A System Dynamics Simulation Model of the U.S. Marine Corps Manpower System.

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Abstract

A number of different methodologies have been applied to the study of manpower planning systems. This paper presents and develops a computer simulation approach through the use of System Dynamics in study of the manpower requirements of the U.S. Marine Corps. A number of different recruitment policies were studied to observe their impact on the total manpower system. In addition, the ramifications of the economy, the unemployment rate, the socio-biological trend of a reducing population segment of recruitable age, and the increasing political uncertainty on the combat effectiveness of the first line combat infantry force are studied.

1. Introduction

Manpower planning systems are concerned with the interaction of positions, people and time. Within an organizational context, the basic goal of a manpower planning system is to provide the proper number of the right type of people in the correct numbers at the right time to the organization. A wide variety of techniques and methodologies have been applied to the study of the manpower planning process through the use of mathematical models. These mathematical models are designed to relate system performance to manpower policy. The decision variables of the mathematical models can then be varied to observe the impact the decision variables have in the short-run and long-run on overall system performance.

A large number of studies have utilized the methodology of Markov chains to study the personnel movements through an organization (see for example Bartholomew (1), Gani (6), Grinold and Marshall (7), and Hayne and Marshall (9)). Dynamic programming (10), goal programming (2) (11), mathematical programming (8), stochastic processes (1) (4) (8) (12) and computer simulation (12) are representative of some of the mathematical models that have developed to study and optimize the performance of the manpower planning systems under study.

This paper will be concerned with the development of a computer simulation model based on the methodology of System Dynamics (5) to study and analyse a number of different recruitment policies for the U.S. Marine Corps. The purpose of this analysis is to improve the overall system performance (see Thie and Lorbeer (13)). The focus of this analysis will be upon enlisted infantry sector of the U.S. Marine Corps. (see (14)).

In Section II a brief description of System Dynamics is provided describing some of its characteristics and structure. Section III provides information about the U.S. Marine Corps and its manpower planning policies and practices. In Section IV, a description of the computer simulation model is provided and the details concerning the model's development is given. Section V is an analysis of the output of the computer simulation model. Section VI contains a summary of the research and provides directions for further research.

II. The Role of System Dynamics in Manpower Planning Systems

System Dynamics, (5), is particularly well-suited to modelling manpower systems for several reasons. First, System Dynamics can explicitly incorporate the effects of behavior in the computer model. In many cases, this capability can be effectively utilized to describe what actually occurs in realistic situations. Second, the effects of delays of information or action can be studied in detail to view their effect on manpower policies and procedures. In many cases, the time to actually implement a particular policy or procedure can be quite lengthy. Research on the effect of particular manpower policies can be performed to determine the length of time involved between the initiation and final completion of a particular policy. Since time delays can be quite significant in such systems, careful study of time delays can be quite useful. In addition, the time horizon for manpower policies can be quite lengthy and System Dynamics explicitly incorporates the time horizon into the modelling process so that changes in rates and levels can be studied. And third, the language of System Dynamics is already familiar to manpower planners: who speak of the workforce in terms of manning or staffing levels and rates of turnover; the same concepts, level and rates, describe the states and activities in a System Dynamics model.

The DYNAMO (5) programming language has been used for many System Dynamics studies; however, the computer model that has been developed for this paper was programmed in the MIMIC programming language which is quite similar (see reference (16) for a complete description of the simulation language).

III. The Manpower System of the U.S. Marine Corps

There are two key variables which determine the worth of a military force: men and hardware. Presently, the hardware is purposely negotiated to be equivalent in military technology. As a result, the key variable to a strong defence establishment is the quality and quantity of its military personnel. This study is designed to simulate the inflows, levels and outflows of this most crucial resource in the occupational field of infantry. Vital to the impact of this study is the basic understanding that the U.S. Marine Corps is literally in a constant state of 24 hours preparedness. This implies the likelihood that this armed contingency is America's first line of defence. Like the other military services, the U.S. Marine Corps, which maintains three divisions and three aircraft wings, has a budget constraint for it's operations established by the U.S. Congress (see reference (14)). The key components of the organization are the rifle infantryman, non-commissioned officers, and staff non-commissioned officers. The computer simulation model will deal explicitly with these.

