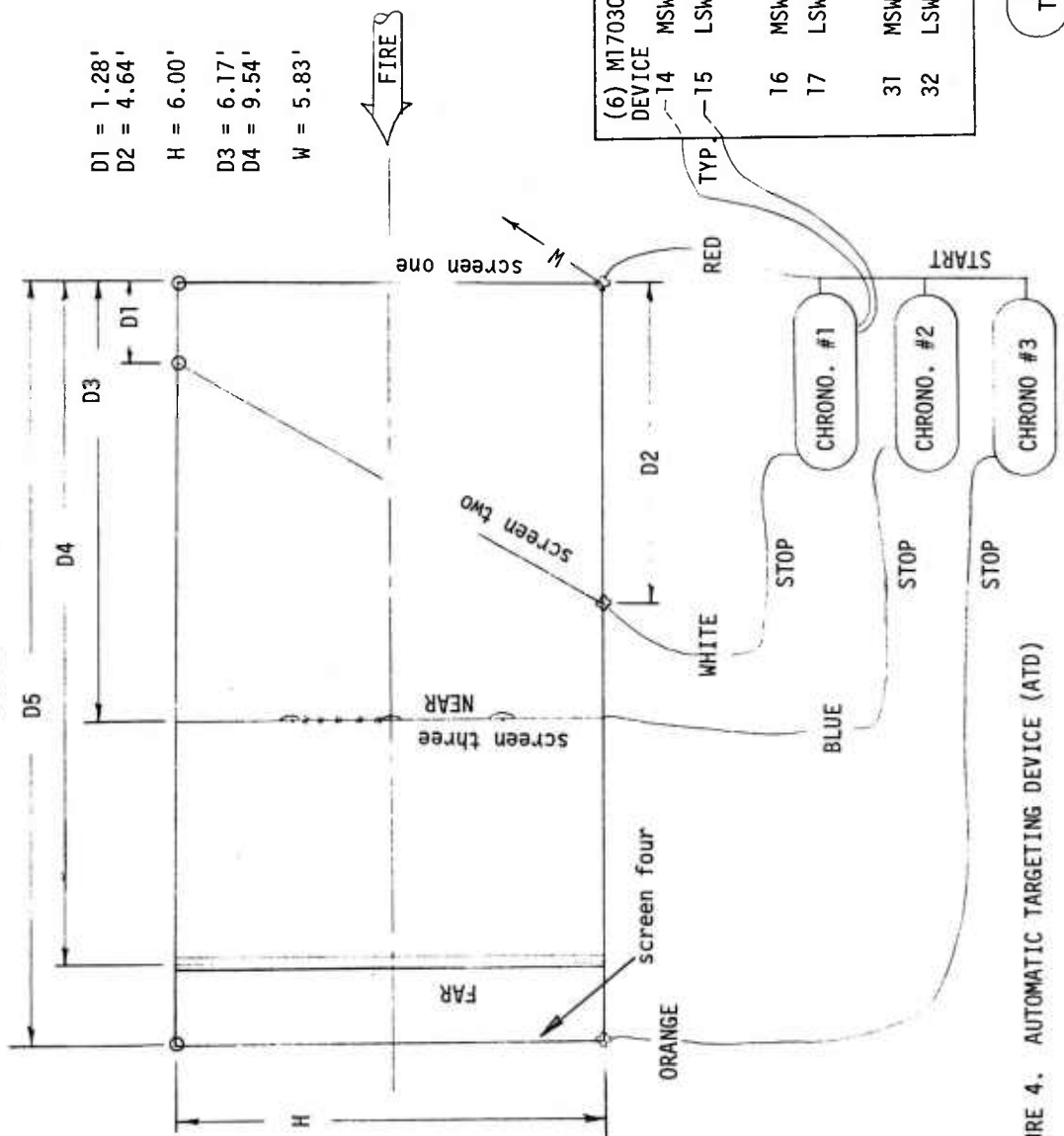


FIGURE 4. AUTOMATIC TARGETING DEVICE (ATD)

on the ASR (teletype). The assembly language program designated FN performs this operation. $N = FN(-L)$ is the form of this subroutine where N is the number of rounds fired and $L = 60$, the maximum rounds per burst in this configuration. With extended core, L may be increased. Due to core limitation, only the BCD of the time and its pointers are retained in the computer, other variables are calculated each time they are used. To retrieve the BCD chronograph times in FOCAL floating point (3 words per variable), the assembly language subroutine $FT(N,CR)$ is used where N is the round number and CR is the chronograph number.

To calculate the displacement, first the computer calculates the velocity for the respective round by $V = D5/T3$ (See Figure 4 for symbols). The time to the first possible "Y" location for this round is $YFT = D1/V$, the time to the last possible "Y" location is $YLT = D2/V$, using similar triangles the following proportionality holds:

Y : H as

$(T1 - YFT) : (YLT - YFT)$

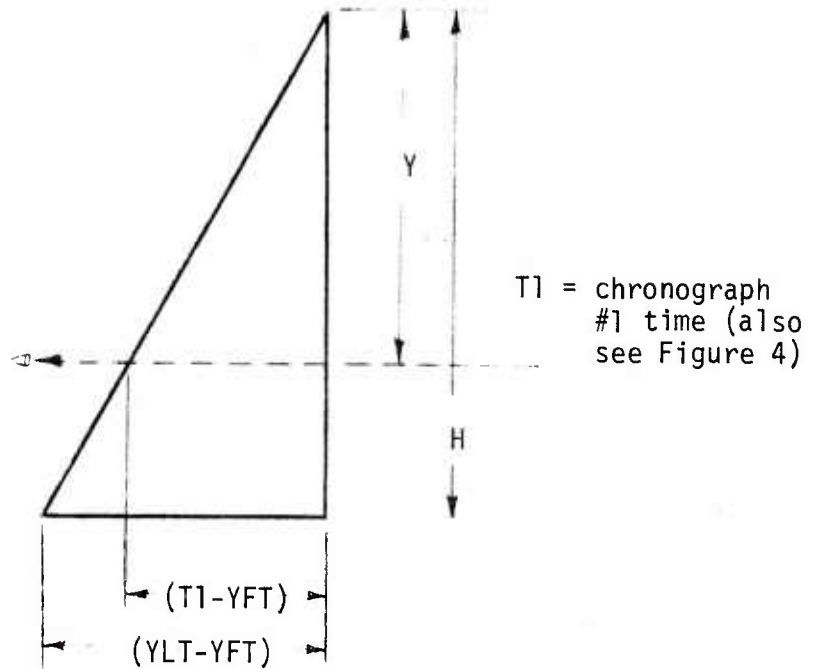


FIGURE 5. TIME/DISPLACEMENT RELATIONSHIP FOR "Y"

From the above, by substitution, the resulting equation for Y is as follows:

$$Y = H\{(D5 \cdot T1 - D1 \cdot T3) \div (D2 \cdot T3 - D1 \cdot T3)\}$$

The program may be operated either in automatic or command mode by setting variable switch AZ = 101 or 0 respectively. The commands are shown and explained in the command mode of the FOCAL program (See Group 23, Appendix A, page A-5).

The major area of concern in this device is the character of the signal between the ballistic screens and the chronographs (See Appendix C). With the chronograph in start and stop mode instead of

common mode, the chronographs themselves act as one-shots. That is, only the first start pulse of many is used while the respective chronograph is stopped and only the first stop is used while the chronograph is running. Therefore, many erroneous pulses noted in Appendix C are eliminated by the chronograph counters. Sensitivity and pulse width of the ballistic screens (Oehler Research) can be adjusted with two 25 turn potentiometers (i.e., two on each of the 16 screens). As can be seen in Appendix C, the sensitivity adjustment is critical (See System Accuracy, Section IV, for reasons). These ballistic screens are the weakest link in this system. With the 30MM, only 50,000 rounds were fired before more than 8 of the screens required replacement or were disconnected because of erroneous output (excessive pulses). This low life and reliability can be explained by the excessive abuse the 30MM round delivers in the confined ballistic screen location. Sonic shock, floor vibration and expelled propellant and debris encountered were reduced by additions to the set up shown in Figures 2 and 3. The 15 foot square firing bay does not allow firing shocks to dissipate as rapidly as desired. The affect of these set up changes was noticeable on ballistic screen reliability; however, their life was still considered marginal. These modifications consisted of sound insulating material draped along the sides of the screens to break up shock waves bouncing off the range walls. A plywood shield was placed between the weapon, and the screens to break up the shock wave and reduce the propellant

and debris flow through the screens. Finally, rubber and foam pads were placed under the screens feet to reduce vibration transfer from the floor to the screens.

The extended distance and angle limitations from the illuminiline to the light sensitive diodes were not covered in the manufacturer's literature and were considered major factors in screen life.

Even with all the problems encountered, the time saved in reducing targets is well worth the effort. The time to set up, retrieve, and reduce a 1st round color coded paper target to the statistics presented by the computer is estimated to be 40 minutes and require 3 to 4 people. With the aid of a digitizing table and computer, this time is reduced to approximately 20 minutes. With the Automatic Targeting Device, this process takes less than 2 minutes and requires only one person to accomplish the work. The time savings is, therefore, estimated at 2,000% or 20 times faster.

