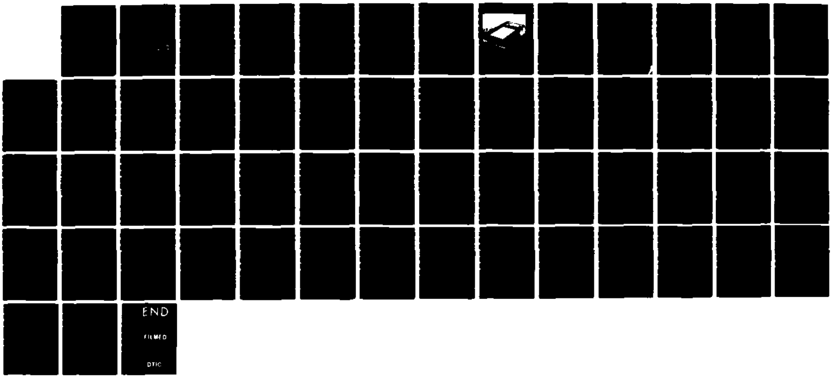
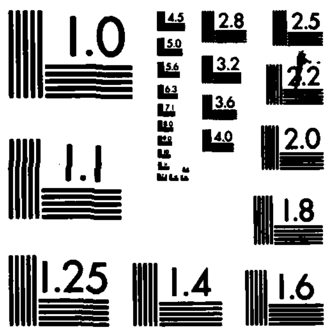
AD-A159 467 ARTILLERY FIRE CONTROL PROGRAM FOR PAAC (PORTABLE ALL ARMS CALCULATOR)(U) WEAPONS SYSTEMS RESEARCH LAB ADELAIDE (AUSTRALIA) R M THAMM FEB 84 WSRL-0362-TR 1/1

UNCLASSIFIED F/G 9/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

WSRL-0362-TR

AR-004-078

# DEPARTMENT OF DEFENCE

## DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

## WEAPONS SYSTEMS RESEARCH LABORATORY

DEFENCE RESEARCH CENTRE SALISBURY
SOUTH AUSTRALIA



## TECHNICAL REPORT

WSRL-0362-TR

# ARTILLERY FIRE CONTROL PROGRAM FOR PAAC

R.M. THAMM







Approved for Public Release



COPY No. 52

UNCLASSIFIED

AR-004-078

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS SYSTEMS RESEARCH LABORATORY

WSRL

TECHNICAL REPORT

WSRL-0362-TR

# ARTILLERY FIRE CONTROL PROGRAM FOR PAAC

R.M. Thamm


## SUMMARY

The "Portable All Arms Calculator" (PAAC) was developed ~~by WSRL~~ to carry out gun fire control applications. This document describes the program developed at Weapons Systems Research Laboratory to demonstrate artillery fire control for the M2A2 gun system on PAAC. Additional keywords: Australia; portable equipment; liquid crystal displays; microprocessors.



POSTAL ADDRESS: Director, Weapons Systems Research Laboratory,
Box 2151, GPO, Adelaide, South Australia, 5001.


UNCLASSIFIED

TABLE OF CONTENTS

LIST OF TABLES

Page

## LIST OF FIGURES

# 1. INTRODUCTION

The "Portable all Arms Calculator" (PAAC) was developed by WSRL to carry out a variety of fire control applications. PAAC is a fully portable device somewhat larger than typical commercial hand-held calculators. The front panel of PAAC has the following features:

(a) Two sixteen-character liquid crystal displays.

(b) A five-by-eight keyboard.

The artillery application version of PAAC (see figure 1) has a Z80 microprocessor, 56 kbytes of erasable programmable read only memory (EPROM) and 8 kbytes of read/write memory (RAM). The power supply consists of rechargeable silver zinc batteries together with a small backup supply to maintain RAM for a few hours so that battery changes can be made without loss of information. RAM is maintained for up to twelve months by the main battery supply when the calculator is switched off. PAAC also features a low battery hardware interrupt.

Information on artillery procedures was provided by the School of Artillery, North Head, NSW. Explanation of artillery procedures and terminology can be found in references 1 and 2 and in various publications produced by the School of Artillery.

Software for the artillery application of PAAC is based on the concept of up to six concurrent missions, each for any grouping out of six guns in an artillery battery. Some of the features are:

(a) targets nominated by grid, target number or by polar coordinates;

(b) meterological corrections either by met message or using registration corrections;

(c) corrections for all nonstandard conditions;

(d) parallel, converge, linear, circular, or range and lateral spread distributions of fire;

(e) crest clearance factor calculation;

(f) thirty stored target positions, which can be calculated by "target reduction" if desired;

(g) the location of up to fifteen forward observers;

(h) safety check for forward observers and up to twelve friendly troop positions;

(i) battery survey and change of grid calculations;

The artillery program requires 48 kbytes of EPROM and 8 kbytes of RAM for the M2A2 gun system. Calculation time (including crest clearance factors) is less than five seconds, once mission data is entered.

The program, as described, provides a demonstration of artillery fire control using PAAC and serves as a basis for further artillery software development as specified by the School of Artillery.

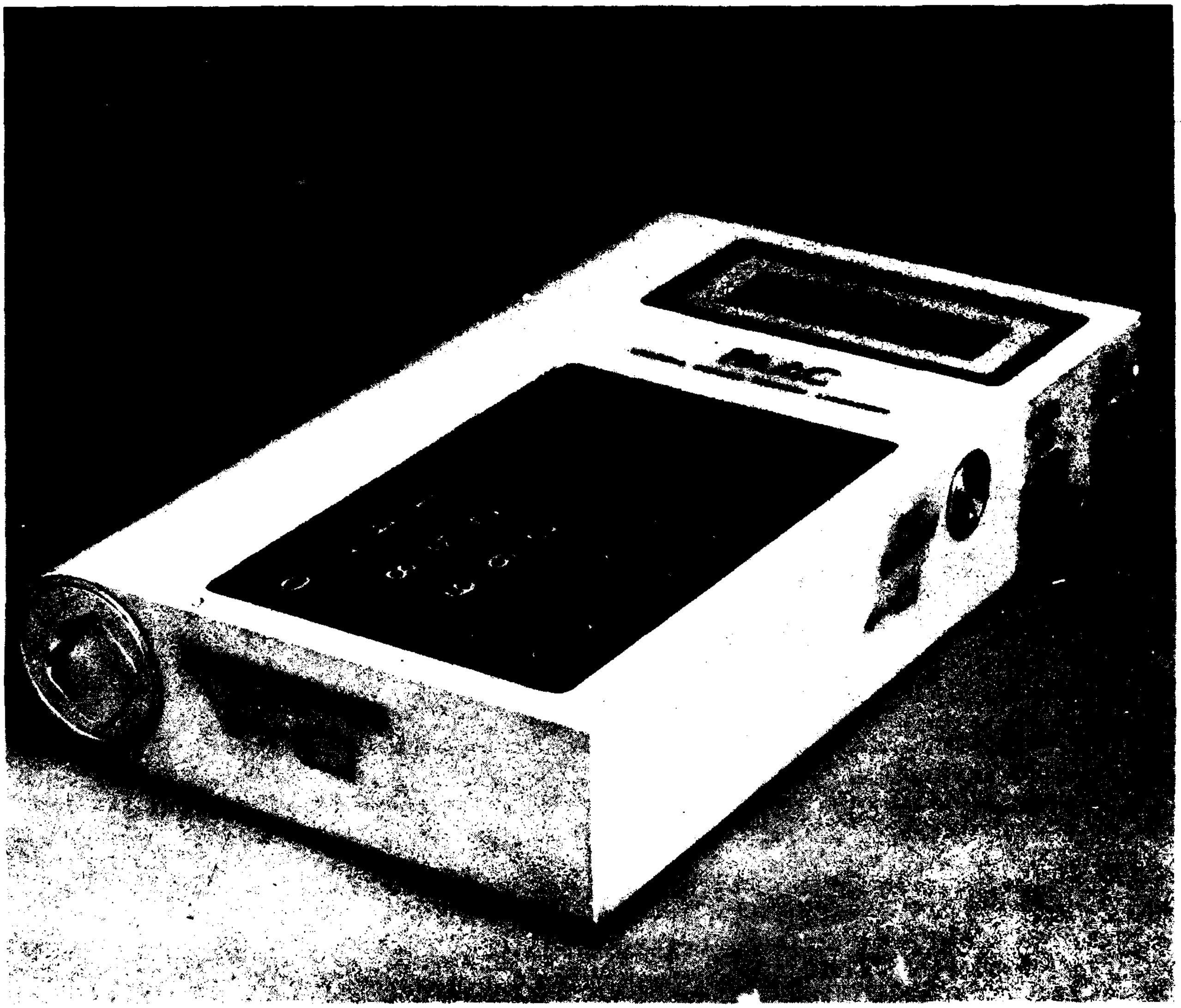


Figure 1. Artillery fire control version of PAAC

## 1.1 Notation

This report was written as a guide for those programmers who will maintain and modify the PAAC artillery fire control program for the M2A2 gun system and those who adapt the program for use with other gun systems. Consequently it was appropiate to use the notation of computer languages rather than standard mathematical notation.

A variable is denoted as an alphanumeric string beginning with a letter, for example, AB or B2. The expression AB * B2 means the quantity AB multiplied by the quantity B2. Arrays of variables are denoted with square brackets around the index. For example, A[J] indicates the Jth element in the array A, A[1..N] denotes an array of N elements and A[I,J] denotes an element of a two dimensional array.

In most of the equations given in this report the actual variable names used in the artillery program are used. These variable names are given in upper case. Quantities represented in lower case correspond to quantities which are stored as temporary variables in the artillery program.

# 2. KEYBOARD AND DISPLAY

## 2.1 Key functions

The keys on the PAAC keyboard have been divided into three categories, namely:

(a) Data entry keys.

(b) Wait-for keys.

(c) Exit-type keys.

### 2.1.1 Data entry keys

The data entry keys are those keys used for entry of data and include the numeric keys (0-9), the decimal point key and the change sign (CHS) key. These keys are used in the conventional way.

### 2.1.2 Wait-for keys

The wait-for keys are used to select different options offered at different points in the program. The following belong to this category:

(1) YES and NO keys

These keys are used mainly to confirm that previously entered data or default values are the required ones. These keys are also used as "menu" selection keys.