The computer simulation model developed is a broad conceptualization incorporating only a portion of the many considerations that must be involved in managing manpower in the U.S. Marine Corps. As Major D.E.Christy explains (3):

> "Detailed manpower requirements are continually being developed and updated. This process entails a great deal of negotiation among all headquarters agencies. Any change in manpower requirements due to a change in mission or structure operates under the constraint that the total strength of the Marine Corps can not exceed force levels approved by Congress or programmed by DOD".

The Marine Corps employs several complex simulation programs in efforts to determine the most efficient structure for force requirements. Maintaining "end strength goals" is the primary objective in most of these programs. For example, Major Christy describes one vital model (3):

> "The Automated Simulation for Total Requirements and Authorization Forecast and Evaluation (STRAFE) model produces forecasts of the desired occupational and grade composition of the Marine Corps".

Among the outputs, this simulation produces the Marine Corps manpower requirements in terms of occupational specialty needed to <u>support</u> all authorized billets.

An overview of manpower planning simulation models reveals that most models employed by manpower managers are designed to allocate the proper number of personnel with appropriate skill designations deemed most effective in meeting ever-changing mission requirements and technological developments. The simulation presented in this paper differs in several key ways. First, it deals with one specific occupational speciality, infantryman. Second, it is designed to measure effectiveness as a ratio of actual numbers of personnel to desired numbers of personal at any one point in time. Effectiveness is, of course, a function of quality of training as well as a number of qualitative aspects that are exceedingly difficult to quantify.

Specifically, the problems of leadership and morale are excellent examples of this. The computer model employs a ratio as the most effective way to measure preparedness. Third, a main concern in the computer model is the effect of important exogenous variables on the effectiveness of the infantry. Two such variables are illustrated in Figure 1 and Figure 2 and these variables deal with economic and social conditions respectively. Figure 1 depicts the relationship between the 16-21 teenage U.S. unemployment rate and the difficulty of recruiting new enlistments into the U.S. Marine Corps. In general, the lower the unemployment percent, the more difficult it is to successfully recruit new U.S. Marines. The data for this observation comes from a number of studies (see Gilfillan and Brown (7) for further information). Figure 2 illustrates the relationship between the declining birth rate projected and time. Over the next twenty years, there will be a shrinking group in the recruitable age population due primarily to the falling birth rate in the U.S. (see (7)).

Thus in these specific regards, the fundamental difference between this computer simulation and the more traditional uses of simulation in the U.S. Marine Corps is the capability of this simulation to model these other areas of the recruiting problem in the overall manpower planning problem.

IV. Computer Simulation Model Construction and Description

This section describes in detail the construction of the computer simulation model. A flow chart of the model is provided in Figure 3. The notation of the flow chart follows the methodology of Forrester (5). These are three different types of entities on the flow chart: levels, rates and auxiliary functions. Levels are indicated by the rectangular boxes, rates are noted by the signal flow meters and auxiliary functions are shown as circles. The sources and sinks of labor are shown as "pools". The dashed lines indicate information flow among the various components of the system and the solid lines that connect the various components are the actual flow of people. Appendix III contains a complete listing of the program. The computer program was written in MIMIC which accomplishes virtually the same purpose as Forrester's DYNAMO (5) (16). In Appendix IV, a list of the key abbreviations used in the computer simulation model are provided.