IV. SYSTEM ACCURACY

A. FACTORS AFFECTING SYSTEM ERROR

PROGRAM PARAMETERS

D1, D2, and H are the programming parameters that affect the "Y" coordinate calculations (See Figure 4) where:

H - height of the screen

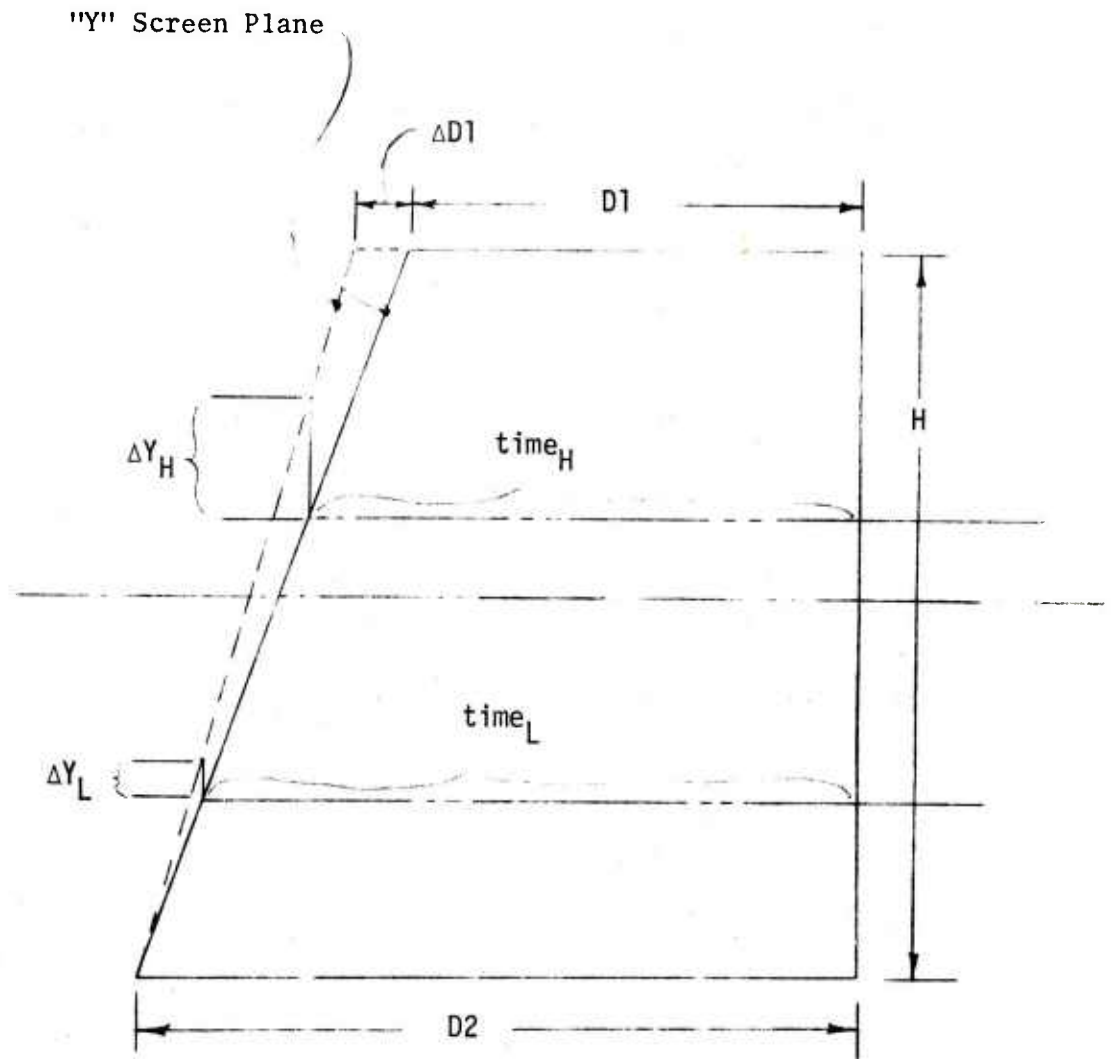
D1 - top distance to "Y" detecting screen from start screen

D2 - bottom distance to "Y" screen from start screen.

The DEC PDP 8/E must have six M1703C input boards and FOCAL programming available for the PDP 8/E in order to have the capability to work the problem.

The three parameters (H, D1, and D2), therefore, establish the effective angle the "Y" detecting screen is to the line of fire.

Increasing H will increase the extreme vertical spread evenly, while increasing D1 will spread the upper half of the target area rounds more than the lower half and increasing D2 will spread the lower half more than the upper half. This is shown in Figure 6. D3, D4, and W for "X" are similar to the "Y" parameters; however, an error is introduced because D3 and D4 are larger than D1 and D2. Since D3 and D4 are larger (3 millisecond at 2,200 feet/second), the assumption of a straight line round path is more critical. On the other hand, this is more than compensated by the increased time of flight to screen 3.



Changing $D1$ will rotate "Y" screen plane about lower corner.

Changing H will rotate plane about the center.

Changing $D2$ will rotate plane about upper corner.

"X" plane is similar but with $D3$; $D4$; and W

Displacement instead of angles and trigonometry was used in order to provide this increased flexibility.

FIGURE 6. "Y" PARAMETERS SETUP

SENSITIVITY

Sensitivity can affect system error as shown by the following example:

$\Delta D1 = 0"$, $\Delta D2 = 6"$, $\Delta H = 2"$, $\Delta EV = 1"@10"$

ALL @ 1000" Range.

$\Delta D3 = 5"$, $\Delta D4 = 4"$, $\Delta W = 3"$, $\Delta EH = 1"@16"$

EV = Extreme Vertical Spread

EH = Extreme Horizontal Spread

YLT and YFT are microsecond times to $Y = 0$ inches and $Y = 72$ inches, the minimum and maximum Y coordinates. They are calculated for each round and are, therefore, a function of round velocity and parameters D1 and D2. A one microsecond error in the chronograph can be resolved into a 0.052 inch error in the "Y".

XLT and XFT are similar to the above, but over a 70.0 inch span instead of a 72.0 inch span. A 1 microsecond error in time from the first screen to the third screen can be resolved into a 0.047 inch error, the percentage being 3 times lower.

A three or four word (12 bit) variable size had no appreciable effect.

BALLISTIC SCREEN

(Oehler Research Model 55) Quantity: 16 with 4 per stack.

Ballistic screens can affect system accuracy. The generated pulse, per specification, is 12 volts for 2-8 milliseconds with a 0.1 microsecond rise time and 0.1 millisecond fall time. Pulses are generated by five light sensitive diodes observing a 60 watt lumiline. Sensitivity is controlled by a 25 turn potentiometer. The highest number of errors are produced by the ballistic screens. These errors are

easily detected by the program and result in deletion of the entire round. Some error causes are listed below:

1. Flash and other external lighting
 2. Blast
 3. Debris covering the plexiglass window
 4. Dust accumulation on lumiline
 5. Vibration through floor
 6. Shock waves directly from rounds and weapon, and reflected from walls and floor.
 7. Misalignment and vibration of sensor shading and aiming column.
- The last plane of ballistic screens seems to be the most susceptible to failure, presumably caused by shock transfer.

COUNTER CHRONOGRAPH

The chronograph (E.C.I. Model 4604, quantity: 3) has a 1 megahertz time base crystal with a 10 nanosecond error from -20°F to $+130^{\circ}\text{F}$ after 30 minutes of warm-up time. Error from the chronograph is, therefore, considered only a factor of readout, i.e., ± 1 microsecond.

B. TOTAL SYSTEM ERROR

The total system error was established with the aid of a digitizing table having an absolute accuracy of measured distance equal to ± 2.5 parts in 10^4 (e.g., $\pm .00025$ inch in 1 inch), and paper targets with colored round signatures collected directly behind the velocity screens. The accuracy of this table output was, therefore, considered only a function of its follower's position.

For comparison, round displacement for both programs was taken from the second round. For a 20 round burst the average "X" error was -0.95 inch to +0.38 inch at a range of 1,000 inches. The maximum variation for 20 rounds was +1.14 to =0.87 calibers for "X" and +.32 to -1.11 calibers for "Y".

The system error (for 20 rounds with 50% probability) can be designated within $\pm 1/2$ inch from actual position at 1,000 inches. This equates to 10 microseconds timing error.

See Appendix B for sample output.

APPENDIX A
COMPUTER PROGRAMS

The following program calculates the velocity, dispersion, and accuracy from the respective three times for each round. Other functions may be performed on command as noted in the command node group 23. The language is Digital Equipment Corporation's FOCAL.

Reference is given to Digital Equipment Corporation's "FOCAL-8 Programming Manual", No. DEC-08-AJAD-D, dated January 1970.

@@@@@@@@@@

*C-8K FOCAL @1969

*

```
*01.01 C **V 18** AUTOMATIC TARGETING DEVICE PROGRAM
*01.02 T "!!!!!!" ;D 1.09;D 1.10;D 1.04;D 1.07;D 1.03;D 1.08;G 1.13
*01.03 T "AMMO LOT NUMBER" :LC-13-003",!
*01.04 T "GUN & S/N" :XM230, 14",!
*01.07 T "VERTICAL RESTRAINT" :NO",!
*01.08 T "AMMO & CAL." :XM639B1, 30MM",!
*01.09 A "TEST NUMBER" :",%5,K1
*01.10 A "SPRING RATE & DAMPING" :",K2,K3
*01.13 S P1=0.0;S P2=0.0
*01.14 S DM=25*12 ;S D5=129.5;S II=0
*01.15 S H=71.00;S D1=15.00;S D2=49.00
*01.16 S W=73.00;S D3=74.00;S D4=110.5
*01.17 T "DATE : 21JUNE76",!
*01.20 S N9=60
*01.30 S N=FN(-N9)
*01.31 I (N)1.3,1.3;I (N9-N) 1.38,1.4,1.32
*01.32 S NN=N;F I=1,N;S N(I)=I
*01.33 I (DM)1.34,1.36,1.34
*01.34 T "NO. RDS.= ",%3,N,!
*01.35 S Z=0;G 17.02
*01.36 D 1.13;D 1.14;D 1.15;D 1.16;G 1.34
*01.38 T "CORE OVERFLOW",!;S N=60;G 1.32
*01.40 T "CORE FILLED",!;G 1.32
```