(2) CONT and ENTER keys

These keys are the basic menu selection keys. ENTER selects the option presently displayed and CONT displays the next option.

ENTER is also used to terminate data entry.

CONT is also used to continue with the normal sequence when several options are available or when the sequence halts for a display.

(3) CE DEL key

The cancel entry/delete record key is used as an edit key during data entry and as a delete key to cancel saved records.

(4) GUN No key

This key requests a display of fire mission results for a particular gun.

(5) CREST key

This key requests the display of the crest clearance factors of all crests with respect to a particular gun. A display of trajectory vertex height is also shown in the crest sequence.

(6) EXIT key

This key is a reset mission key. It is used to rerun the present fire mission and/or reset the mission profile to standard.

(7) CONV key

This key alternates the distribution of fire between converge and parallel fire.

(8) DISTR key

This key allows the selection of a distribution of fire other than parallel and converge.

(9) H/A key

This key alternates the angle of fire for the mission between high and low angle.

(10) PROJ key

This key allows the selection of ammunition type and round weight.

(11) CH key

This key allows a specific charge to be selected.

(12) CORR REDN key

This key allows the accumulated target location corrections to be saved for use in another mission. The artillery procedures used are registration reduction and laser/witness point reduction.

2.1.3 Exit-type keys

The artillery fire control program for PAAC has been designed as a series of non-terminating modules each of which is selected or exited by use of a series of keys. Selection of one of these exit-type keys returns control to the master routine. The master routine passes control to the module appropiate to the key selected. This approach was adopted to allow greater manoeuverability in the program.

(1) SUD key

This key selects the data set-up module.

(2) TEST PRINT key

This key selects the PAAC test routines.

(3) BTY SVY key

This key selects the survey routine module.

(4) FM and FM POLAR keys

These keys initiate a new fire mission. The first allows the mission target to be specified by target grid or target number, the second is for a polar mission.

(5) CORR and POLAR CORR keys

These keys select the target location correction routines.

(6) RCL FM key

This key causes a previously stored mission to be recalled and rerun.

(7) TGT REDN key

This key is used to store the present mission target or to correct the target location for a new estimate of the target altitude.

(8) ALT/FUZE UP/DOWN key

This key allows the target altitude or burst height for a mission to be altered.

(9) CHG GRID key

The change of grid key allows the battery location and stored target locations to be altered, if required, according to a new estimate of map position and orientation.

(10) MET REGN key

This key allows the entry of meteorological data, the entry of registration corrections and the selection of the meteorological corrections to be applied to a mission.

(11) AMMO key

This key selects an ammunition inventory module.

(12) CALIB key

Discussions with the School of Artillery led to the nomination of this key function. However, the function has not been implimented.

The following keys cause entry into the main fire mission module: FM, FM POLAR, CORR, POLAR CORR, RCL FM, ALT/FUZE. The TGT REDN key causes entry into the main fire mission module if the altitude adjustment option is selected.

### 2.2 Paac display

The PAAC display consists of two sixteen-character displays arranged in two parallel rows.

The upper display is normally reserved for prompts and descriptions of numerical quantities displayed in the lower display.

The lower display is normally reserved for data entry and the display of numerical quantities.

## 3. SET UP DATA

The set-up-data routines allow the entry, display or modification of various data groups. This module is the first selected by the master routine. The sequence of data input is shown in Table 1. The default value of a variable is the value assigned to that variable if no value is specified by the user operating PAAC. The following notes refer to assignments made in the set-up-data routines:

(a) There are no default values for RGUN and BGUN. When all data are deleted at the start of the set-up-data sequence the exit-type-key function is disabled until the gun data are entered (Item 2.1).

(b) The valid forward observer numbers are : 11, 12, 13, 14, 19, 21, 22, 23, 24, 29, 31, 32, 33, 34, 39 (Item 5.1).

(c) Valid troop numbers must be integers in the range 00 to 99 (Item 6.1).

(d) Valid target numbers must be integers in the range 0001 to 9999 (Item 7.1).

(e) Location records are saved by the survey routines and can only be viewed or deleted from the setting up data routine (Item 9.1).

## 4. SURVEY ROUTINES

The survey routines have been provided to solve simple trigonometrical problems so that certain quantities required to run a fire mission can be calculated from known data.

### 4.1 Traverse

A traverse is performed to calculate the grid and altitude of a series of locations given a known initial point and known bearing, distance and angle of sight between successive locations. The locations calculated may be stored (see Section 3 note(f)).

### 4.2 Intersection and resection

This routine is used to calculate the grid reference and altitude of an unknown location given two known locations, the bearings from each known location to the unknown location and the angle of sight from one known location to the unknown location.

TABLE 1. DATA INPUT SEQUENCE

| Data group | Item | Variable names | Default values |
|---|---|---|---|
| 1. Battery data | 1.1 Battery latitude<br>1.2 Battery grid and altitude | ALAT<br>XBAT,YBAT<br>ABAT | -34<br>0,0<br>0 |
| 2. Gun position | 2.1 Distance and bearing of each gun from battery centre | RGUN[1..6]<br>BGUN[1..6] | |
| 3. Gun muzzle velocity data | 3.1 Muzzle velocities for each gun and charge | MV[1..6,1..7] | Standard values |
| 4. Charge data | 4.1 Charge temperature | XCHT | 21°C |
| 5. Forward observer | 5.1 Forward observer number<br>5.2 Forward observer grid and altitude | FON<br>FOX[1..15]<br>FOY[1..15]<br>FOA[1..15] | |
| 6. Troop data | 6.1 Troop number<br>6.2 Troop grid | TPN<br>TPX[1..12]<br>TPY[1..12] | |
| 7. Target data | 7.1 Target number<br>7.2 Target grid and altitude | TGN<br>TGX[1..30]<br>TGY[1..30]<br>TGA[1..30] | |
| 8. Crest data | 8.1 Range of crest from battery centre<br>8.2 Crest height | RCREST[1..10]<br>HCREST[1..10] | |
| 9. Location data | 9.1 Location grid and altitude | XLS[1..9]<br>YLS[1..9]<br>ALS[1..9] | |

### 4.3 Bearing distance

This survey calculates the bearing, distance and angle of sight between two known locations.

## 5. PAAC TEST ROUTINES

The PAAC test routines allow the power supply, the PAAC display and the PAAC keyboard to be tested.

On entry to the test routines a "low battery" message is displayed if the PAAC batteries have discharged to the point where re-charging is advisable.

Selection of the display test option causes all displayable characters to be displayed in order.

If the keyboard test option is selected, PAAC requests that all keys on the keyboard be selected in order.

## 6. CHANGE OF GRID ROUTINE

The change of grid routine has been provided to allow certain records to be adjusted according to an improved estimate of the actual battery position and/or an improved estimate of true north with respect to the battery.

This module allows the battery grid position and altitude to be directly altered and optionally adjusts stored target records to account for the new battery position and slew.

## 7. FIRE MISSION

The fire mission calculations are based on the algebraic approach described in reference 3.

Four ammunition classes are differentiated:

(a) HE/SMK - high explosive and smoke rounds. (Sections 7.1 to 7.4)

(b) ILLUM - illuminating rounds. (Sections 7.1 to 7.4)

(c) HEPT - high explosive plastic-tracer rounds. (Section 7.5)

(d) APERS - anti-personnel rounds. (Section 7.6)

Table 2 shows the different ammunition/fuse combinations which the program handles together with the entry codes.

TABLE 2. AMMUNITION AND FUSE TYPES

| Code | Ammunition and Fuse | Abbreviation |
|---|---|---|
| 0 | High explosive - point detonating | HE-PD |
| 1 | High explosive - proximity fuse | HE513 |
| 2 | High explosive - M564 time fuse | HE564 |
| 3 | High explosive - M520 time fuse | HE520 |
| 4 | Smoke - M501 time fuse | SM501 |
| 5 | Smoke - point detonating | SM-PD |
| 6 | Illuminating - M501 time fuse | IL501 |
| 7 | Illuminating - M565 time fuse | IL565 |
| 8 | High explosive plastic-tracer | HEPT |
| 9 | Anti-personnel | APERS |

### 7.1 Fire mission algorithm

#### 7.1.1 Quantities to be calculated

(a) QUADRANT ELEVATION for each gun.

(b) BEARING (AZIMUTH) for each gun.

(c) FUSE SETTING for each gun if appropiate.

(d) CHARGE for mission.

(e) CREST CLEARANCE FACTORS for each gun and crest.

(f) TIME OF FLIGHT for high explosive and smoke rounds.

(g) IMPACT RANGE for illuminating ammunition.

(h) ANGLE OF SIGHT for adjusting gun.

(i) VERTEX HEIGHT for high explosive and smoke rounds.

Those quantities that are calculated for each gun are stored in arrays which are indexed by gun number. Guns are numbered from one to six. Gun number seven is reserved for an imaginery ideal gun positioned at the battery centre. In the discussion that follows, the Ith element of one of these arrays is denoted by XX[GUNI] and the element corresponding to the adjusting gun is denoted by XX[JAD], where XX is the array name.

### 7.1.2 Charge selection

The charge (K) for a particular mission is selected by map range when required. Once a charge has been selected every attempt is made to retain that charge for subsequent runs of the mission. The charge will only be recalculated if the mission is re-run with a different ammunition class or if computed charge is requested (see Section 7.2.4(2)).

### 7.1.3 Initial quadrant elevation calculation

An initial approximation to the quadrant elevation (QE) is obtained to enable the calculation of many of the corrections. This initial approximation is calculated from the actual range between battery and target (map range). Details of the QE calculation are as follows:

(1) High explosive and smoke ammunition

The range quadrant elevation equation for HE/SMK has the following form:

$$x = a_1 + a_2 * s + a_3 * s^2 + a_4 * s^3$$

where x = range/XULM[K].

XULM[K] is the maximum range for the charge.

s = SIN 2(q + $\phi$).

q = qe - QULM[K] (low angle).

q = QULM[K] - qe (high angle).

qe is the quadrant elevation (mils).

QULM[K] is the quadrant elevation for XULM[K].

$\phi = \pi/4$.

Coefficients are stored in an array denoted CQR which is indexed by charge and angle.