Each level and rate shown in Figure 3 is represented by an equation. As an illustration of how the computer model equations were developed, the equation which calculates the number of riflemen (RIFLM) will be shown in detail. This level is a function of several different components in the model. The specific equation is:

(1) RIFLM = INT(INPUT − (RTRNR + RPROM), INRFM)

Rearranging terms: $\text{RIFLM} = \text{INRFM} + \int_0^T (\text{INPUT} - (\text{RTRNR} + \text{RPROM})$

where:

RIFLM = the number of riflemen (units)

INRFM = the initial number of riflemen (units)

INT = integration function over a specified period

INPUT = the number of new recruit accessions (units/time)

RTRNR = the number of riflemen transferred (units/time)

RPROM = the number of riflemen promoted (units/time)

Thus, to determine the number of riflemen in the next time period, one level and three rates are needed for this calculation. The initial number of riflemen is carried forward period by period so that the data is constantly being updated by the latest calculation. The three rates (units/period of time) reflect one positive input rate and two negative output rates into the level of riflemen. As a further illustration of these equations, the equation for the number of recruits input is developed:

(2) INPUT = ((QUOTA x POMLT) UNMLT) (1/QAJT)

where INPUT = number of recruits input (units/period of time)

QUOTA = number of recruits needed (difference between the desired level of riflemen and the current number of riflemen (units)

POMLT = population multiple (the multiple of a function that expressed the market shrinkage due to a population decline)%

UNMLT = unemployment multiple (the multiple of a function that expresses the market shrinkage or growth due to increased or decreased employment alternatives)%

QAJT = qualification adjustment time (which is equal to the length of recruit training time) (period of time)

Note that the units on both sides of the equation balance out correctly. That is, recruits per period of time eventually equals recruits per period of time. These two equations are merely representative of the equations that were developed for this specific model. The reader is referred to Appendix 1 for a detailed listing of the remainder of the equations.

FIGURE 1

ACCESSION FACTOR (ASFCT)