*

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*02.01 T "***ACCURACY*** TEST ",%4,K1,!
*02.02 A "POINT OF AIM X&Y (IN.) ",%6.02,PW,PF
*02.03 S P1=PW-53.0;S P2=98.5-PF
*02.05 S AX=0;S AY=0;D 2.11;D 2.12;G 2.15
*02.10 T "*** DESPERSION*** TEST ",%6,K1,!
*02.11 S AR=0;S E=0;S G=0;S O=0;S MS=0;S R=0
*02.12 S MX=9999;S MY=9999;S LX=-9999;S LY=-9999
*02.13 S P1=0;S P2=0
*02.14 D 11
*02.15 F I=1,N;D 12;D 3;D 4;D 5;D 6;D 7;D 8
*02.50 T !, "EXTREME VERTICAL ",%8.02,(LY-MY)," MILLS",!
*02.60 T "EXTREME HORIZONTAL",%8.02,(LX-MX)," MILLS",!
*02.70 T "MEAN RADIUS ",%8.02,AR," MILLS",!
*02.72 T "STANDARD DEVIATION X",%5.02,FSQT(E/(N-1))," MILLS",!
*02.74 T "STANDARD DEVIATION Y",%5.02,FSQT(G/(N-1))," MILLS",!
*02.76 S R=0;S O=0;F I=1,N;D 12;D 7.10;D 10.05
*02.78 T "STANDARD DEVIATION R",%5.02,FSQT(O/(N-1))," MILLS",!
*02.90 T "FIGURE OF MERIT ",%8.02,(LX+LY-MX-MY)/2,!
*02.91 T "NUMBER OF ROUNDS ",%5,N,!
*02.92 T "!!!;G 23.01
```

*

```
*03.10 I (LX-X) 3.2;R
*03.20 S LX=X;S Y1=Y;R
```

*

```
*04.10 I (LY-Y) 4.2;R
*04.20 S LY=Y;S X1=X;R
```

*

```
*05.10 I (X-MX) 5.2;R
*05.20 S MX=X;S Y2=Y;R
```

*

```
*06.10 I (Y-MY) 6.2;R
*06.20 S MY=Y;S X2=X;R
```

*

```
*07.10 S R=FSQT((X-AX)2+(AY-Y)2)
*07.20 S AR=AR+R/N
```

*

```
*08.10 S E=E+(AX-X)2
*08.20 S G=G+(AY-Y)2
```

```

*10.05 S O=O+R*2
*
*11.50 C***CALCULATE X-Y COORDINATES***
*11.52 S SV=0; S A=0; S B=0
*11.56 F I=1,N; D 12
*11.57 S AX=A/V; S AY=B/V
*11.58 R
*
*12.10 S T1=FT((N(I)),1)/1000000; S T2=FT((N(I)),2)/1000000
*12.11 S T3=FT((N(I)),3)/1000000; IF (T3) 12.12,15.01,12.12
*12.12 S V=D5/T3
*12.14 S YF=D1/V; S YL=D2/V
*12.16 S Y=-((H*(T1-YF)/(YL-YF))-P2); S B=B+Y
*12.18 S XF=D3/V; S XL=D4/V
*12.20 S X=(W*(T2-XF)/(XL-XF))-P1; S A=A+X
*
*13.10 S NB=N
*13.12 S I=0; S NB=NB-1
*13.14 I (NB-2) 28.11,13.16,13.16
*13.16 S I=I+1
*13.17 D 12; S Y1=FABS(Y); S I=I+1; D 12; S Y2=FABS(Y); S I=I-1
*13.18 I (Y1-Y2)13.22,13.22,13.2
*13.20 S CO=N(I); S N(I)=N(I+1); S V(I+1)=CO
*13.22 I (I-NB)13.16,13.12,13.12
*
*15.01 T "T3=0",!
*15.10 T "***CHRONOGRAPH TIMES*** TEST ",%5,K1,!
*15.20 T "TEST NO.      T(1)      T(2)      T(3)",!
*15.22 S I=1; I (N-1)15.3,15.4,15.3
*15.30 F I=1,N-1; D 15.4
*15.40 T %3,(N(I)), "      ",%10,FT((N(I)),1),FT((N(I)),2),FT((N(I)),3),!
*15.60 T !!!; G 23.01
*
*17.02 F I=1,N; D 12.1; D 12.11; D 12.12; D 12.14; D 12.13; D 17.04
*17.03 S II=0; G 23.01
*17.04 I (YL-T1)18.7,18.7; I (XL-T2)18.7,18.7,17.06
*17.06 I (T1-YF)18.7,18.7; I (T2-XF)18.7,18.7,17.08
*17.08 S II=II+1; S N(II)=N(I)
*
*18.70 S N=N-1; I (N) 18.8,18.8
*18.80 T "ALL RDS. DELETED",!; S AZ=101; G 23.01
*
*20.02 S I=N2; D 12; G 21.3
*20.03 S N2=1; S N3=N; G 20.1
*20.06 A N2,N3; S L=-1
*20.07 I (N-N3)20.03,20.08,20.08
*20.08 I (N2)20.03,20.03,20.09
*20.09 I (N3-N2)20.03,20.02,20.2
*20.10 T "***X-Y COORDINATES *** TEST ",%5,K1,!; I (AX+AY)20.11,20.15,14
*20.11 I (P1-AX)20.15,20.12,20.15
*20.12 I (P2+AY)20.15,20.13,20.15
*20.13 T "***CENTER OF IMPACT***",!
*20.15 T "      RD. NO.      X      Y",!
*20.17 S I=1; I (N3-1)20.2,21.3,20.2
*20.20 F I=N2,N3; D 12; D 21.30
*20.40 T "",!!!!!!; S L=0; G 23.01
*
*21.30 T "      ",%3,N(I),"      ",%5.02,X,"      ",Y; I (L) 21.4; T !
*21.40 T %10,FT((N(I)),1),FT((N(I)),2),FT((N(I)),3),!
*21.50 S L=0; T !; G 23.01
*

```

```

*23.01 C***COMMAND NODE***
*23.02 S Z=Z+1; I (AZ-101)23.03,23.05
*23.03 S A(1)=0V; S A(2)=0101; S P1=AX; S P2=-AY; S A(3)=0PXY; S A(4)=0Q
*23.04 S AA=A(Z); G 23.12
*23.05 T "#"; A AA
*23.12 I (AA-0RT)23.13,24.01
*23.13 I (AA-0RR)23.14,24.01
*23.14 I (AA-0PT) 23.16,15.1
*23.16 I (AA-0V)23.18,24.11
*23.18 I (AA-0PXY)23.19,20.03
*23.19 I (AA-0L)23.2,20.06
*23.20 I (AA-0101)23.21,2.1
*23.21 I (AA-0S) 23.22,23.01
*23.22 I (AA-0PV)23.23,24.2
*23.23 I (AA-0A)23.24,2.01
*23.24 I (AA-0Q)23.25,24.1
*23.25 I (AA-0DT)23.26,26.05
*23.26 T "PT-----PRINT CHRONOGRAPH TIMES",!
*23.30 T "PKY-----PRINT X-Y COORDINATES",!
*23.31 T "L N2,N3--LIST RDS. N2 TO N3",!
*23.32 T "101-----RUN PROG. 101 DESPERSION",!
*23.33 T "V-----PRINT AVERAGE VELOCITY",!
*23.34 T "PV-----PRINT ALL VELOCITIES",!
*23.35 T "DT N1----DELETE TEST NO.",!
*23.36 T "RR-----RESTORE ALL ROUNDS",!
*23.38 T "A-----CALCULATE ACCURACY",!
*23.39 T "RT-----RESTORE ALL TESTS",!
*23.40 T "S-----PLOT ALL SELECTED POINTS",!
*23.98 T "Q-----QUIT",!
*23.99 G 23.01
*
*24.01 C***RESTORE ALL DELETED RDS.***
*24.03 F I=1,NN; S N(I)=I
*24.05 S N=NN; G 23.01
*24.10 QUIT
*24.11 S SV=0; D 2.12
*24.12 F I=1,N; D 25.1; D 25.11; D 25.13
*24.14 D 24.8; D 24.81; D 24.82; G 24.85
*24.20 T "***PRINT ALL VELOCITIES*** TEST ",%5,K1,!
*24.30 D 2.12
*24.40 T "RD. NO. VELOCITY (FT./SEC.)",!
*24.50 S SV=0
*24.60 F I=1,N; D 25
*24.80 T !, "AVERAGE VELOCITY ",%8.02,SV/N," FOR ",%3,N," RDS.",!
*24.81 T "HIGHEST VEL.",%8.02,LX,!
*24.82 T "LOWEST VEL. ",%8.02,MX,!
*24.85 T !!!!!; G 23.01
*
*25.10 S T3=FT((N(I)),3)/1000000; S V=(D5/T3)/12
*25.11 S SV=SV+V
*25.12 T %3,I," ",%8.02,V,!
*25.13 S X=V; D 3; D 5
*25.14 R
*
*26.05 C***DELETE ROUND***
*26.10 A %3,N1
*26.16 F I=1,N; D 27
*26.18 G 23.01
*
*27.05 I (N(I)-N1)27.4,27.1,27.1
*27.10 I (I-N)27.16,27.2,27.16
*27.16 S N(I)=N(I+1); R
*27.20 S N=N-1; R
*27.40 R
*

```