This equation is solved by Newton's Method to obtain the quadrant elevation. The first approximation to the solution is:

$$Range/XULM[K].$$

(2) Illuminating ammunition

The quadrant elevation for an illuminating mission is obtained by evaluating the following equation:

$$SIN(QE) = a_1 + a_2 * R3 + a_3 * R3^2 + a_4 * R3^3 + a_5 * R3^4 \text{ (mils)}$$

where R3 = minimum(XL[NCHG],r) (km).

NCHG is the number of charges (7).

XL[NCHG] is the maximum range for an illuminating round.

r is the range (m).

Coefficients are stored in an array denoted CQRI which is indexed by charge.

7.1.4 Initial fuse calculation

An initial approximation to fuse setting (FUSE) is obtained by evaluating the following expressions:

(1) High explosive and smoke

$$FUSE = a_1 + a_2 * SQ + a_3 * SQ^2 \text{ (s)}$$

where SQ = SIN(QE).

Coefficients are stored in an array denoted CFUSE which is indexed by charge.

(2) Illuminating

$$FUSE = a_1 + a_2 * R3 + a_3 * R3^2 + a_4 * R3^3 \text{ (s)}$$

where R3 = minimum(R,XL[NCHG]) (km).

R = map range (m)

XL[NCHG] is the maximum range for illuminating rounds.

Coefficients are stored in an array denoted CFUI which is indexed by charge.

7.1.5 Initial vertex height calculation

An initial approximation to the vertex height (VERTEX) is obtained to enable calculation of the ballistic temperature, density and wind for HE/SMK missions. The vertex height is calculated as follows:

$$VERTEX = a_1 + a_2 * QX + a_3 * QX^2 + a_4 * QX^3$$

where QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CVH which is indexed by charge.

7.1.6 Predicted range and bearing for each gun

The range and bearing for each gun (RG,BG) are calculated by applying corrections for non-standard conditions and stored meteorological corrections to the map range and bearing. The range and bearing for each gun are further adjusted to account for a non-standard distribution of fire. The calculation of the corrections for non-standard conditions are described in Section 7.3. The stored meteorological corrections are described in Section 7.8.

(1) Corrections

(a) High explosive and smoke ammunition

RG[GUNI] = map range + muzzle velocity correction + range wind correction + ballistic temperature and density corrections + round weight correction + altitude correction + coriolis (range) correction.

BG[GUNI] = map bearing + cross wind correction + drift correction + coriolis (azimuth) correction.

Stored corrections to RG and BG can be applied under certain conditions (see Section 7.8.4).

(b) Illuminating ammunition

RG[GUNI] = map range + round weight correction.

BG[GUNI] = map bearing + drift.

(2) Distribution of fire

After the corrections have been added, the predicted range and bearing for each gun are further adjusted according to the distribution of fire. This accounts for the gun to battery centre offset and the gun aiming point to target centre offset. No adjustment is made for a parallel distribution of fire.

7.1.7 Adjusting gun quadrant elevation and fuse setting calculation

The quadrant elevation (QG[JAD]) and fuse setting (FG[JAD]) for the adjusting gun are calculated in the same way as the initial approximations except RG[JAD] (the predicted range for the adjusting gun) is used instead of the map range (R).

The fuse and quadrant elevation corrections are now applied.

(a) Alternative fuse correction is added to FG[JAD] if appropiate.

(b) Altitude fuse correction is subtracted from FG[JAD] (HE/SMK).

(c) Burst height fuse correction is added to FG[JAD] if appropiate.

(d) Burst height quadrant elevation correction is added to QG[JAD]

7.1.8 Time of flight and vertex height calculation

For a HE/SMK mission the time of flight (TOF) is calculated on the adjusting gun trajectory.

$$TOF = a_1 + a_2 * SQ + a_3 * SQ^2 + a_4 * SQ^3 \text{ (s)}$$

where SQ = SIN(QG[JAD])

Coefficients are stored in an array denoted CFUSE which is indexed by charge.

The altitude fuse correction is subtracted from the time of flight for the same reason it is subtracted from the fuse setting (see Section 7.3.4 (2)).

The vertex height is calculated on the adjusting gun quadrant elevation using the same algorithm as used for the initial vertex height calculation (HE/SMK only).

7.1.9 Adjusting gun crest clearance factors calculation

The crest clearance factors are calculated using the crest clearance model to determine the height of the trajectory over each of the crests (see Section 7.4). The range to impact is required to scale the crest clearance model. For high explosive and smoke ammunition the range to impact is the range from the adjusting gun to the target RG[JAD]. For illuminating ammunition the range to impact (RIM) is calculated thus:

$$RIM = a_1 + a_2 * S2Q + a_3 * S2Q^2 + a_4 * S2Q^3 + a_5 * S2Q^4 \text{ (m)}$$

where S2Q = SIN(2 * QG[JAD]).

XL[NCHG] is the maximum range of an illuminating round.

Coefficients are stored in an array denoted CIRI which is indexed by charge.

7.1.10 Calculations for other guns

The calculation of quadrant elevation, bearing and crest clearance factors is the same for the other guns as for the adjusting gun. However, these quantities are not calculated unless requested by the user operating PAAC.

The time of flight and impact range for these other guns are calculated, if requested, but the time of flight and impact range displayed is always that for the adjusting gun.

7.2 Fire mission parameters

There are a very large number of different fire missions that can be run. The actual calculations done by the fire mission module are determined by a pool of variables which exactly describe the present combination of ammunition, fuse type, distribution, angle and stored corrections as well as target data.

All the fire mission parameters are stored before the display of the fire mission results to enable the mission to be recalled at a later time.

7.2.1 Target data

The target location is defined on initial entry into a new fire mission. Adjustments can be made to the target location data using the CORRN, FM_CORRN, TGT_REDN and ALT_FUZE keys. The target location data is stored as shown in Table 3.

TABLE 3. TARGET DATA

| Item | Variable names |
|---|---|
| Target grid and altitude | TARX,TARY,ATAR |
| Polar coordinates of target with respect to forward observer | RFOT,BFOT |
| Total corrections parallel and perpendicular to the observer to target vector | ATOT,RTOT |

7.2.2 Meteorological type

These data indicate the meteorological corrections carried out. These corrections are:

Computer Met : meteorological corrections are calculated from a standard computer meteorological message.

Registration Met : stored registration corrections are applied in addition to computer met.

Laser Witness Point Met : stored laser or witness point corrections are applied in addition to computer met.

A flag, denoted METYPE in the program, indicates which met corrections are to be applied and provides an index to the stored corrections to be used if appropiate.

7.2.3 Profile data

The profile data are those data which are selected within the main fire mission routine. These parameters can be changed before each run through the mission. Table 4 shows the variables used to store the profile data.

TABLE 4. PROFILE VARIABLES

| Item | Variable names |
|---|---|
| Charge which can be selected or calculated | K |
| Current ammunition type | AMMO |
| Flag indicating if fuse is standard type | IFUSE |
| Current distribution of fire | NDF |
| Distribution parameters | DISTANCE, ATTITUDE |
| Flag indicating low or high angle | HIANGLE |
| Burst height | BURST |
| Set indicating which guns are participating in mission | GUNMASK |
| Adjusting gun | JAD |

### 7.2.4 Flags

(1) Mission history flag (ADJFLAG)

This flag is used to indicate the prior history of the current mission. The flag is set to zero when a new mission is initiated and is set to two for all subsequent runs through the mission. However, if the target location is adjusted by the target reduction routine , ADJFLAG is set to one and the display of results sequence is altered for the next run of the mission.

(2) Charge selection flag (CHGFLG)

This flag is used to indicate computed or set charge. The flag is set to false when a new mission is initiated and when the ammunition class is altered. If registration met is being used CHGFLAG cannot be set to false.

CHGFLG is set to true for all other subsequent runs through the mission.

The value of this flag can be altered using the CH key. Selecting charge zero sets CHGFLG to false.

When CHGFLG is false the charge for the mission is calculated by map range, otherwise the current charge is retained. In addition, if the range corrections force the adjusting gun out of range for a particular charge, the next higher charge will be tried if CHGFLG is false.

(3) Range flags (IFLAG)

IFLAG is an array of flags used to indicate if each gun is in range. These flags are set during the mission calculation and can have the following values:

0 - gun is in range.

2 - adjusted range for gun is less than 100 m.

3 - gun is out of range.

4 - quadrant elevation for gun is greater than 1250 mils.

### 7.3 Corrections for non-standard conditions

The correction terms described in this section are mainly corrections for non-standard conditions but also include corrections due to the rotation of the earth and projectile spin. They are distinct from the target location corrections which are adjustments applied when a fired projectile fails to hit the target.

#### 7.3.1 Standard conditions

The standard conditions for a fire mission are as follows:

(a) Target and battery are at the same altitude as the meteorological station (MDP).

(b) No ballistic wind.

(c) Ballistic temperature is 100% of standard.

(d) Ballistic density is 100% of standard.

(e) Round Weight is 2 squares (a variation of 1 square in round weight is equivalent to a variation of 0.11 kg).

(f) Charge temperature is 21°C.

(g) Guns fire at standard muzzle velocity.

(h) Standard fuses are used.

#### 7.3.2 Range corrections

(1) Muzzle velocity correction

The muzzle velocity correction is a range correction due to non-standard muzzle velocity.

The non-standard muzzle velocity has two components:

(a) variation of muzzle velocity from standard (gun dependent).

(b) component due to non-standard charge temperature (XM).

The total range correction due to non-standard muzzle velocity is calculated by multiplying the variation of muzzle velocity from the standard (here denoted $\delta mv$) by a correction coefficient (DMV). This coefficient has two values. The value used depends on the sign of $\delta mv$.

$$\delta mv = MV[GUNI,K] - VMST[K] + XM$$

$$XM = a_1 + a_2 * XC3 + a_3 * XC3^2$$

$$DMV = a_1 + a_2 * QX + a_3 * QX^2$$

where QX is quadrant elevation in mils divided by one thousand.

MV[GUNI,K] is the actual muzzle velocity for a particular gun and charge.

VMST[K] is the standard muzzle velocity for the same charge.

XC3 is the charge temperature in °C divided by one thousand.

Coefficients for XM are stored in an array denoted CTMV which is indexed by charge.

Coefficients for DMV are stored in an array denoted CBW which is indexed by angle, charge and sign of $\delta mv$.

The muzzle velocity correction is the only correction which is gun dependent.

(2) Range wind correction

The range wind correction is a range correction due to the wind component parallel to the line of fire.