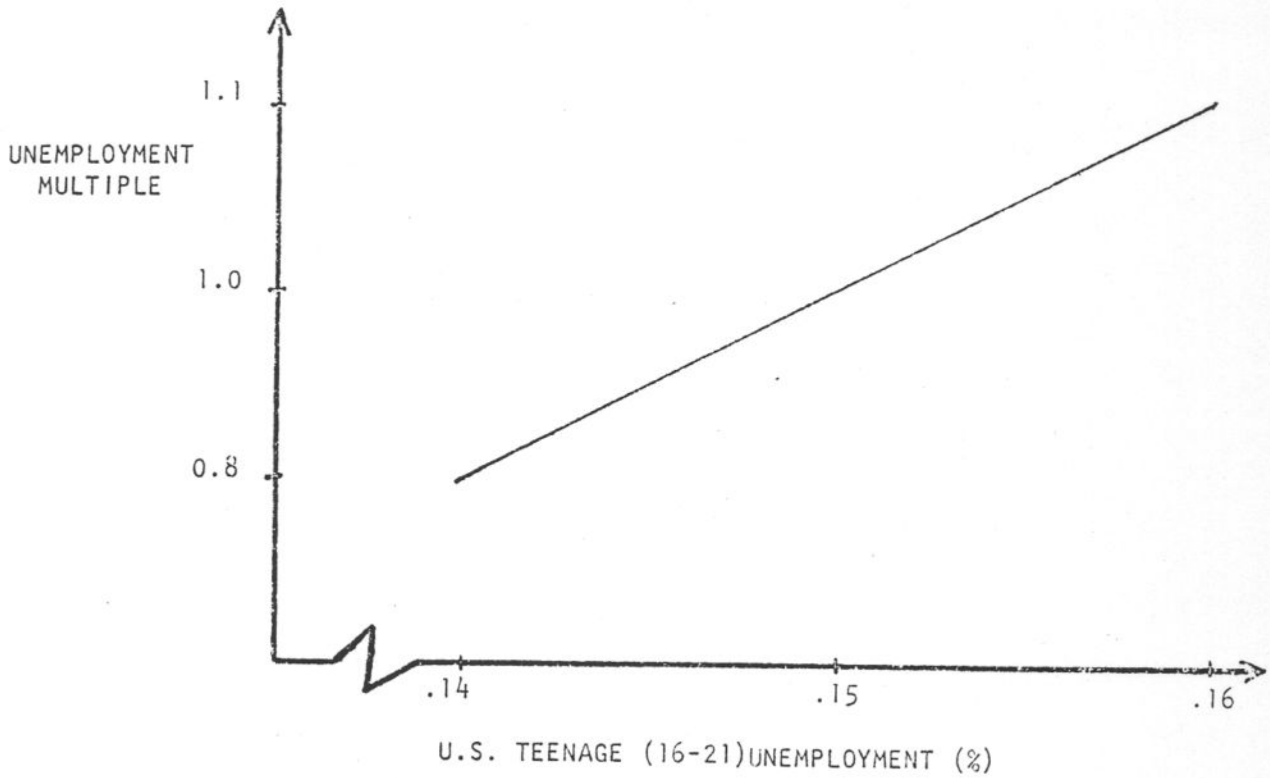


FIGURE 2

RECRUITABLE AGE POPULATION DECLINE (PODRC)