```

*28.01 S P1=0;S P2=0
*28.02 T !,"TEST NO. ",%3,K1,!!!," "
*28.03 T "0000000000011111111122222222223333333333344444444445555555555"
*28.04 T !," ";F L=1,6;T "0123456789"
*28.08 T !
*28.10 G 13.1 -
*28.11 C***PLOT X-Y***
*28.12 S I=1;D 12;T !,%2,FITR(FABS(Y)),#;S X2=X;D 28.3;D 28.4
*28.15 F I=2,N;D 28.18;D 28.19;D 28.3;D 28.4;
*28.17 T !!!;G 23.01
*28.18 S I=I-1;D 12;S Y1=FABS(Y);S I=I+1;D 12;S Y2=FABS(Y);S X2=X
*28.19 I (FITR(Y1)-FITR(Y2))/28.2,28.25,28.2
*28.20 F J=FITR(Y1)+1,FITR(Y2);T !,%2,J,#
*28.25 T #
*28.30 F K=-1,FITR(X2);T " "
*28.40 T "+"
*****

```

The following subroutines are written in Digital Equipment Corporation's PAL III assembly language and are overlays to and interfaces with FOCAL.

Subroutine XFILL fills core in field 1 with chronograph BCD data.

Subroutine XFT retrieves this data, converts the BCD to FOCAL floating point variables and interfaces with FOCAL.

There are two sources of information which are helpful in setting up programs. They are: "Focal, How to Write New Subroutines and Use Internal Routines"¹, and overlays² from the Bedford Computer System, Inc. for the digitizing table.

¹Doug Wrege, "Focal, How to Write New Subroutines and Use Internal Routines", Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, circa 1970, 37 pp.

²Private communication from Bedford Computer System, Inc., 14616 Southland Lane, Rockville, Maryland 20850.

AARRAY	4571
ABLOCK	4676
ACONV1	4572
ACOUNT	4577
AGET	4573
ALIMIT	4570
APOINT	4557
ARG	4647
ARRAY	4631
ASTO	4574
AXX10	4567
BLOCK	4576
CONV	4515
CONV1	4600
COUN1	4645
COUN11	4556
C0002	4563
C0013	4575
C0017	4616
DEL	4410
DELAY	4564
DELAY1	4565
DELAY2	4566
END	4421
FLPC	4610
GET	4660
LIMIT	4617
LLOP1	4405
LOOP	4415
MCOMMA	4657
M101	4646
POINT	4675
PTABLE	4560
RD	4430
SD	4666
TEMP	4561
TEMP1	4562
TIME	4555
XFILL	4400
XF1	4456
XF2	4510
XF3	4512
XX1	4501
XX10	4613

EXPUNGE
FIXMRI AND=0000
FIXMRI TAD=1000
FIXMRI ISZ=2000
FIXMRI DCA=3000
FIXMRI JMS=4000
FIXMRI JMP=5000
FIXMRI FADD=1000
FIXMRI FDIV=3000
FIXMRI FMUL=4000
FLAC=44
FEXT=0
FINT=JMS I 7
HLT=7402
CAF=6007
IOF=6002
SXF=7410
CMA=7040
CLL=7100
CLA=7200
IAC=7001
SZA=7440
SNA=7450
SMA=7500
RTL=7006
RTR=7012
TABLE=126
ERROR3=4566
ERROR2=4566
EFUN3I=136
BOTTEM=35
FNTABF=374
FNTABL=2165
INTEGER=53
BOFR=60
ENDT=135
START=4400
CHAR=66
PUSHJ=4540
EVAL=1613
POPJ=5541
FIXTAB
PAUSE

```

*BOTTEM
0035 4377 START-1
*BOFFN
0060 0750 TABLE+622
*ENDT
0135 0750 TABLE+622
*FNTABF+14
0410 4400 XFILL
0411 4456 XFT
*FNTABL+14
2231 0316 316 /FNLL ASCII "G"
2202 0324 324 /FT ASCII "I"
*START
4400 4770 XFILL, JMS I ALIMIT
4401 3356 DCA COUNT1
4402 1360 TAD PTABLE
4403 3757 DCA I APOINT
4404 7000 7000 /NOP
4405 7000 LLOP1, 7000 /NOP
4406 1364 TAD DELAY
4407 3365 DCA DELAY1
4410 2366 DEL, ISZ DELAY2
4411 5215 JMP LOOP
4412 2365 ISZ DELAY1
4413 5210 JMP DEL
4414 5221 JMP END
4415 6153 LOOP, 6153
4416 7410 SKP
4417 5230 JMP RD
4420 5210 JMP DEL
4421 7200 END, CLA
4422 1375 TAD C0013
4423 3044 DCA FLAC
4424 3046 DCA FLAC+2
4425 1356 TAD COUNT1
4426 3045 DCA FLAC+1
4427 5536 JMP I EFUV3I
4430 7200 RD, CLA
4431 3366 DCA DELAY2
4432 6144 6144 /READ 454
4433 4774 J4S I ASTO
4434 6154 6154 /READ LSW & RESET
4435 4774 J4S I ASTO
4436 6173 6173 /SKP IF FLAG SET
4437 5236 JMP --1 /NO THEN LOOP
4440 6164 6164 /YES READ 454

```

4441	4774	JMS I ASTO
4442	6174	6174 /READ LSW
4443	4774	JMS I ASTO
4444	6323	6323 /FLAG 32 SET?
4445	5244	JMP --1 /NO: LOOP
4446	6314	6314 /YES: READ MSW
4447	4774	JMS I ASTO
4450	6324	6324 /READ LSW & RESET
4451	4774	JMS I ASTO
4452	2356	ISZ COUNT1
4453	2777	ISZ I ACCOUNT
4454	5205	JMP LLOP1
4455	5221	JMP EVD
4456	4770	XFT, JMS I ALIMIT
4457	4771	JMS I AARRAY
4460	4540	PUSHJ
4461	4647	ARG
4462	7402	HLT /ERROR
4463	4453	JMS I INTEGER
4464	7041	CMA IAC /NEG IN AC
4465	3355	DCA TIME
4466	1376	TAD BLOCK
4467	2355	ISZ TIME
4470	7410	SKP
4471	5301	JMP XX1
4472	2355	ISZ TIME
4473	7410	SKP
4474	5310	JMP XF2
4475	2355	ISZ TIME
4476	7410	SKP
4477	5312	JMP XF3
4500	7402	HLT /ERROR
4501	1360	XX1, TAD PTABLE
4502	3757	DCA I APOINT
4503	4773	JMS I AGET
4504	3361	DCA TEMP /LSW
4505	4773	JMS I AGET
4506	3362	DCA TEMP1 /LSW
4507	5315	JMP CONV
4510	1363	XF2, TAD C0002
4511	5301	JMP XX1
4512	1363	XF3, TAD C0002
4513	1363	TAD C0002
4514	5301	JMP XX1

4515	7344	COV,	CLA CLL	
4516	3044		BCA FLAC	
4517	3245		BCA FLAC+1	
4520	3046		BCA FLAC+2	
4521	1361		TAD TEMP	
4522	7112		RTR CLL	
4523	7012		RTR	
4524	7012		RTR	
4525	7012		RTR	
4526	4772		JMS I ACONV1	
4527	1361		TAD TEMP	
4530	7112		RTR CLL	
4531	7012		RTR /MS BCD	
4532	4772		JMS I ACONV1	
4533	1361		TAD TEMP	
4534	4772		JMS I ACONV1	
4535	1362		TAD TEMP1	
4536	7112		RTR CLL	
4537	7012		RTR	
4540	7012		RTR	
4541	7012		RTR	
4542	4772		JMS I ACONV1	
4543	1362		TAD TEMP1	
4544	7112		RTR CLL	
4545	7012		RTR	
4546	4772		JMS I ACONV1	
4547	1362		TAD TEMP1	/LS BCD
4550	4772		JMS I ACONV1	
4551	4407		FINT	
4552	3767		FDIV I AXX10	
4553	0000		FEXT	
4554	5536		JMP I EFUN3I	
4555	0000	TIME,	0	
4556	0000	COUNT1,	0	
4557	4675	APOINT,	4675	
4560	0126	PTABLE,	TABLE	
4561	0000	TEMP,	0	
4562	0000	TEMP1,	0	
4563	0002	C0002,	2	
4564	7700	DELAY,	7700	
4565	0000	DELAY1,	0	
4566	0000	DELAY2,	0	
4567	4613	AXX10,	4613	
4570	4617	LIMIT,	4617	
4571	4631	AARRAY,	4631	
4572	4600	ACONV1,	4600	
4573	4660	AGET,	4660	
4574	4666	AST0,	4666	
4575	0013	C0013,	0013	
4576	0000	BLOCK,	0000	
4577	4645	ACOUNT,	4645	

		*4600	
4600	0000	CONVI,	0
4601	0216		AND C0017 /MASK & GET BCD
4602	3211		DCA FLPC+1
4603	4407		FINT
4604	1210		FADD FLPC /CONVERT FROM BCD
4605	4213		F MUL XX10 / TO FLOATING PT.
4606	0000		FEXT
4607	5600		JMP I CONVI
4610	0013	FLPC,	13
4611	0000		0
4612	0000		0
4613	0004	XX10,	4
4614	2400		2400
4615	0000		0
4616	0017	C0017,	0017
4617	0000	LIMIT,	0
4620	4453		JMS I INTEGER
4621	3245		DCA COUNT
4622	1245		TAD COUNT
4623	7450		SNA
4624	7402		HLT /ERROR
4625	1246		TAD M101
4626	7700		SMA CLA
4627	7402		HLT /ERROR
4630	5617		JMP I LIMIT
4631	0000	ARRAY,	0
4632	7040		CMA
4633	1245		TAD COUNT /SUBTRACT 1 FROM COUNT
4634	3245		DCA COUNT
4635	1245		TAD COUNT
4636	1245		TAD COUNT
4637	1245		TAD COUNT
4640	1245		TAD COUNT
4641	1245		TAD COUNT
4642	1245		TAD COUNT /MUL COUNT BY 6
4643	3676		DCA I ABLOCK
4644	5631		JMP I ARRAY /BLOCK CONTAINS APP. BLOCK
4645	0000	COUNT,	0
4646	7633	M101,	-145
4647	1066	ARG,	TAD CHAR
4650	1257		TAD MCOMMA
4651	7640		SZA CLA /A COMMA?
4652	5256		JMP .+4 /YES: EXIT VIA POPJ
4653	4540		PUSHJ
4654	1612		EVAL-1
4655	7001		IAC
4656	5541		POPJ
4657	7524	MCOMMA,	7524
4660	0000	GET,	0
4661	6211		6211

4662	1675		TAD I POINT
4663	6201		6201
4664	2275		ISZ POINT
4665	5660		JMP I GET
4666	0000	STO,	0
4667	6211		6211
4670	7040		CMA /COMP. OF LCD RECIEVER
4671	3675		DCA I POINT
4672	6201		6201
4673	2275		ISZ POINT
4674	5666		JMP I STO
4675	0000	POINT,	000
4676	4576	ABLOCK,	4576

AAARRAY	4571
ABLOCK	4676
ACONV1	4572
ACOUNT	4577
AGET	4573
ALIMIT	4570
APOINT	4557
ARG	4647
ARRAY	4631
ASTO	4574
AXX10	4567
BLOCK	4576
CONV	4515
CONV1	4600
QUNT	4645
QUNT1	4556
Q0002	4563
Q0013	4575
Q0017	4616
DEL	4610
DELAY	4564
DELAY1	4565
DELAY2	4566
END	4421
FLPC	4610
GET	4660
LIMIT	4617
LLOP1	4405
LOOP	4415
MCOMMA	4557
M101	4646
POINT	4675
PTABLE	4560
RD	4430
STO	4666
TEMP	4561
TEMP1	4562
TIME	4555

The following external ballistic program is written in FOCAL and used to establish the effective muzzle velocity given the ballistic screen velocity and location downrange. Other input requirements are documented in the program. This program provides engineering approximations and can be used for any caliber and configuration projectile.

Due to core requirements of the PDP 8, program accuracy is limited; however, this accuracy is well within test requirements.

The program was originated at Rodman Laboratory, Rock Island Arsenal by Dennis D. Ladd.

W A

C-8K FOCAL @1976

01.01 T !!!!!!!!, "***EXTERNAL BALLISTICS PROGRAM***V5",!
01.02 C THIS PROGRAM USES COL. MAYEVSKI'S BRACKET FUCTION
01.04 C OBTAINED FROM FIRINGS DONE BY KRUPP AT MEPPEN GERMANY
01.06 C (1881) USEING A PROJECTILE 3 CAL. LONG ; 2 CAL. OGIVAL
01.08 C HEAD RADIUS ; WEIGHT 1 LB. ; DIA. 1 IN.. THIS SAME PROJECTILE
01.10 C WAS FIRED BY THE GAVRE COMMISSION (1918) RESULTING IN THEIR
01.12 C G-FUNCTION . ONLY SLIGHT MODIFICATIONS WERE MADE FOR A.P.G.'S
01.14 C G1-FUNCTION.
01.16 C THE FORM FACTOR (I) CORRECT DIFFERENCES BETWEEN THE ABOVE
01.18 C STANDARD PROJECTILE AND THE PROJECTILE BEING EVALUATED.
01.20 C THIS FACTOR MAY BE OBTAINED FROM THE REF. NOTED BELOW.
01.22 E

02.01 A "PROJECTILE WEIGHT (GRAINS) ? ",%,W0
02.02 S $W=W0/7000$
02.04 A "PROJECTILE DIAMETER (MM) ? ",%,D0
02.06 S $D=D0*.03937$
02.08 A "AIR DENSITY RAITO ? ",%,DR
02.10 C REF. HATCHER'S NOTEBOOK P.574 & 430
02.12 A "FORM FACTOR ? ",%,I
02.14 C REF. HATCHER'S NOTES P.571 & 572 OR "SHORT CUT TO BALLISTICS"
02.16 S $C=DR*W/(I*D^2)$

03.01 A "VELOCITY (FT/SEC) & RESPECTIVE RANGE (IN,) ?? ",%,VX,XX
03.02 S $XX=XX/12$
03.03 A "MAXIMUM RANGE (M) ? ",%,XE
03.04 S $XE=XE*3.280833$
03.06 A "RANGE INCREMENT (M) ? ",%,XI
03.07 C INCREMENT IS CRITICAL TO ACCURACY !!
03.08 S $XI=XI*3.280833$
03.10 A "ANGLE OF ELEVATION (DEGREES) ? ",%,TH; S $TH=TH*3.1416/180$

04.01 S $V=VX; D 10$
04.02 S $AX=R/C$
04.04 S $V0=FSQT(VX^2+2*AX*XX)$
04.06 S $V=V0; D 10$
04.08 S $AF=R/C; S AX=(AF+AX)/2; D 4.04$