The range wind correction is calculated by multipling the variation of the ballistic range wind from the standard (XBW) by a correction coefficient (DBW). This coefficient has two values. The value used depends on the sign of XBW.

$$XBW = \text{ballistic range wind (kn)} - 0$$

$$DBW = a_1 + a_2 * QX + a_3 * QX^2$$

where QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CBW which is indexed by angle, charge and sign of XBW.

(3) Ballistic density correction

The ballistic density correction is a range correction due to non-standard ballistic density.

The density correction is calculated by multipling the variation of the ballistic density from the standard (XDN) by a correction coefficient (DEN). This coefficient is equal to the change in range for every percent variation in density from the standard, and has two values. The value used depends on the sign of XDN.

XDN = ballistic density as percentage of standard - 100%

$$DEN = a_1 + a_2 * QX + a_3 * QX^2$$

where QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CDEN which is indexed by angle, charge and sign of XDN.

(4) Ballistic temperature correction

The ballistic temperature correction is a range correction due to non-standard ballistic temperature.

The temperature correction is calculated by multipling the variation of the ballistic temperature from the standard (XTP) by a correction coefficient (DTP). This coefficient is equal to the change in range for every percent variation in temperature from the standard, and has two values. The value used depends on the sign of XTP.

XTP = ballistic temperature as percentage of standard - 100%

$$DTP = a_1 + a_2 * QX + a_3 * QX^2$$

where QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CTP which is indexed by angle, charge and sign of XTP.

(5) Round weight correction

The round weight correction is a range correction due to non-standard round weight.

The round weight correction is calculated by multipling the variation of round weight from the standard (XPW) by a correction coefficient (DPW). This coefficient has two values. The value used depends on the sign of XPW.

XPW = actual round weight (squares) - 2

$$DPW = a_1 + a_2 * QX + a_3 * QX^2$$

where QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CPW which is indexed by angle, charge and sign of XPW.

(6) Altitude correction

The altitude correction (RHEIGHT) is a range correction due to the altitude difference between the battery and the target.

$$RHEIGHT = ZD/TAFL \text{ (m)}$$

where ZD is the altitude difference between battery and target.

TAFL is TAN(angle of fall).

(7) Coriolis (range) correction

The coriolis correction (CORI) is a range correction due to the rotation of the earth and is calculated by:

$$CORI = a_1 + SIN(BRAD) * (a_2 + a^3 * QX + a_4 * QX^2) \text{ (m)}$$

where BRAD is map bearing in radians.

QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CORIOL which is indexed by charge.

7.3.3 Azimuth (bearing) corrections

(1) Cross wind correction

The cross wind correction is an azimuth correction due to the wind component perpendicular to the line of fire.

The cross wind correction is calculated by multipling the variation of cross wind from the standard (XCW) by a correction coefficient (DCW).

$$XCW = \text{ballistic cross wind (kn)} - 0$$

$$DCW = a_1 + a_2 * TQ + a_3 * TQ^2 + a_4 * TQ^3 \text{(mil/kn)}$$

where TQ is TAN(quadrant elevation).

Coefficients are stored in an array denoted CCW which is indexed by charge.

(2) Drift correction

The drift correction is an azimuth correction due to projectile spin.

$$DRIFT = a_1 + a_2 * TQ + a_3 * TQ^2 \text{ (mils)}$$

where TQ is TAN(quadrant elevation)

Coefficients are stored in an array denoted CDRFT which is indexed by angle and charge.

(3) Coriolis azimuth correction

The coriolis correction (COAZ) is a correction to azimuth due to the rotation of the earth.

$$COAZ = a_1 + SIN(AX) * (a_2 + a_3 * QX) + COS(AX) *$$

$$COS(BRAD) * (a_4 + a_5 * QX + a_6 * QX^2) \text{ (mils)}$$

where BRAD is map bearing in radians.

AX is the battery latitude * π/180.

QX is quadrant elevation in mils divided by one thousand.

Coefficients are stored in an array denoted CORIAZ which is indexed by charge.

7.3.4 Fuse corrections

(1) Alternative fuse correction

The alternative fuse correction (FCOR) is a correction to fuse setting due the the use of M520A1 or M501 fuses.

$$FCOR = a_1 + a_2 * FQ + a_3 * FQ^2 \text{ (s)}$$

where FQ is the fuse setting (s) divided by one thousand.

Coefficients are stored in an array denoted CFCOR which is indexed by charge.

(2) Altitude fuse correction

The altitude correction (FHTERM) is a correction to fuse setting to negate the effect of RHEIGHT, whose effect is propagated through the corrected range and quadrant elevation. This correction is also applied to time of flight (TOF).

$$FHTERM = ZD/(SIN(AOF) * TVEL) \text{ (s)}$$

$$TVEL = a_1 + a_2 * QX + a_3 * QX^2 + a_4 * QX^3 \text{ (m/s)}$$

where ZD is the altitude difference between battery and target.

AOF is the angle of fall.

TVEL is the terminal velocity of the projectile.

QX is the quadrant elevation (mils) divided by one thousand.

Coefficients are stored in an array denoted CTV which is indexed by charge.

(3) Burst height correction

The burst height correction (DFU) is a correction to fuse setting due to the variation of burst height from the standard.

(a) High explosive and smoke.

(i) high angle. DFU = -(FHC * R)/XL[K]$^2$) * BURST (s).

(ii) low angle. DFU = -(FHC/R) * BURST (s).

where R is map range (m).

BURST is the burst height (m).

FHC is 100 * CFZHT[K].

CFZHT is an array indexed by charge.

XL[K] is the maximum range for charge K.

(b) Illuminating

DFU = DFSE * ((BURST + ZD) - 750) * 0.02 (s)

DFSE = $a_1 + a_2$ * R3 + $a_3$ * DR * T2Q + $a_4$ * DR$^2$ * T2Q (s/50 m)

where DFSE is the change in fuse setting for every 50 m by which the burst height varies from 750 m above the battery.

BURST is the burst height above the target.

ZD is the altitude difference between battery and target.

R3 is minimum(R,XL[K]) (km).

XL[K] is the maximum range for charge K (m).

DR is R3 - RMIN[K] (km).

RMIN[K] is the minimum range for charge K (km).

T2Q is TAN(2 * QE).

Coefficients are stored in an array denoted CDFI which is indexed by charge.

7.3.5 Quadrant elevation correction

The only direct correction to quadrant elevation (DEL) is due to non-standard burst height for an illuminating mission.

DEL = DQDH * ((BURST + ZD) - 750) * 0.02 (mils)

DQDH = $a_1 + a_2$ * R3 + $a_3$ * DR * T2Q + $a_4$ * DR$^2$ * T2Q (mils/50 m) where DQDH is change in quadrant elevation for every 50 m by which burst height varies from 750 m above battery.

BURST is the burst height (m).

ZD is the altitude difference between battery and target.

R3 is minimum(R,XL[K]) (km).

XL[K] is the maximum range for charge K (m).

DR is R3 - RMIN[K] (km).

RMIN[K] is the minimum range for charge K (km).

T2Q is TAN(2 * QE).

Coefficients are stored in an array denoted CDQI which is indexed by charge.

7.3.6 Ballistic temperature and density corrections

The ballistic air temperature and density are calculated from the meteorological data and must be corrected if the battery is not at MDP (meteorological station altitude).

$$TCOR = a_1 + a_2 * HX + a_3 * HX^2 \text{ (pct)}$$

$$DCOR = a_1 + a_2 * HX + a_3 * HX^2 \text{ (pct)}$$

where HX is the battery altitude - MDP (km).

coefficients are stored in arrays denoted CTH, CDH.

## 7.4 Crest clearance model

The crest clearance model (CCM) is a complex equation of the form:

$$ht = f(rt,qt,vt)$$

where ht is the trajectory height above the battery at rt.

qt is the quadrant elevation of the trajectory.

vt is the standard muzzle velocity for the charge used.

rt is the range.

For a given trajectory qt and vt are constant and the CCM can be evaluated to determine the height of the trajectory above the battery at a certain range from the battery or solved to determine the range from the battery for which a trajectory is at a certain height.

However, the CCM when evaluated at the range from which the qt was calculated, does not normally return zero height. That is the CCM does not exactly match the range-quadrant elevation equation. Therefore, a scaling term is applied when the CCM is used.

The CCM is used to calculate crest clearances. The crest clearance is the height of the trajectory above the particular crest. To evaluate the crest clearance the CCM is solved for zero height to give RCCF, the range of the trajectory according to CCM. The CCM is solved using the actual range to impact as the initial approximation of the solution and TAN(quadrant elevation) as an approximation to the first derivative of the crest clearance equation. The CCM is then evaluated at scaled crest range to give the height of the trajectory at the crest range (see figure 2).

Scaled crest range = actual crest range * RCCF/r.

where r is the range to impact. For high explosive and smoke ammunition, r is the predicted range to target and for illuminating ammunition, r is the impact range calculated from the predicted range to target.

7.5 Mission algorithm for high explosive plastic-tracer rounds

The quantities to be calculated for a HEPT fire mission are:

(a) quadrant elevation.

(b) bearing of fire.

(c) time of flight.

$$QE = a_1 + a_2 * R3 + a_3 * R3^2 + AOS \text{ (mils)}$$

$$AOS = \text{ARCTAN}(ZD/R) * 1018.59 \text{ (mils)}$$

$$TOF = a_1 + a_2 * QX + a_3 * QX^2 \text{ (s)}$$

$$BER = \text{map bearing} + DRIFT \text{ (mils)}$$

$$DRIFT = a_1 + a_2 * QX + a_3 * QX^2 \text{ (mils)}$$

where ZD is the altitude difference between battery and target.

R is map range (m).