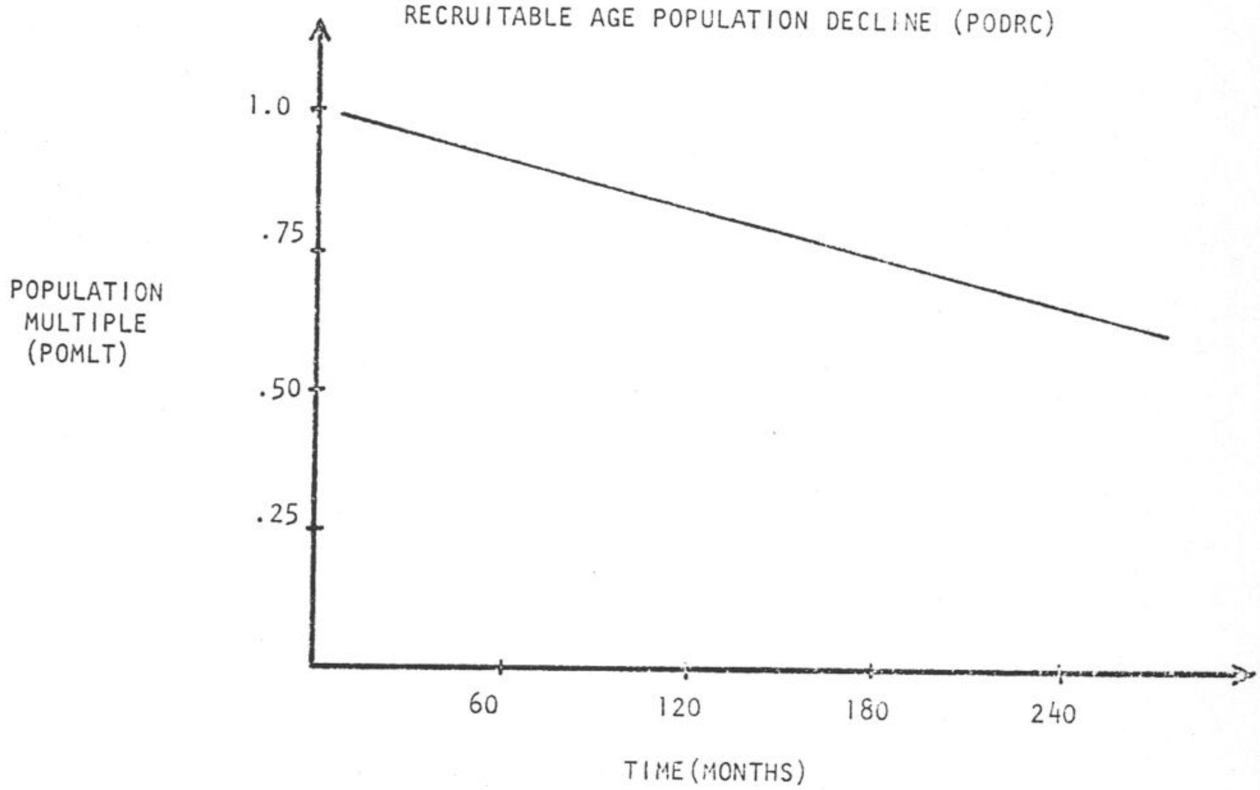
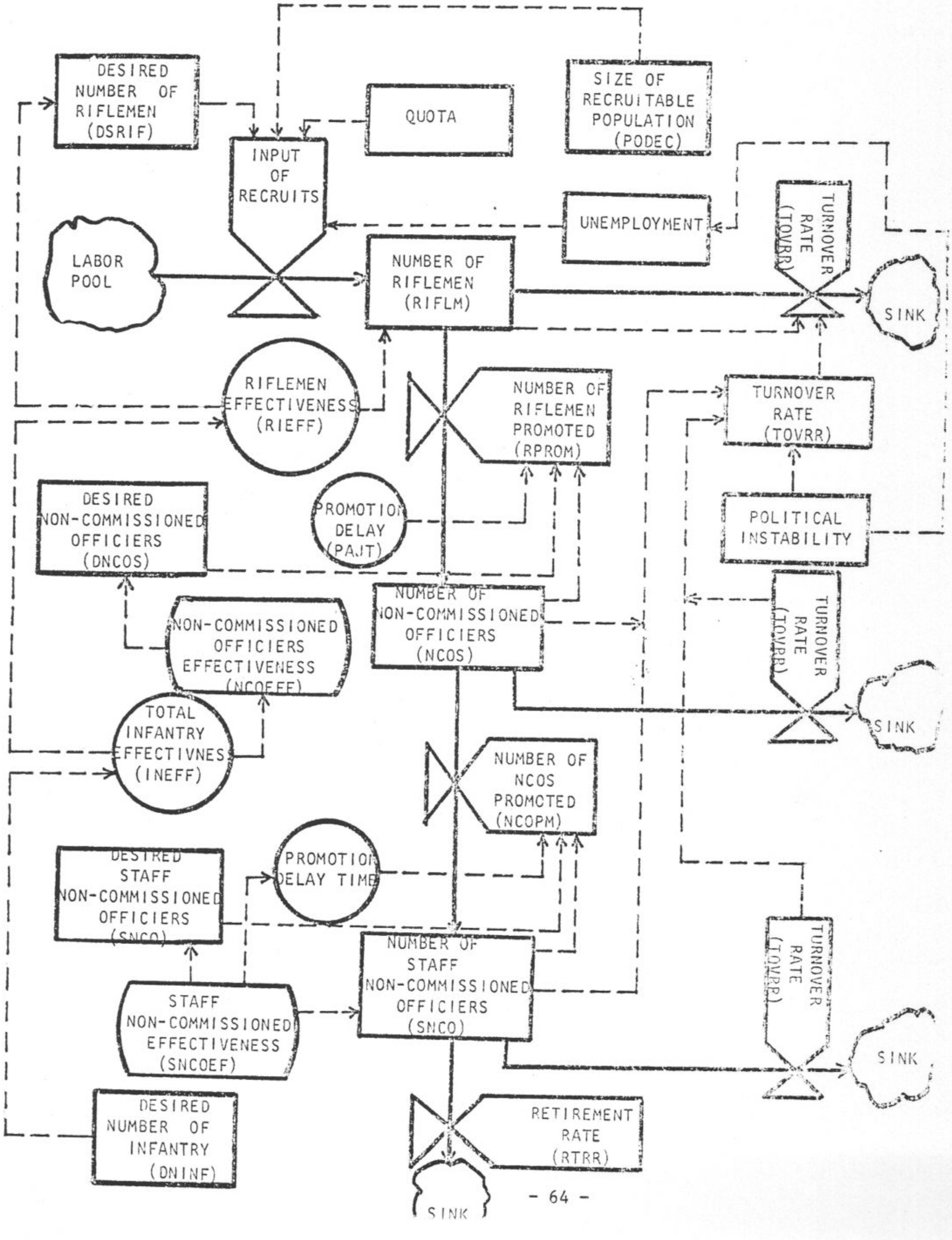