```

05.01 T !!!
05.02 T "PROJECTILE WEIGHT      :",%5.04,W," LBS.",!
05.04 T "PROJECTILE DIAMETER    :",%5.04,D," INCHES",!
05.06 T "FORM FACTOR            :",%5.04,I,!
05.08 T "AIR DENSITY RAITO      :",%5.04,DR,!
05.10 T "BALLISTIC COEFFICIENT  :",%5.04,C,!
05.11 T "MUZZLE VELOCITY        :",%5.02,V0," FT/SEC",!!
05.14 T "                        REMAINING          TOTAL          TRAJECTORY"!
05.16 T " RANGE      TIME      HORZ. VEL.          VELOCITY          DROP ",!
05.18 T " (M)      (SEC)      (FT/SEC)          (FT/SEC)          (FT) ",!!

```

```

06.01 S V1=V0*FCOS(TH); S V3=V1
06.02 S V2=V0*FSIN(TH); S V4=V2
06.04 S X=0; S Y=0; S T=0
06.06 D 7.18; D 7.20
06.08 F X=XI,XI,XE; D 7
06.10 QUIT

```

```

07.02 S V=V3; D 10; S A0=R/C
07.04 S V5=FSQT(V3+2-2*A0*X1)
07.06 S T1=2*(1/(V3+V5))
07.08 S V3=V5
07.10 S V6=V4-32.16*T1
07.12 S T=T+T1
07.14 S Y=Y+T1*(V4+V6)/2
07.16 S V4=V6
07.18 T %5.00,X/3.280833,%8.05,T,%8.01,V3,%15.01,FSQT(V3+2+V4+2)
07.20 T "      ",%8.04,Y,!

```

```

10.01 C MAYEVSKI RETARDATION FUCTION (R=A*V+M) FT/SEC+2
10.02 I (840-V)10.04
10.03 S S5=V+38; D 11.02; S R=7.442E-04*V*S6; R
10.04 I (1040-V)10.08
10.06 S R=5.9939E-08*V+3; R
10.08 I (1190-V)10.12
10.10 S S5=V+29; D 11.02; S R=2.3385E-18*V+6*S6; R
10.12 I (1460-V)10.16
10.14 S R=9.5408E-08*V+3
10.16 I (2000-V)10.20
10.18 S S5=V+51; D 11.02; S R=5.9814E-04*V*S6; R
10.20 I (2600-V)10.24
10.22 S R=5.8495E-03*V*FSQT(V); R
10.24 I (4000-V)10.28
10.26 S S5=V+43; D 11.02; S R=1.5366E-03*V*S6; R
10.28 T "VELOCITY OUT OF RANGE",!
10.30 QUIT

```