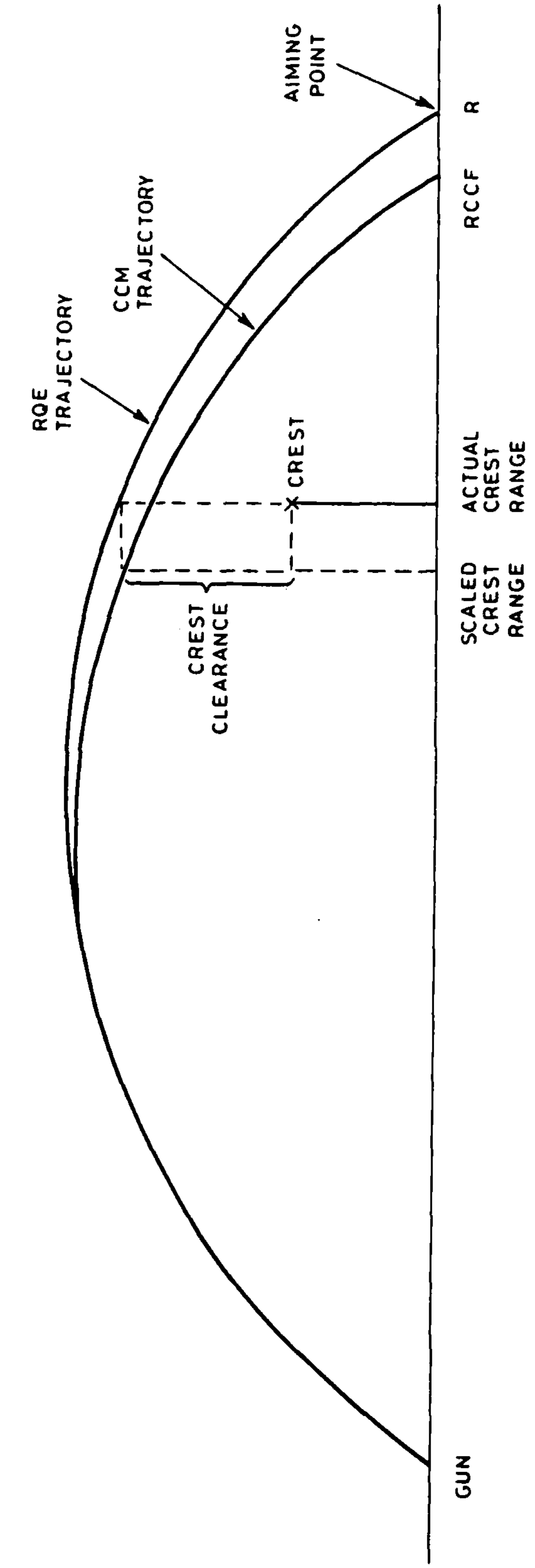



Figure 2. Calculation of crest clearance by CCM

AOS is angle of sight (mils).

R3 is map range (km).

QX is (quadrant elevation - TOF (mils)) divided by one thousand.

Coefficients are stored in arrays denoted HPTQR, HPTOF and HPTDRF.

## 7.6 Mission algorithm for anti-personnel rounds

The quantities to be calculated for an APERS fire mission are:

(a) quadrant elevation.

(b) bearing of fire.

(c) three fuse settings.

$$QE = a_1 + a_2 * R3 + a_3 * R3^2 + AOS \text{ (mils)}$$

$$AOS = ARCTAN(ZD/R) * 1018.59 \text{ (mils)}$$

$$F2 = a_1 + a_2 * QX + a_3 * QX^2 \text{ (s)}$$

$$F3 = a_1 + a_2 * QX + a_3 * QX^2 \text{ (s)}$$

$$F4 = a_1 + a_2 * QX + a_3 * QX^2 \text{ (s)}$$

$$BER = \text{map bearing}$$

where ZD is the altitude difference between battery and target.

R is map range (m).

AOS is angle of sight (m).

R3 is map range (km).

QX is (quadrant elevation - AOS (mils)) divided by one thousand.

Coefficients are stored in arrays denoted APQR, APER2, APER3 and APER4.

## 7.7 Target location corrections

When a projectile is fired according to the calculated quadrant elevation and bearing, it may fail to hit the target. This could be due to incorrect estimation of target location or non-standard conditions or other factors. The estimated target location can be adjusted according to where the projectile lands.

### 7.7.1 Non-polar target location correction

This option is selected by the CORR key. An observer sees that the projectile failed to hit the target and he reports a correction to be applied to the estimated target location. The mission is re-calculated according to the new target location and another round is fired. This process of adjustment continues until the projectile finds its mark.

The correction reported by the observer is given by three quantities

BFOT is the bearing from the observer to the target.

ADD is the component of the correction parallel to BFOT.

RIGHT is the component of the correction perpendicular to BFOT.

The estimated target location is adjusted according to the corrections and the main mission calculation routine is entered.

### 7.7.2 Polar target location correction

This option is selected by the POLAR CORR key. This type of correction is applied to a polar mission, that is, a mission where the target location is specified by range, bearing and angle of sight from a forward observer position. These quantities are measured by the observer using a laser range finder. When a projectile which is fired using predicted firing data fails to hit the target, the forward observer reports the range and bearing from his location to the point of impact (or burst) as measured by the laser range finder.

The program converts this data into ADD and RIGHT corrections with respect to the observer to target vector and adjusts the target location accordingly.

Due to the accuracy of the laser range finder, the polar correction is normally a once only correction.

The program allows a polar correction to be applied to a non-polar mission. In effect this allows a 'polar' mission target to be specified by target number.

### 7.7.3 Target reduction

This option is selected by the TGT REDN key. The target reduction module allows the storage of the target location or the adjustment of the estimated target location according to a better estimate of the actual target altitude.

If the latter option is selected, the estimated target grid is adjusted so that a projectile fired at the original quadrant elevation will also hit the new target grid and altitude (see figure 3).

The new target location is calculated by the following algorithm:

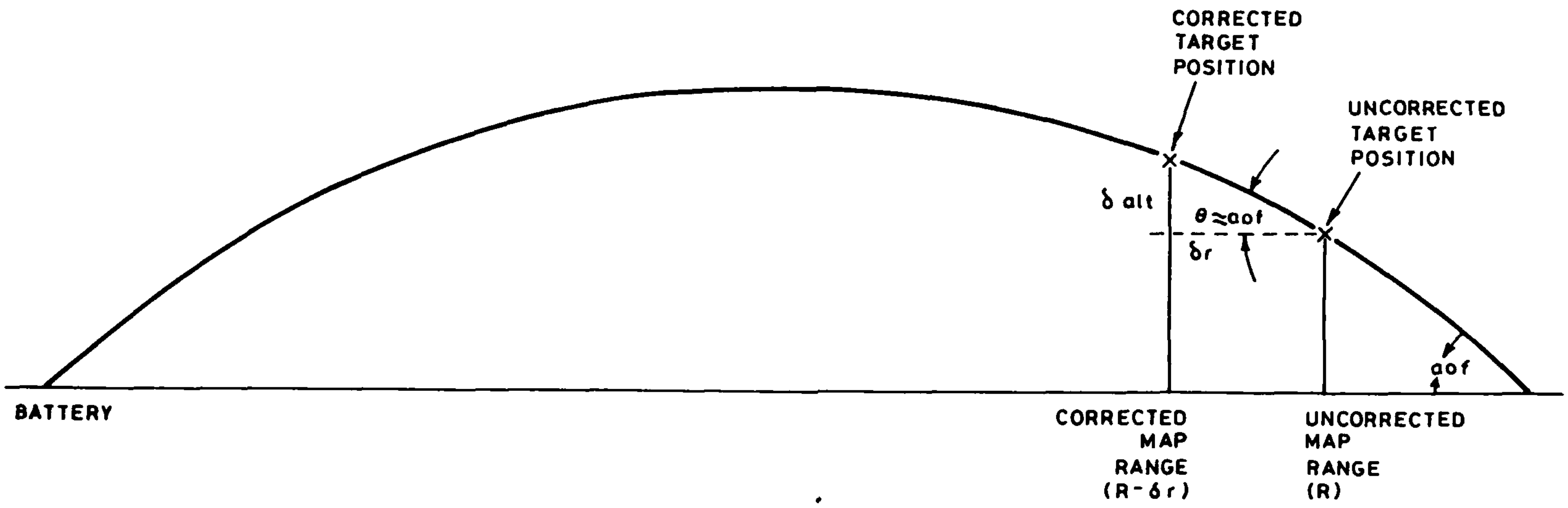



Figure 3. Target location adjustment by target reduction

$$ATAR = ATAR + \delta alt$$

$$TARX = XBAT + rx * (R - \delta r)/R$$

$$TARY = YBAT + ry * (R - \delta r)/R$$

where $\delta$alt is the altitude adjustment entered.

R is uncorrected map range (battery to target).

rx, ry are the x and y components of R.

$\delta$r is range correction.

The range correction ($\delta$r) is approximated by:

$$\delta r = \delta alt/TAN\ (\text{angle of fall})$$

As the angle of fall is not calculated for illuminating missions, this algorithm will not work for this type of mission.

#### 7.7.4 Altitude or fuse correction

This option is selected by the ALT/FUZE key. Using this option either the target altitude or the mission burst height can be adjusted.

### 7.8 Meteorological conditions

#### 7.8.1 Computer meteorogical message

The computer meteorological message consists of the actual values of wind velocity and direction and air temperature at various set heights above the met station as well as the height of the met station above mean sea level (MDP) and the atmospheric pressure at MDP. The computer met messages consist of several groups of data which express the atmospheric conditions. Only three of these groups of data are important.

Group 4 data are in the form hhhPPP.

where hhh is MDP in tens of meters.

PPP is the atmospheric pressure at MDP (milibars). When the pressure at MDP is 1000 mbars or greater the initial digit (1) is omitted from the message.

For example, 014002 indicates that MDP is 140 m above mean sea level and the atmospheric pressure at MDP is 1002 mbars.

Groups 5 and 6 data consist of several lines of data. Each line contains data for one stratum of the atmosphere.

Group 5 data are in the form ZZdddFFF.

where ZZ is the line number which indicates the heights above MDP for which the data are valid.

ddd is the direction from which the wind is blowing (tens of mils).

FFF is the wind speed (kn).

Group 6 data are in the form TTTTPPPP.

where TTTT is the air temperature in °K rounded to one decimal place.

PPPP is the air pressure in mbars.

The group 6 pressure data are not used to calculate the effect of atmospheric conditions and are not entered into PAAC.

7.8.2 Ballistic meteorological data

The computer met message must be converted into a form which can more readily be used to calculate the effect of atmospheric conditions on various trajectories. A table of effective mean values of the atmospheric conditions is calculated from the met message.

The effective mean values for a certain line number indicate the theoretical constant atmospheric structure which will have the same effect on a trajectory whose vertex height is equal to the maximum height of the line number as the actual atmospheric conditions.