FIGURE 3
COMPUTER SIMULATION FLOW CHART



V. Analysis of Computer Simulation Results

This section presents the results of a series of four different computer simulations under a variety of assumptions. As Table 1 indicates, this study considers four parameters that influence the percentage effectiveness of the infantry. The first parameter, turnover rate, refers to the percentage of infantry personnel transferred in a one-month period either to other occupations, non-infantry assignments or to the civilian community. Qualification adjustment time refers to the amount of time required to bring a raw recruit from the civilian environment and place that recruit into the infantry unit with adequate confidence in his preparedness. Unemployment random variance refers to the random oscillations experienced in the unemployment rates; it is proposed that this variation is related to the success of recruitment efforts. Amplitude in unemployment variation refers to the amount that the unemployment rate is changed, on a continuous time correlation, during each run. For example, in these computer simulations the unemployment rate varies plus or minus 5% over the test period of ten years.

TABLE 1 - COMPUTER SIMULATION OUTPUT

COMPUTER RUN	TURNOVER RATE	QUALIFICATION ADJUSTMENT TIME (MONTHS)	UNEMPLOYMENT RANDOM VARIANCE	AMPLITUDE IN UNEMPLOYMENT VARIATION
1	.04166	3.7	0	.05
2	.04166	3.7	.02	.05
3	.05826	3.0	0	.05
4	.05826	3.0	.02	.05

The output for the first computer simulation, as shown in Figure 4, illustrates the impact of changing economic factors and the decline in recruitable age population. This simulation shows the effect of unemployment since about year five the effectiveness of the infantry begins to fall in direct proportion with the riflemen not attained. It should also be noted that in all runs, effectiveness follows closely the riflemen effectiveness because the other two levels, that of non-commissioned officers and staff non-commissioned officers, are supplied from this first entry level. The turnover rate of 4% per month allows the infantry unit to maintain an effectiveness ratio of approximately 86% during slow economic growth or recession, and an effectiveness ratio of about 82% in times of rapid economic growth.

Figure 5 illustrates the effect of random variation often witnessed in seasonally unadjusted data. The result is a less effective infantry force and a considerably more uncertain level of riflemen from period to period. This uncertain level of riflemen makes it difficult to definitively meet new and changing mission obligations. If such conditions are realized, this could be damaging to the sense of continuity required among combat units.

Figure 6 illustrates the same conditions as does computer simulation number one, but reduces the amount of time required to bring a replacement to the field (a phenomenon witnessed during all conflicts). The effectiveness ratio is increased over the whole period by approximately three percent, even with increased turnover.

The fourth computer simulation, shown in Figure 7, demonstrates the conditions of computer simulation number two, but the qualification adjustment time has been reduced and the turnover rate has been increased. This results in considerably instability that would be extremely uncomfortable to manpower managers.

VI. Summary and Recommendations for Further Research

The following conclusions can be drawn by the computer simulation results: (1) Decreasing the time required to replace a transferred individual will increase the effectiveness ratio, as we have measured it. (2) The effects of random variation in unemployment may have serious consequences on short term management if this variation is believed to indicate a trend to those planning to leave the infantry.