```

11.01 C S6= 64 TH ROOT OF S5
11.02 S S6=FSQT(FSQT(FSQT(FSQT(FSQT(FSQT(S5))))))
*
```

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APPENDIX B
SYSTEM ACCURACY

The following ASR output is from the paper target (Figure B-1) using the digitizing table. These X and Y coordinates, as explained earlier, are to be considered actual within $\pm .05$ inches. The statistics are also considered accurate and can be compared to the ATD output.

TEST NO. & DATE: 454, 2JUN76
 WEAPON & S/N: XXXXXXXXXX
 VERTICAL SUPPORT: YES
 SPRING RATE & DAMPING: 65K, .3
 30 MM XM639B1 AMMO LOT: LC-13-002
 NUMBER OF ROUNDS: 20

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

EXTREME VERTICAL 9.61 MILLS
 EXTREME HORIZONTAL 10.85 MILLS
 EXTREME SPREAD 11.86 MILLS
 MEAN RADIUS 2.49 MILLS
 STANDARD DEVIATION X 2.59 MILLS
 STANDARD DEVIATION Y 1.80 MILLS
 STANDARD DEVIATION R 1.85 MILLS

CENTER OF IMPACT:

X 0.62 MILLS
 Y - 5.67 MILLS

FROM RD # 2

*** X-Y COORDINATES ***

RD NO	X	Y
1	6.94	- 9.62
2	0.00	- 0.00
3	- 3.90	- 5.18
4	- 3.81	- 7.56
5	- 2.79	- 4.52
6	- 0.86	- 5.59
7	3.22	- 5.85
8	3.05	- 4.57
9	- 0.25	- 5.28
10	1.51	- 6.40
11	0.00	- 5.46
12	- 1.37	- 5.92
13	- 0.21	- 5.88
14	0.22	- 4.97
15	1.31	- 5.94
16	3.23	- 6.75
17	1.09	- 4.50
18	0.04	- 7.27
19	2.10	- 6.69
20	2.31	- 5.50

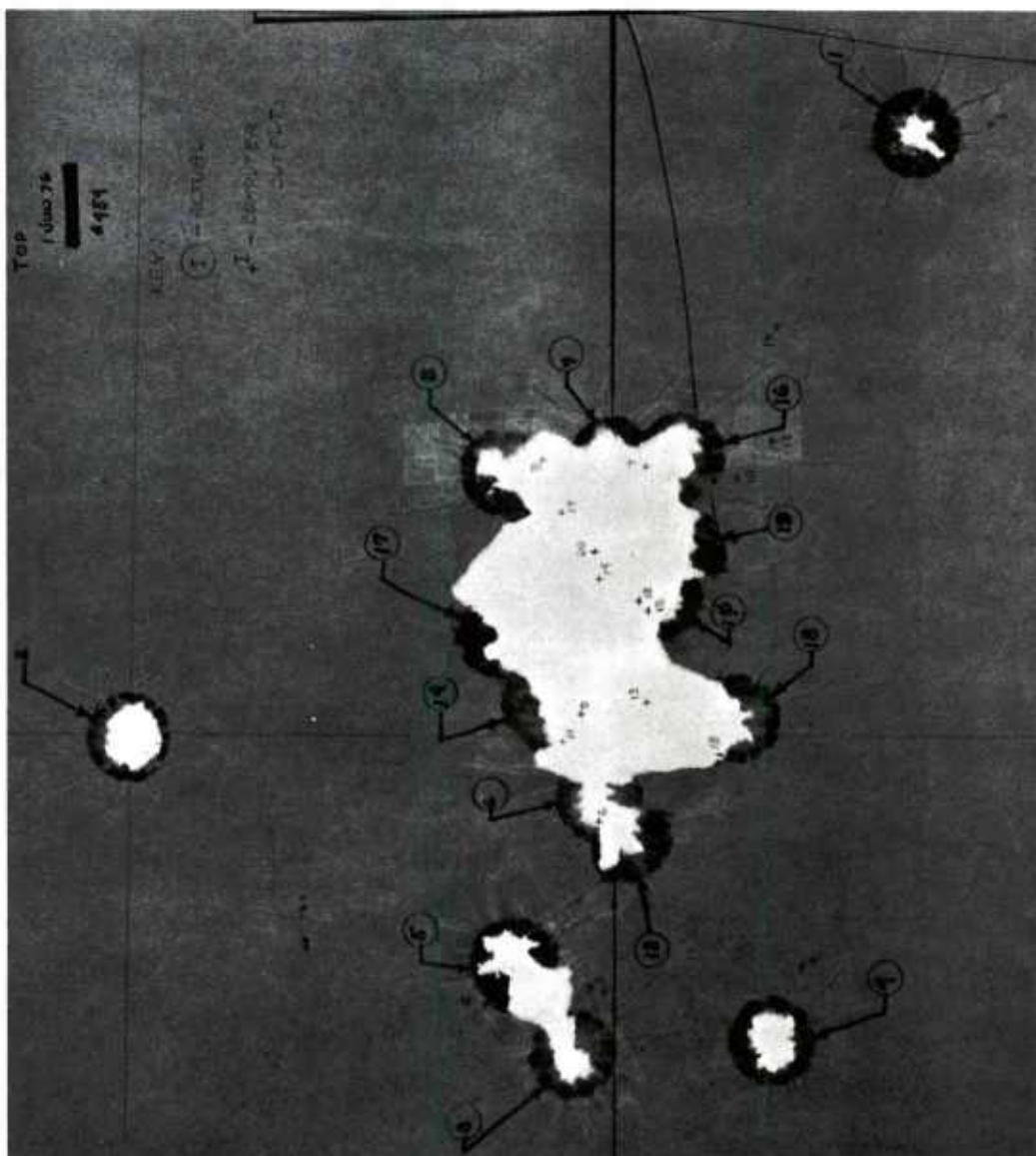


FIGURE B-1. COLOR CODED PAPER TARGET

TEST NO. & DATE: 454, 200076
 WEAPON & S/N: XXXXXXXXXX
 VERTICAL SUPPORT YES
 SPRING RATE & DAMPING: 65K, .3
 30 MM XM639B1 AMMO LOT: LC-13-002
 NUMBER OF ROUNDS: 20

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

EXTREME VERTICAL 9.61 MILLS
 EXTREME HORIZONTAL 10.85 MILLS
 EXTREME SPREAD 11.86 MILLS
 MEAN RADIUS 2.49 MILLS
 STANDARD DEVIATION X 2.59 MILLS
 STANDARD DEVIATION Y 1.80 MILLS
 STANDARD DEVIATION R 1.85 MILLS

CENTER OF IMPACT:

X 0.62 MILLS
 Y - 5.67 MILLS

RD # 2

*** X-Y COORDINATES ***

RD NO	X	Y
1	6.94	- 9.62
2	0.00	- 0.00
3	- 3.90	- 5.18
4	- 3.81	- 7.56
5	- 2.79	- 4.52
6	- 0.86	- 5.59
7	3.22	- 5.85
8	3.05	- 4.57
9	- 0.25	- 5.23
10	1.51	- 6.40
11	0.00	- 5.46
12	- 1.37	- 5.92
13	- 0.21	- 5.88
14	0.22	- 4.97
15	1.31	- 5.94
16	3.23	- 6.75
17	1.09	- 4.50
18	0.04	- 7.27
19	2.10	- 6.69
20	2.31	- 5.50

#PXY

***X-Y COORDINATES *** TEST 454

RD.	NO.	X	Y
2	-	0.00	0.00
5	-	3.29	4.33
8	-	3.46	4.90
11	-	0.05	5.15
17	-	2.73	5.17
9	-	0.21	5.37
6	-	1.17	5.50
20	-	2.24	5.52
3	-	2.98	5.58
14	-	1.89	5.63
12	-	1.69	5.96
13	-	0.42	6.11
7	-	3.44	6.23
15	-	1.57	6.32
10	-	3.16	7.16
18	-	0.15	7.44
19	-	3.57	7.67
16	-	5.14	7.79
4	-	2.74	8.17
1	-	7.47	10.13

#RR

#PXY

***X-Y COORDINATES *** TEST 454

RD.	NO.	X	Y
1	-	7.47	10.13
2	-	0.00	0.00
3	-	2.98	5.58
4	-	2.74	8.17
5	-	3.29	4.33
6	-	1.17	5.50
7	-	3.44	6.23
8	-	3.46	4.90
9	-	0.21	5.37
10	-	3.16	7.16
11	-	0.05	5.15
12	-	1.69	5.96
13	-	0.42	6.11
14	-	1.89	5.63
15	-	1.57	6.32
16	-	5.14	7.79
17	-	2.73	5.17
18	-	0.15	7.44
19	-	3.57	7.67
20	-	2.24	5.52

#PXY

***X-Y COORDINATES *** TEST 454

RD. NO. X Y
5 34.68 - 5700.00 @ 20.20

*S P1=37.97; S P2=48.26

*G 23.01

#PXY

***X-Y COORDINATES *** TEST 454

RD.	NO.	X	Y
5	-	3.29	- 4.33
3	-	2.98	- 5.58
4	-	2.74	- 8.17
12	-	1.69	- 5.96
6	-	1.17	- 5.50
18	-	0.15	- 7.44
11	-	0.05	- 5.15
2	-	0.00	- 0.00
9	-	0.21	- 5.37
13	-	0.42	- 6.11
15	-	1.57	- 6.32
14	-	1.89	- 5.63
20	-	2.24	- 5.52
17	-	2.73	- 5.17
10	-	3.16	- 7.16
7	-	3.44	- 6.23
8	-	3.46	- 4.90
19	-	3.57	- 7.67
16	-	5.14	- 7.79
1	-	7.47	- 10.13

#S

TEST NO. 454

000000000001111111112222222222333333333344444444445555555555