The effective mean values calculated for line 7 (3000 to 4000 m) above MDP) are constant values of wind, temperature and density which will cause the same effect on a trajectory whose vertex height is 4000 m as the actual atmospheric profile. This assumes that the battery is at MDP.

The effective mean values for trajectories whose vertex height is not equal to the maximum height of a line are calculated by interpolation using the mean values for the lines above and below the vertex.

The ballistic data (effective mean values) are stored in four arrays which are indexed by line number (see Table 5).

TABLE 5. BALLISTIC METEOROLOGICAL DATA

| Item | Variable names | Units |
|---|---|---|
| Bearing of ballistic wind | ANG | mils |
| Velocity of ballistic wind | VEL | kn |
| Ballistic temperature | BTEMP | pct |
| Ballistic density | BDEN | pct |

When the battery is not at the same altitude as MDP, corrections are applied to the ballistic temperature and density (see Section 7.3.6).

7.8.3 Calculation of ballistic data

The ballistic temperature and wind for line j (j > 0) are calculated using the computer data for lines 1 to j. The values of wind and temperature for lines 1 to j, converted to the correct units, are appropiately weighted and summed to return ballistic values which are representative of that stratum of the atmosphere between MDP and the maximum height for line j.

The ballistic density for each line is calculated from the ballistic temperature for that line and the atmospheric pressure at MDP.

(1) Ballistic wind

The ballistic wind is calculated as follows:

$$ANG[j] = 10 * d_j \text{ (mils).} (j = 0)$$

$$ANG[j] = ARCTAN(WE[j]/WN[j]) * 1018.59 \text{ (mils).} (j > 0)$$

$$VEL[j] = v_j. \quad (j = 0)$$

$$VEL[j] = \sqrt{(WN[j]^2 + WE[j]^2)} \ . \ (j > 0)$$

$$WN[j] = \sum_{k=1}^{j} v_k * COS(d_k/101.859) * SWW[j,k]$$

$$WE[\xi] = \sum_{k=1}^{j} v_k * SIN(d_k/101.859) * SWW[j,k]$$

where $d_j$ is the computer wind direction for line j.

$v_j$ is the computer wind velocity for line j.

WN[j] is the weighted and summed north component of the wind for line j.

WE[j] is the weighted and summed east component of the wind for line j.

SWW is a table of weights.

(2) Ballistic temperature

The ballistic temperature is calculated as follows:

$$BTEMP[j] = t_j * 10/SVT[j] \text{ (pct).} (j = 0)$$

$$BTEMP[j] = \sum_{k=1}^{j} t_k * 10/SVT[k] * STW[j,k] \text{ (pct). } (j > 0)$$

where $t_j$ is the computer temperature for line j.

SVT[j] is the standard temperature for line j.

STW is a table of weights.

(3) Ballistic density

The ballistic density is calculated as follows:

$$BDEN[j] = BDENZ - (BTEMP[j] - 100) * TDE[j]$$

$$BDENZ = MPRES/10.1325 \text{ pct}$$

where MPRES is the pressure at MDP (mbars).

TDE is table of standard densities.

### 7.8.4 Stored corrections

When a projectile which is fired using the predicted firing data fails to hit the target, it is assumed that this is due to the wind. Although this assumption is not necessarily true, the polar and non-polar target location corrections made while adjusting onto the target are considered to be meteorological corrections (see Sections 7.7.1 and 7.7.2).

For each mission, the program maintains the accumulated polar or non-polar target location corrections as the total add and right corrections with respect to the forward observer to target vector. These accumulated corrections can be saved (correction reduction) and applied directly to other missions to minimise the process of adjusting onto the target. There are two different ways in which the stored corrections are used.

(1) Registration met

The accumulated add and right corrections for a mission are converted to add and right corrections with respect to the initial estimation of the battery to target vector and stored with this vector and the charge used. These stored corrections can then be applied to a mission run by another battery if the battery to target vector is sufficiently similar to the stored vector and the same charge is used.

This type of correction is applied by converting the stored correction to add and right corrections with respect to the battery to target vector for the mission (REGRANG, REGLINE). These values are applied as range and azimuth corrections respectively during the individual gun range and bearing calculation (see Section 7.1.6).

The program allows two corrections to be stored for each charge.

As the registration met correction is meant to be shared between batteries, provision has been made for direct keyboard entry of these values.

(2) Laser witness point met

When it is found that projectiles fired using predicted firing data consistently miss targets by a similar amount, the accumulated add and right corrections for one mission which has adjusted onto target are saved and directly applied to other missions run by the same battery.

The laser witness point correction is saved as an add and right correction with respect to the observer to target vector.

The correction is applied by converting the stored correction to an add and right correction with respect to the battery to target vector for the mission (WLRANG, WLLINE) and applying these values as range and azimuth corrections respectively during the individual gun range and bearing calculation (see Section 7.1.6).

The program allows the storage of six laser witness point corrections.

7.8.5 Storage of corrections

The registration met and laser witness point met corrections are stored by the correction reduction routine which is available during the display of the fire mission results. This option should only be used for HE/SMK missions.

Registration met corrections can also be entered from the keyboard in the met registration routine.

Registration met corrections and laser witness point met corrections are stored in the arrays REGCOR and WLCOR respectively.

7.8.6 Selection of corrections

The met selection routine, which is entered by selecting the MET REGN key at the start of a new mission, allows the operator to select the met type for the current mission (see Section 7.2.2). However, the met type has no effect on illuminating, hep-t and anti-personnel calculations.

If registration met is selected the charge associated with the stored corrections selected is the charge used for the entire mission. Additionally, PAAC issues a warning if an attempt is made to apply a registration met correction to a mission for which the battery to target vector is not sufficiently similar to the stored vector.

## 8. TRIGONOMETRICAL CONSIDERATIONS

### 8.1 The angle problem

The angle problem has two aspects, namely units and measurement.

Angular quantities are expressed in mils and are measured in a clockwise direction from north, whereas the normal convention is that angular quantities are expressed in radians and are measured anti-clockwise from the x-axis (east).

The conversion from mils to rad and vice-versa is merely a matter of applying the conversion factor (1 rad = 1018.59 mils).

Many of the standard trigonometrical formulae used in the program vary from the conventional ones because of the opposite sense of the angle measurement.

For example, the conversion of polar to cartesian coordinates is conventionally calculated by:

$$X = R * COS(\theta), \quad Y = R * SIN(\theta)$$

for PAAC the conversion is accomplished by:

$$X = R * SIN(\theta), \quad Y = R * COS(\theta).$$

As the trigonometrical calculations used in the program are elementary the angle problem does not create immense difficulty.

### 8.2 The grid problem

All grid references are relative to a 100 000 m by 100 000 m grid pattern. The coordinates used only indicate the position relative to a particular grid but do not express which grid.

When calculating the map range from battery to target it is not known if the battery and target are in the same grid. The problem is solved by assuming that the east and north components of the map range are always less than 50 000 m. The components of range are adjusted to fall in the range -50 000 < component < 50 000 m by adding or subtracting 100 000 m. This method selects the only feasible map range.

The reverse problem results in calculated grid coordinates not being in the range 0 <= coordinate < 100 000. For the purposes of the display values which when rounded do not fall into the above range will be displayed as hatches. The unrounded values of the coordinates must be adjusted to fall in the range -0.5 < coordinate < 99 999.5 by adding or subtracting 100 000 s. Note that if the adjusted coordinate value is exactly equal to -0.5, it is given the value -0.499999 so that the rounded value is 0 and not -1.

The routine that adjusts the grid coordinates assumes that the calculated coordinates will always fall in the range -100 000 < coordinate < 200 000. This assumption may not be true for the intersection and resection survey routines.

## 9. LIBRARIES, MODULES AND PROCEDURES

The artillery fire control program was developed on the HP64000 Microcomputer Development System at Aeroballistics Division, WSRL. A PASCAL program development system (PPDS) was written to provide the necessary input/output and floating point functions required to write the artillery fire control program in Hewlett Packard Z80 PASCAL (see reference 4).

Apart from some sections of the PPDS, an initialisation routine and the constant declaration modules, the whole of the artillery fire control program was coded in HPZ80 PASCAL. Due to the limitations of the HP64000 host memory, the program was designed as a series of separate modules which were combined into several libraries (see reference 4). Brief descriptions of the components of the artillery fire control program (excluding the PPDS) and the library creation procedures are given in Appendix I.

## 10. MEMORY REQUIREMENTS

The approximate memory requirements of the different program sections are as follows:

(a) Firing table data - 6 kbytes.

(b) Pascal program development system - 6.5 kbytes.

(c) Pascal library - 1.5 kbytes.

(d) Variable and stack RAM space - 4 kbytes.

(e) Other constants - 3 kbytes.

(f) Program - 28.5 kbytes.

The entire program uses approximately 45.5 kbytes of read only memory and 4 kbytes of read/write memory.

## 11. CONCLUSION AND RECOMMENDATIONS

(a) The artillery fire control application for the M2A2 gun system has been successfully coded in PASCAL. There was little disadvantage in execution time or storage in using PASCAL rather than assembly code. However, there are great advantages in ease of software development and modification.

(b) As PAAC is intended to become part of the equipment of an artillery battery, a given PAAC is required to handle fire control for a single gun system only. There is adequate storage remaining on the 64 kbyte memory card for adaptation to the gun/shell combinations which Army requires on PAAC, as described in Army Staff Requirement 42.5.

## 12. ACKNOWLEDGEMENTS

Mr F.G. Phillips supervised the software development. Particular thanks go to Mr C.J. Bensted, Mr A. Hind and Mr N. Tindal for setting up the PAAC breadboard to run under emulation on the HP64000.

# REFERENCES


| No. | Author | Title |
|---|---|---|
| 1 | - | "Artillery Observers Notebook". School of Artillery, 1973 |
| 2 | | "Ballistics and Technical Aspects of Field Gunnery". UK WO Code No. 9522, March 1959 |
| 3 | Sayer, A.M. and Coleby, J.R. | "A Comprehensive Algebraic Shell Impact Range Prediction Method Using an Improved Range Prediction Model". WSRL-0168-TR, August 1980 |
| 4 | Thamm, R.M. and Lambert, D.A. | "Pascal Program Development System for Portable All Arms Calculator". WSRL-0336-TM, October 1983 |

# APPENDIX I

## GLOBAL PROCEDURES AND FUNCTIONS IN ARTILLERY FIRE CONTROL PROGRAM

Tables I.2 to I.10 give brief descriptions of all the global procedures and functions in the artillery fire control program excluding the Pascal Program Development System which is described in detail in reference 4. The procedures and functions are also identified by the module names, file names and library names used.