012345678901234567890123456789012345678901234567890123456789

48
49
50
51
52
53
54
55
56
57
58

+

+
+ + + + + +
+ + +
+ +
+ +

+

#C

*S AZ=101
*G 23.01
#S

TEST NO. 454

000000000011111111112222222222333333333344444444445555555555
012345678901234567890123456789012345678901234567890123456789

48
49
50
51
52
53

+ 2

+ 5

+ 8

+ 11

+ 17

+ 9

+ 6

+ 20

+ 3

+ 14

54

+ 12

+ 13

+ 7

+ 15

55

+ 10

+ 18

+ 19

56

+ 16

+ 4

57

58

+ 1

AMMO & CAL. : XM639B1, 3044
 AMMO LOT NUMBER : LC-13-002
 GUN & S/N [REDACTED]
 VERTICAL RESTRAINT : YES
 TEST NUMBER : 454
 SPRING RATE & DAMPING : 65K, .3
 DATE : 1JUNE76
 NO. RDS.= 20

AVERAGE VELOCITY 2253.51 FOR 20 RDS.
 HIGHEST VEL. 2285.40
 LOWEST VEL. 2232.91

*** DESPERSION*** TEST 454

EXTREME VERTICAL	10.13	MILLS
EXTREME HORIZONTAL	10.76	MILLS
MEAN RADIUS	2.82	MILLS
STANDARD DEVIATION X	2.83	MILLS
STANDARD DEVIATION Y	1.97	MILLS
STANDARD DEVIATION R	1.38	MILLS
FIGURE OF MERIT	10.44	
NUMBER OF ROUNDS	20	

***X-Y COORDINATES *** TEST 454
 CENTER OF IMPACT

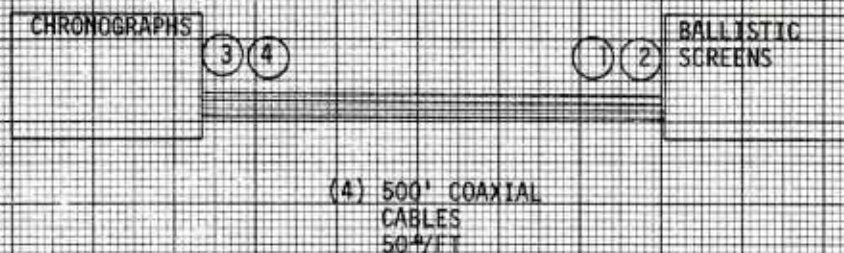
RD.	NO.	X	Y
1		6.31	- 4.12
2	-	1.17	6.00
3	-	4.14	0.42
4	-	3.90	- 2.17
5	-	4.45	1.68
6	-	2.33	0.50
7		2.27	- 0.22
8		2.30	1.11
9	-	0.95	0.64
10		2.00	- 1.16
11	-	1.21	0.86
12	-	2.85	0.05
13	-	0.74	- 0.10
14		0.73	0.37
15		0.41	- 0.32
16		3.98	- 1.78
17		1.57	0.83
18	-	1.31	- 1.43
19		2.41	- 1.66
20		1.08	0.48

This page is intentionally left blank.

APPENDIX C

CHRONOGRAPH/BALLISTIC SCREEN INTERFACE

The interface pulses between the chronographs and the ballistic screens are relevant in observing proper operation of the system. Page C-3 shows the pulse shape for the test conditions (oscilloscope readings) 1, 2, 3, and 4. The effects of line capacitance and impedance mismatch can be seen in test 3 and 4. Page C-4 shows the pulse time relationship as obtained from a 4 channel storage tube oscilloscope for test condition 1. The positive active chronographs will then record times T1, T2, and T3. Page C-5 is a listing of the times T1, T2, and T3 in microseconds from the computer core. The actual number of rounds fired was 30. The 2nd, 3rd, 4th, 28th, and 30th test number would be deleted automatically by the computer for further calculations. The program will then obtain a renumbering for the rounds. The program can actually delete either the erroneous test number or round number on command. The distinction between erroneous test number and round number is obvious in this example due to the extra pulse received in test 2, because all three times are beyond reasonable limits. Once acceptable criteria for the distinction is made, the program could be improved to automatically perform this operation. Pages C-6 through C-8 are TEXTRONIX 4010 printouts of the respective screen plane pulses. The screen printouts can be compared directly to the listing on page C-5. Erroneous pulses shown on page C-8 are eliminated by the one-shot action of the chronographs. A 10 volt cut-off of the pulses is due to A/D saturation. The elimination of erroneous pulses from page C-8 to the print-out on page C-5 illustrates the effectiveness of the setup.

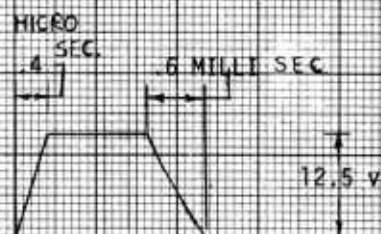


SPECS. for MODEL 55 Oehler Ballistic screens

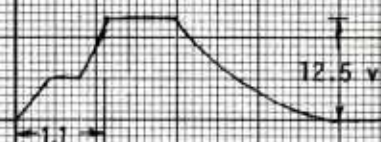


Oscilloscope readings:

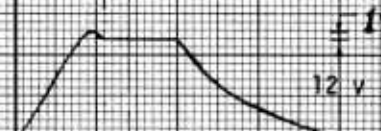
① at screens without cables connected



② at screens with cables connected

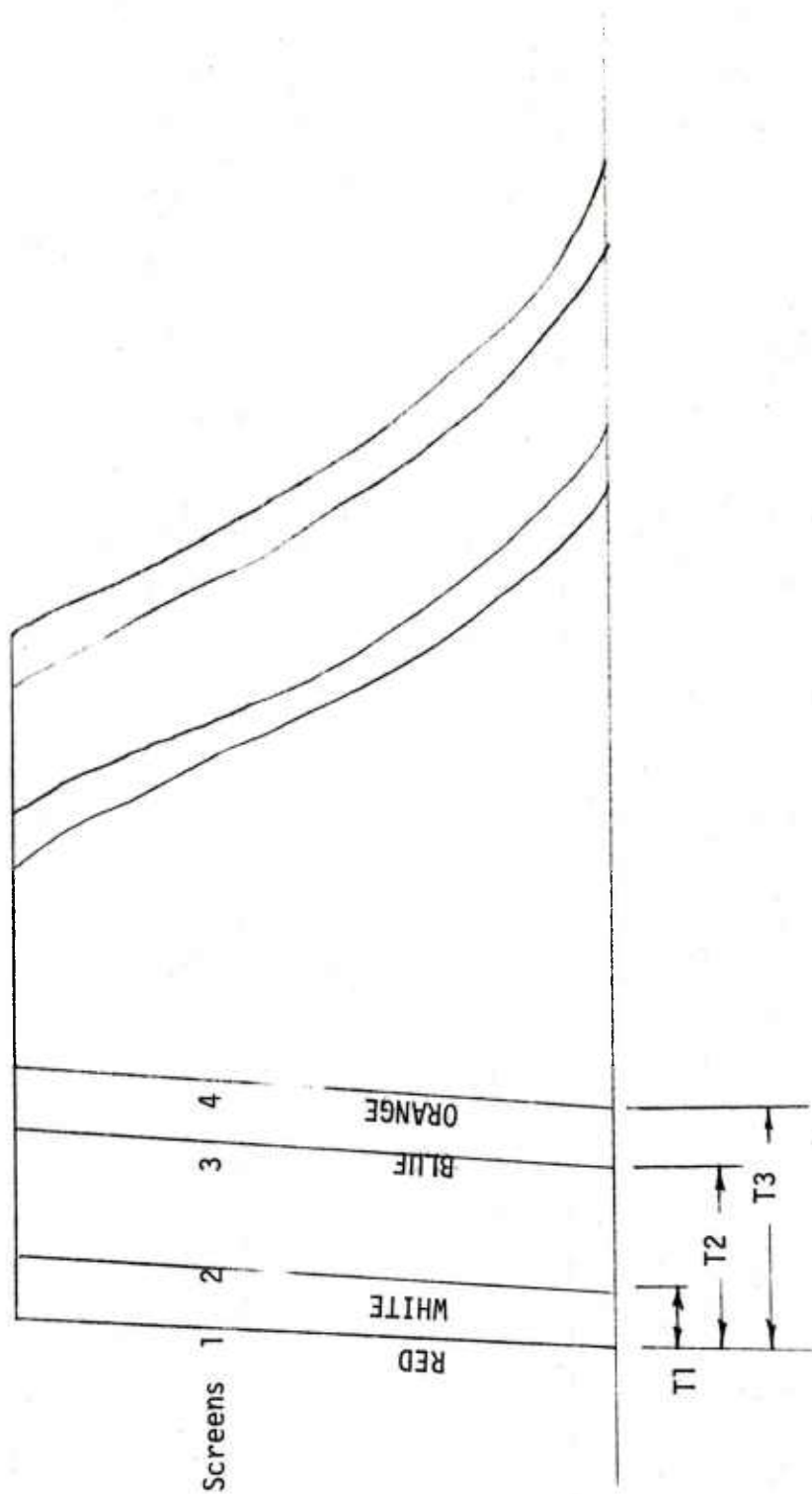


③ at chronographs with chronograph connected



④ at chronograph without chronographs connected





PULSE RELATIONSHIP (See Fig. 4 for Explanation)

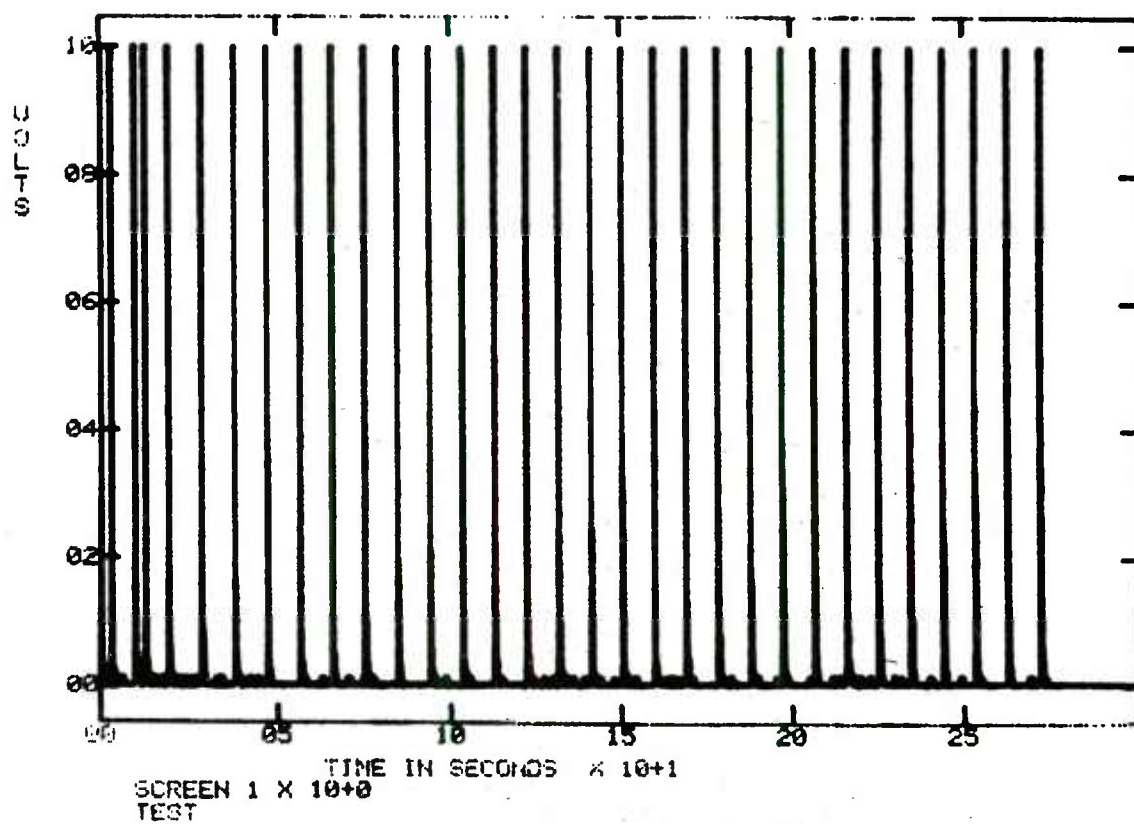
Q
*G

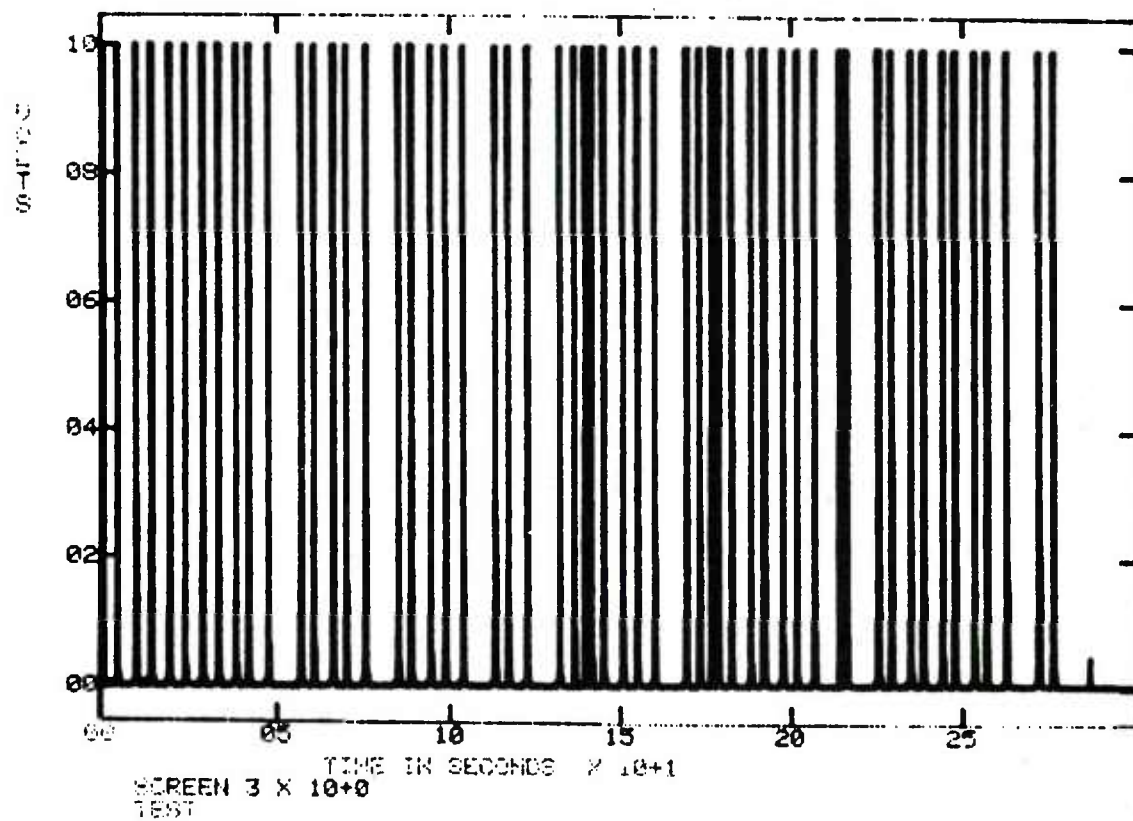
TEST NO. : [REDACTED]
NO. RDS.= 31

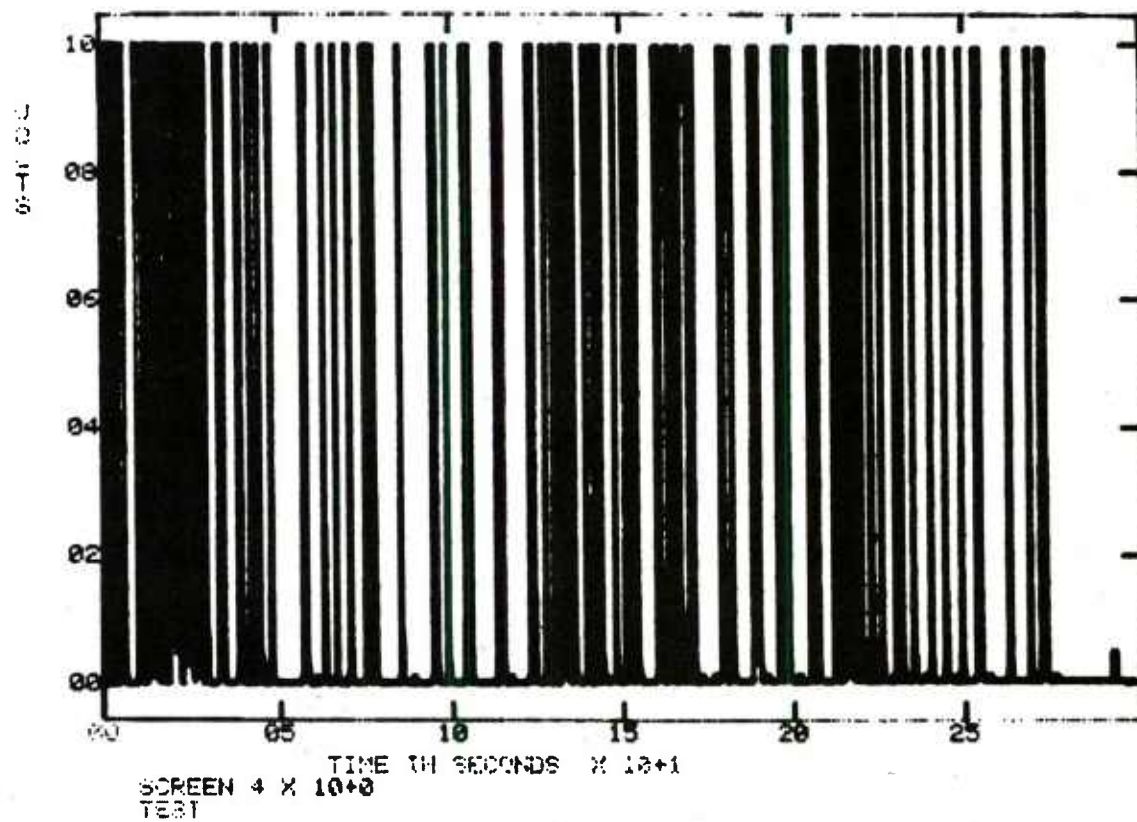
#P1

CHRONOGRAPH TIMES TEST [REDACTED]

TEST NO.	T(1)	T(2)	T(3)
1	1609	3818	4906
2	66184	17384	9503
3	7648	17302	3917
4	1366	3533	17391
5	1457	3473	4784
6	1551	3550	4839
7	1558	3576	4801
8	1450	3698	4818
9	1420	3777	4817
10	1467	3791	4804
11	1498	3784	4810
12	1480	3724	4782
13	1478	3685	4839
14	1404	3584	4726
15	1449	3551	4728
16	1513	3588	4789
17	1480	3639	4793
18	1450	3688	4782
19	1434	3711	4729
20	1429	3701	4707
21	1444	3680	4705
22	1468	3655	4736
23	1439	3629	4796
24	1445	3583	4710
25	1475	3613	4732
26	1464	3669	4803
27	1455	3707	4794
28	17024	3725	4808
29	1434	3688	4723
30	19330	3698	4797
31	1452	3685	4797







APPENDIX D
EQUIPMENT LIST

D-1

DISTRIBUTION LIST

E-1

EQUIPMENT LIST

QTY	DESCRIPTION	APPROXIMATE UNIT COST	APPROXIMATE TOTAL COST
(16)	Model 55 Ballistic Screens Oehler Research Post Office Box 9135 Austin, TX 78756	\$450	\$7,200
(3)	Model 4604 Counter Chronograph (ECI) Electronic Counters, Inc. Englewood, New Jersey	1,000	3,000
(1)	8K PDP 8/E Computer (DEC) Digital Equipment Corp. Maynard, MA	6,000	6,000
(1)	ASR-33 Teletype	1,200	1,200
Software: a. FOCAL-8K 3 word variables		50	50
b. Program listing (inclosed)			
Misc: Interface cabling			
(4)	500 foot section of coaxial cable, 50 Ω impedance	80	320
(6)	computer ribbon cable and		

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Mr. V. Gardy
General Electric Company
Lakeside Avenue
Burlington, VT 05410

2

AO	ACCESSION NO.	UNCLASSIFIED
Commander, Rock Island Arsenal General Thomas J. Rodman Laboratory Rock Island Arsenal, Rock Island, Illinois 61201 Automatic Targeting Device in Support of the XM188/ XM230 Data Acquisition Test (OAT) Prepared By: Dennis O. Helstrom, Robert A. Peterson, and Wayne Piehl Security Class. (of this report): UNCLASSIFIED Technical Report R-TR-76-046 December 1976 65 Pages, Incl Figures, Tables, Illustrations, and Appendices	1. Ballistic Screens 2. Computer Program (TARGET) 3. Chronographs 4. Instrumentation Interface I. Dennis Helstrom, Robert Peterson, and Wayne Piehl II. General Thomas J. Rodman Laboratory III. Keith L. Ware Simulation and Experimental Firing Center DISTRIBUTION Approved for public release; Distribution unlimited.	1. Ballistic Screens 2. Computer Program (TARGET) 3. Chronographs 4. Instrumentation Interface I. Dennis Helstrom, Robert Peterson, and Wayne Piehl II. General Thomas J. Rodman Laboratory III. Keith L. Ware Simulation and Experimental Firing Center DISTRIBUTION Approved for public release; Distribution unlimited.

This report covers the development and operating procedure for a computer operated automatic targeting device. This device automatically obtains and outputs both dispersion coordinates and velocities for an automatic weapon in bursts up to 60 rounds. The chronological order of rounds is maintained. Statistics on dispersion (and accuracy, if point of aim is input to the computer) is also output. Accuracy of this system, with 50% confidence, is within $\pm 1/2$ inch from actual location at 1,000 inches firing 20 rounds at 2,200 ft/sec at a 600 shots per minute. The system cost is approximately \$20K.

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