The module name for a PASCAL module is the PASCAL program name. Assembly language modules have no module name.

The file name is the HP64000 system file name for the file in which a module is stored. Both source and object file versions of a particular module have the same name.

A library is a concatenation of the object file versions of its members. Libraries cannot be directly edited and therefore a consistant file nomenclature was adopted to enable automated library creation.

### I.1 Library creation

Each library has a three letter prefix which defines the library name as well as the file names of its members. The library name is defined as 'prefix'LIB and the file names of its members are defined as PAAC_'prefix'n, where n is the member number. Members are numbered sequentially from one. The maximum number of members belonging to a particular library is nine.

The command files LIB and LIBCOM have been written to enable automated library creation. The procedure for constructing a library is as follows:

(a) Invoke LIB by entering 'LIB' at the HP64000 keyboard.

(b) Enter the library prefix when prompted.

The command file LIB creates a new command file TEMPCOM by editing LIBCOM, replacing all occurances of 'XXX' in LIBCOM with the library prefix. TEMPCOM is then invoked, thus creating the library.

If there are less than nine members in a library, the library creation sequence will end with an error message:

"file not found file = PAAC_'prefix'n:'userid':reloc"

where n is the number of members plus one. This error message may be ignored.

The PPDS is contained in a library called FPIOLIB. This library can be created by invoking a command file also called LIB. This command file is stored together with the PPDS under a different user-id (user identification) from the rest of the program. The system can therefore differentiate between the two library creation procedures. The library creation command files are listed in Tables I.11 to I.13.

TABLE I.1 SET UP DATA LIBRARY (SUDLIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_SUD1 | PAAC_SUD | SUD | Set up data main routine. |
| PAAC_SUD2 | PAAC_LOCZ | LOCZ | Display/delete location records. |
| PAAC_SUD3 | PAAC_GUND | GUND | Enter/display gun displacements. |
| PAAC_SUD4 | PAAC_FOS | FOS | Enter/display forward observer records. |
| PAAC_SUD5 | PAAC_TGTS | TGTS | Enter/display target records. |
| PAAC_SUD6 | PAAC_MVS | MVS | Enter/display muzzle velocity records. |
| PAAC_SUD7 | PAAC_CREZT | CREZT | Enter/display crest records. |
| PAAC_SUD8 | PAAC_TPS | TPS | Enter/display troop records. |
| PAAC_SUD9 | AMMO_DATA | CHECK_AMMO | Ammo inventory routine. |

TABLE I.2 SURVEY LIBRARY (SUVLIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_SUV1 | PAAC_SURVEY | SUV<br>TRAV | Survey main routine.<br>Traverse routine. |
| PAAC_SUV2 | PAAC_RESECTION | RESINT | Intersection/resection routine. |
| PAAC_SUV3 | PAAC_BGDS | BGDS | Bearing distance survey. |

TABLE I.3 FIRE MISSION LIBRARY 1 (FM1LIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_FM11 | PAAC_FMSNA | FMSNA | Initiate fire mission and enter target data. |
| PAAC_FM12 | PAAC_ZED | ZED | Main fire mission routine. |
| PAAC_FM13 | PAAC_SELCHG | SELECT_CHARGE | Select charge for mission, initial range check. |
| PAAC_FM14 | PAAC_GUNRNGBER | GUNRNGBER | Calculate range and bearing for each gun corrected for non-standard conditions and distribution. |
| PAAC_FM15 | PAAC_DSPFM | DISPLAY_FM | Display fire data calculating qe and fuse for each gun. |
| PAAC_FM16 | PAAC_GMA | GMA<br>GMA1 | Set gun mask for mission.<br>Set gun mask for mission (parallel/converge). |
| PAAC_FM17 | PAAC_PROFILE | PROFILE | Display/modify mission profile. |
| PAAC_FM18 | PAAC_POLER | POLER | Enter target data for polar mission. |
| PAAC_FM19 | PAAC_SAFETY | SAFETY_CHECKS | Check safety of troops and forward observers. |

TABLE I.4 FIRE MISSION LIBRARY 2 (FM2LIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_FM21 | PAAC_RESET_MSN | RESET_MISSION | Set mission profile to standard. |
| PAAC_FM22 | PAAC_DISTR | DISTRIBUTION<br><br>PROJECTILE | Select distribution of fire.<br>Select ammunition type. |
| PAAC_FM23 | PAAC_OORG | OORG<br><br>OORG1 | Issue out of range message for battery.<br>Issue out of range message for single gun. |
| PAAC_FM24 | PAAC_QEC | QEC | Qe and fuse calculation for HE/SMK. |
| PAAC_FM25 | PAAC_QEI | QEI | Qe and fuse calculation for ILLUM. |
| PAAC_FM26 | PAAC_FT1 | FIRING_TABLE | Calculate corrections for non-standard conditions HE/SMK. |
| PAAC_FM27 | PAAC_FT2 | FTAB1 | Continuation of above. |
| PAAC_FM28 | PAAC_ILLUMTAB | ILLUM_TABLE | Calculate corrections for non-standard conditions ILLUM. |
| PAAC_FM29 | PAAC_KREST | KREST | Calculate crest clearance factors and return minimum. |

TABLE I.5 FIRE MISSION LIBRARY 3 (FM3LIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_FM31 | PAAC_BALLISTIC | BALLISTIC | Calculate variation of ballistic quantities from standard. |
| PAAC_FM32 | PAAC_RNGBERCORR | RNGBERCORR | Apply non-standard corrections and distribution of fire HE/SMK. |
| PAAC_FM33 | PAAC_DIL | DIL | Apply non-standard corrections and distribution of fire ILLUM. |
| PAAC_FM34 | PAAC_FFE | FFE | Solve vector equation x + ? = y. |
| PAAC_FM35 | PAAC_GUNQEFZ | GUNQEFZ<br><br>GUNQF | Calculate/display qe and fuse for a gun.<br>Calculate qe and fuse for a gun. |
| PAAC_FM36 | PAAC_CHKRNG | CHECK_RANGE | Check if guns in range and decide if new charge can be tried when adjusting gun is out of range. |
| PAAC_FM37 | PAAC_RGLAT | RGLAT | Adjust gun R, BER for range and/or lateral spread distribution of fire. |
| PAAC_FM38 | PAAC_DSPCREST | DSPCREST | Calculate/display crest clearance factors for a gun. |
| PAAC_FM39 | PAAC_CALDISTR | CALDISTR | Adjust gun R, BER for distribution of fire and gun to battery centre offset. |

TABLE I.6 FIRE MISSION LIBRARY 4 (FM4LIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_FM41 | PAAC_HEPT | HEPT | Hept mission calculations. |
| PAAC_FM42 | PAAC_APERS | APERS | Apers mission calculation. |
| PAAC_FM43 | PAAC_METREGN | METREGN | Enter met data. |
| PAAC_FM44 | PAAC_CRNREDN | CRNREDN | Store accumulated add and right corrections. |
| PAAC_FM45 | PAAC_REGLWMET | REGMET<br>LWMET<br>ADDRGTADJ | Calculate registration met corrections.<br>Calculate laser witness point met corrections.<br>Convert add and right corrections with respect to one bearing to add and right corrections with respect to a new bearing. |
| PAAC_FM46 | PAAC_TEST | TEST | Test PAAC keyboard and display. |
| PAAC_FM47 | PAAC_CHGGRD | CHGGRD | Change of grid routine. |
| PAAC_FM48 | PAAC_METSELN | METSELN | Select met correction. |

TABLE I.7 READ PRINT LIBRARY (RDPLIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_RDP1 | FOPROCS | READFON | Read forward observer number. |
| | | PRINTFOHEAD | Print heading for input and output of forward observer data. |
| | | PRINTFO | Print forward observer data. |
| | | READFO | Read forward observer data. |
| PAAC_RDP2 | TG_PROCS | FINDSPCTG | Find storage for target record. |
| | | FINDRECTG | Find stored target record. |
| | | READTGN | Read target number. |
| | | READTG | Read target record. |
| | | PRINTTGHEAD | Print heading for input and output of target data. |
| | | PRINTTG | Print target record. |
| | | SPRINTTG | Print target data for mission target. |
| | | TGTSTORE | Store mission target data in record. |
| | | TGTRETRV | Get mission target data from record. |
| | | SREADTG | Read mission target data. |
| PAAC_RDP3 | MSNPROCS | MSNSTORE | Store mission data. |
| | | MSNRETRV | Retrieve mission data. |
| PAAC_RDP4 | TPPROCS | READTPN | Read troop number. |
| | | PRINTTPHEAD | Print heading for input and output of troop data. |
| | | PRINTTP | Print troop record. |
| | | READTP | Read troop record. |
| PAAC_RDP5 | MET_PROCS | ENTER_MET | Enter computer met data. |
| PAAC_RDP6 | PAAC_READMET | READMET | Enter one computer met line. |
| PAAC_RDP7 | PAAC_GRDALT | PRINTGDALT | Print grid and altitude. |
| | | READGDALT | Read grid and altitude. |

TABLE I.8 TARGET LOCATION CORRECTION LIBRARY 4 (CRNLIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_CRN1 | PAAC_FOCORR | FOCORR | Enter polar and non-polar forward observer corrections. |
| PAAC_CRN2 | PAAC_TGREDN | TGREDN | Target reduction routine. |
| PAAC_CRN3 | PAAC_ALTFUZ | ALTFUZ | Alter burst height or target altitude. |
| PAAC_CRN4 | PAAC_RECALL | RECALL_MSN | Recall stored mission. |

TABLE I.9 GENERAL PURPOSE PROCEDURES LIBRARY (GP2LIB)

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC_GP21 | PAAC_POLAR | POLAR | Convert from cartesian to polar coordinates. |
| | | GRIDADJ | Adjust grid coordinates to fall in the range -0.499999 to 99999.5. |
| | | CARTESIAN | Convert range and bearing from known point to cartesian coordinates. |
| PAAC_GP22 | PAAC_CCFNEWT | CCFNEWT | Solve crest clearance model by newtons method. |
| PAAC_GP23 | PAAC_HEIGHT | HEIGHT | Evaluate crest clearance model. |
| PAAC_GP24 | PAAC_PRINTGUN | PRINTGUN | Print predicted data for gun. |
| PAAC_GP25 | PAAC_TARADJ | TARADJ | Adjust target grid for add and right corrections. |

TABLE I.10 OTHER MODULES

| File Name | Module Name | Procedure or Function Name | Description |
|---|---|---|---|
| PAAC | PAAC_MAIN | MAIN | Main control routine. |
| PAAC_CONS | | | Firing table data declared as constants in Z80 package. |
| PAAC_CON1 | | | Other real, integer and byte constants. |
| PAAC_VARS | PAAC_VARS | | Array variable declarations. |
| PAAC_VAR1 | PAAC_VAR1 | | Simple variable declarations. |
| PAAC_STRS | | | String and set constants. |
| PAAC_START | | | Initialise stack and interrupt (Z80). |
| PAAC_INT | INITIALISE | INIT | Initialise variables. |

TABLE I.11 LIBRARY CREATION FILE LIB

| Command | Remarks |
|---|---|
| PARMS &PREFIX | Enter library prefix. |
| purge TEMPCOM | Delete old copy of TEMPCOM. |
| edit LIBCOM into TEMPCOM | Create new copy of TEMPCOM |
| replace "XXX" with "&PREFIX" all | for current library |
| end | End edit |
| TEMPCOM | Invoke TEMPCOM |

TABLE I.12 LIBRARY CREATION FILE LIBCOM

| Command | Remarks |
|---|---|
| purge XXXLIB | Delete old library. |
| library PAAC_XXX1 to XXXLIB | Add file1 to library. |
| library PAAC_XXX2 to XXXLIB | Add file2 to library. |
| library PAAC_XXX3 to XXXLIB | Add file3 to library. |
| library PAAC_XXX4 to XXXLIB | Add file4 to library. |
| library PAAC_XXX5 to XXXLIB | Add file5 to library. |
| library PAAC_XXX6 to XXXLIB | Add file6 to library. |
| library PAAC_XXX7 to XXXLIB | Add file7 to library. |
| library PAAC_XXX8 to XXXLIB | Add file8 to library. |
| library PAAC_XXX9 to XXXLIB | Add file9 to library. |

TABLE I.13 LIBRARY CREATION FILE FOR PPDS

| Command | Remarks |
|---|---|
| purge FPIOLIB | Delete old copy of FPIOLIB. |
| library PAAC_IOZ to FPIOLIB | Add PAAC_IOZ to FPIOLIB. |
| library PAAC_IOP to FPIOLIB | Add PAAC_IOP to FPIOLIB. |
| library PAAC_IOP1 to FPIOLIB | Add PAAC_IOP1 to FPIOLIB. |
| library PAAC_MOD to FPIOLIB | Add PAAC_MOD to FPIOLIB. |
| library PAAC_FLOA to FPIOLIB | Add PAAC_FLOA to FPIOLIB. |
| library PAAC_POLY to FPIOLIB | Add PAAC_POLY to FPIOLIB. |
| library PAAC_TYPE to FPIOLIB | Add PAAC_TYPE to FPIOLIB. |

DISTRIBUTION

| | Copy No. |
|---|---|
| DEPARTMENT OF DEFENCE | |
| Defence Science and Technology Organisation | |
| Chief Defence Scientist | 1 |
| Deputy Chief Defence Scientist | |
| Controller, External Relations, Programs and Analytical Studies | |
| Superintendent, Science Programs and Administration | |
| Defence Science Representative, London | Cnt Sht Only |
| Counsellor, Defence Science, Washington | Cnt Sht Only |
| Deputy Secretary (Manufacturing) | 2 |
| Deputy Secretary (Materiel and Resources) | |
| Controller, Defence Aerospace Division | |
| Controller, Munitions Division | |
| Director, Industry Development, SA/NT | Cnt Sht Only |
| Weapons Systems Research Laboratory | |
| Director, Weapons Systems Research Laboratory | 3 |
| Superintendent, Aeroballistics Division | 4 |
| Head, Ballistics Composite | 5 |
| Principal Officer, Ballistic Studies Group | 6 |
| Principal Officer, Dynamics Group | 7 |
| Principal Officer, Field Experiments Group | 8 |
| Principal Officer, Flight Research Group | 9 |
| Mr F.G. Phillips, Ballistic Studies Group | 10 |
| Mr J.F. Teague, Ballistic Studies Group | 11 |
| Mr S.G. Johnson, Flight Research Group | 12 |
| AD Library | 13 - 14 |
| Author | 15 - 16 |
| Electronics Research Laboratory | |
| Superintendent, Electronic Warfare Division | 17 |

| | |
|---|---|
| Australian Ordnance Council | |
| President | 18 |
| Navy Office | |
| Navy Scientific Adviser (Attention: Mr A.M. Sayer) | 19 |
| Army Office | |
| Scientific Adviser - Army | 20 |
| Director-General, Materiel - Army | 21 |
| Director-General, Logistics - Army | 22 |
| Director of Operations - Army | 23 |
| Director of Operational Requirements - Army | 24 |
| Director, Materiel Assessments - Science | 25 |
| Director, Electronic Procurement - Army | 26 |
| Director Armament Procurement - Army | 27 |
| Director of Infantry - Army | 28 |
| Director of Artillery - Army | 29 |
| Controller, Quality Assurance, HQ Log Command (Attention: Mr P. Buchler) | 30 - 31 |
| Infantry Centre (Attention: Commandant) | 32 |
| School of Artillery (Attention: Captain F. Colley) | 33 |
| Commander, Engineering Development Establishment (Attention: Electronics Engineer) | 34 - 35 |
| Director General, Army Development (NSO), Russell Offices for ABCA Standardisation Officers | |
| UK ABCA representative, Canberra | 36 |
| US ABCA representative, Canberra | 37 |
| Canada ABCA representative, Canberra | 38 |
| NZ ABCA representative, Canberra | 39 |
| Air Office | |
| Staff Officer (Science) HQ 1 Division | 40 |
| Staff Officer (Science) HQ Field Force Command | 41 |
| Staff Officer (Science) HQ Training Command | 42 |

Libraries and Information Services

| | |
|---|---|
| Defence Library, Campbell Park | 43 |
| Document Exchange Centre<br>Defence Information Services Branch for: | |
| Microfilming | 44 |
| United Kingdom, Defence Research Information Centre (DRIC) | 45 - 46 |
| United States, Defense Technical Information Centre | 47 - 58 |
| Canada, Director, Scientific Information Services | 59 |
| New Zealand, Ministry of Defence | 60 |
| National Library of Australia | 61 |
| Director, Joint Intelligence Organistion (DSTI) | 62 |
| Library, Materials Research Laboratories | 63 |
| Library, Aeronautical Research Laboratories | 64 |
| Library, Defence Research Centre Salisbury | 65 |
| Library, Royal Australian Navy Research Laboratory | 66 |
| Library, DDS Central Office | 67 |

IN UNITED KINGDOM

| | |
|---|---|
| Royal Armament Research and Development Establishment<br>(Attention: Mr T.J. Stakemire) | 68 |
| British Library, Lending Division<br>Boston Spa York | 69 |
| Institution of Electrical Engineers<br>Hitchin Hertz SG5 IRJ | 70 |

| | |
|---|---|
| IN UNITED STATES OF AMERICA | |
| Army Ballistic Research Laboratories, Maryland (Attention: Mr H. Reed) | 71 |
| Engineering Societies Library New York NY 10017 | 72 |
| PRIVATE ENTERPRISE | |
| British Aerospace, Australia (Attention: Mr K. Gramp) | 73 |
| Spares | 74 - 83 |

# DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

**1 DOCUMENT NUMBERS**

AR Number: AR-004-078

Series Number: WSRL-0362-TR

Other Numbers:

**2 SECURITY CLASSIFICATION**

a. Complete Document: Unclassified

b. Title in Isolation: Unclassified

c. Summary in Isolation: Unclassified

**3 TITLE**

ARTILLERY FIRE CONTROL PROGRAM FOR PAAC

**4 PERSONAL AUTHOR(S):**

R.M. Thamm

**5 DOCUMENT DATE:**

February 1984

**6**

6.1 TOTAL NUMBER OF PAGES 45

6.2 NUMBER OF REFERENCES: 3

**7**

7.1 CORPORATE AUTHOR(S):

Weapons Systems Research Laboratory

7.2 DOCUMENT SERIES AND NUMBER

Weapons Systems Research Laboratory 0362-TR

**8 REFERENCE NUMBERS**

a. Task: ARM 83/101

b. Sponsoring Agency:

**9 COST CODE:**

318934/342

**10 IMPRINT (Publishing organisation)**

Defence Research Centre Salisbury

**11 COMPUTER PROGRAM(S)** (Title(s) and language(s))

**12 RELEASE LIMITATIONS (of the document):**

Approved for Public Release

Security classification of this page: UNCLASSIFIED

Security classification of this page: UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages):

No limitation

14 DESCRIPTORS:

a. EJC Thesaurus Terms

Gun fire control
Artillery
Portable equipment
Calculators

b. Non-Thesaurus Terms

Portable all arms calculator

15 COSATI CODES:

09020

16 SUMMARY OR ABSTRACT:
(if this is security classified, the announcement of this report will be similarly classified)

The "Portable All Arms Calculator" (PAAC) was developed by WSRL to carry out fire control applications. This document describes the program developed at Weapons Systems Research Laboratory to demonstrate artillery fire control for the M2A2 gun system on PAAC.

Security classification of this page: UNCLASSIFIED

The official documents produced by the Laboratories of the Defence Research Centre Salisbury are issued in one of five categories: Reports, Technical Reports, Technical Memoranda, Manuals and Specifications. The purpose of the latter two categories is self-evident, with the other three categories being used for the following purposes:

| | | |
|---|---|---|
| Reports | : | documents prepared for managerial purposes. |
| Technical Reports | : | records of scientific and technical work of a permanent value intended for other scientists and technologists working in the field. |
| Technical Memoranda | : | intended primarily for disseminating information within the DSTO. They are usually tentative in nature and reflect the personal views of the author. |

# END

# FILMED

10-85

# DTIC