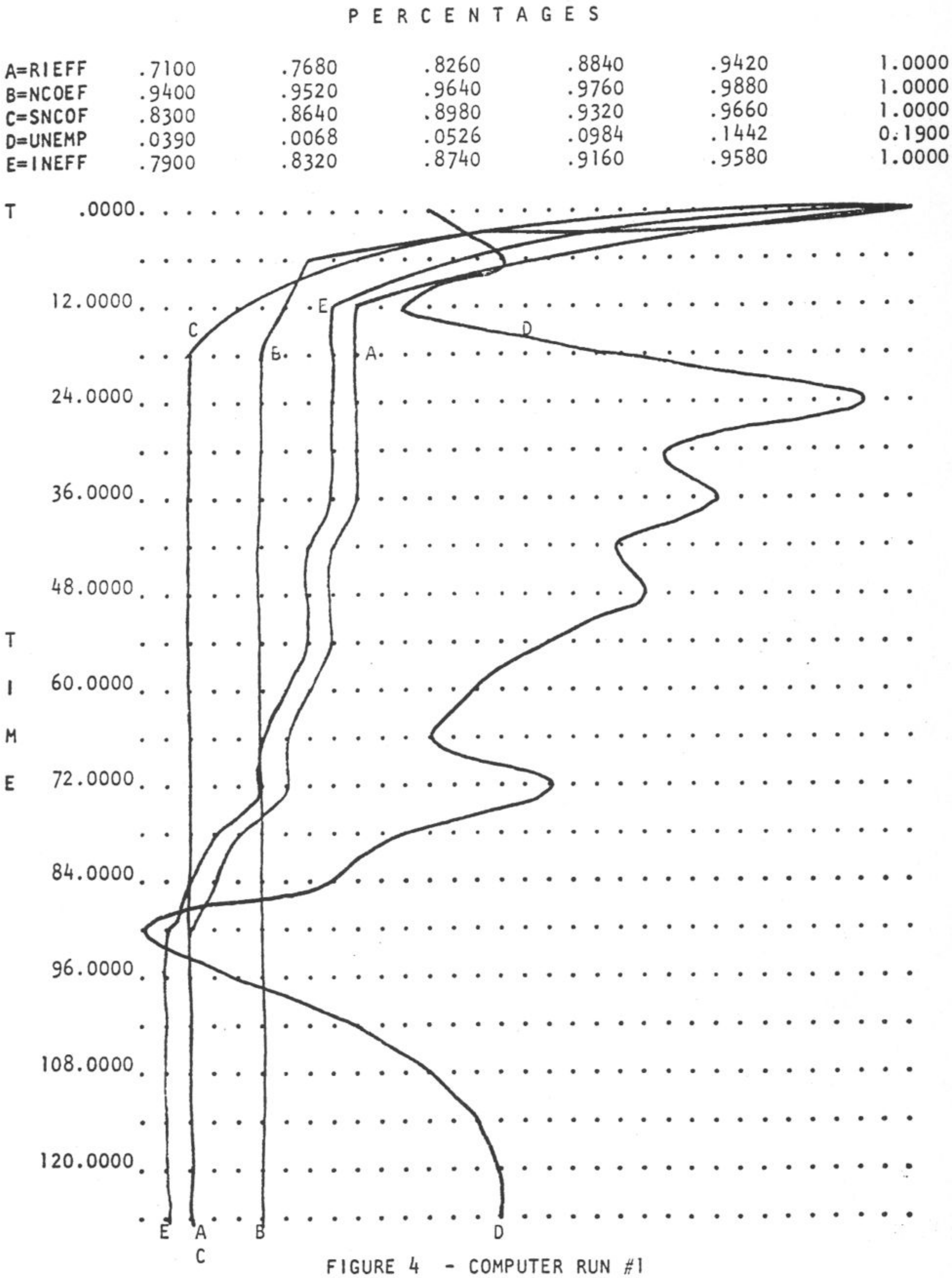


FIGURE 4 - COMPUTER RUN #1

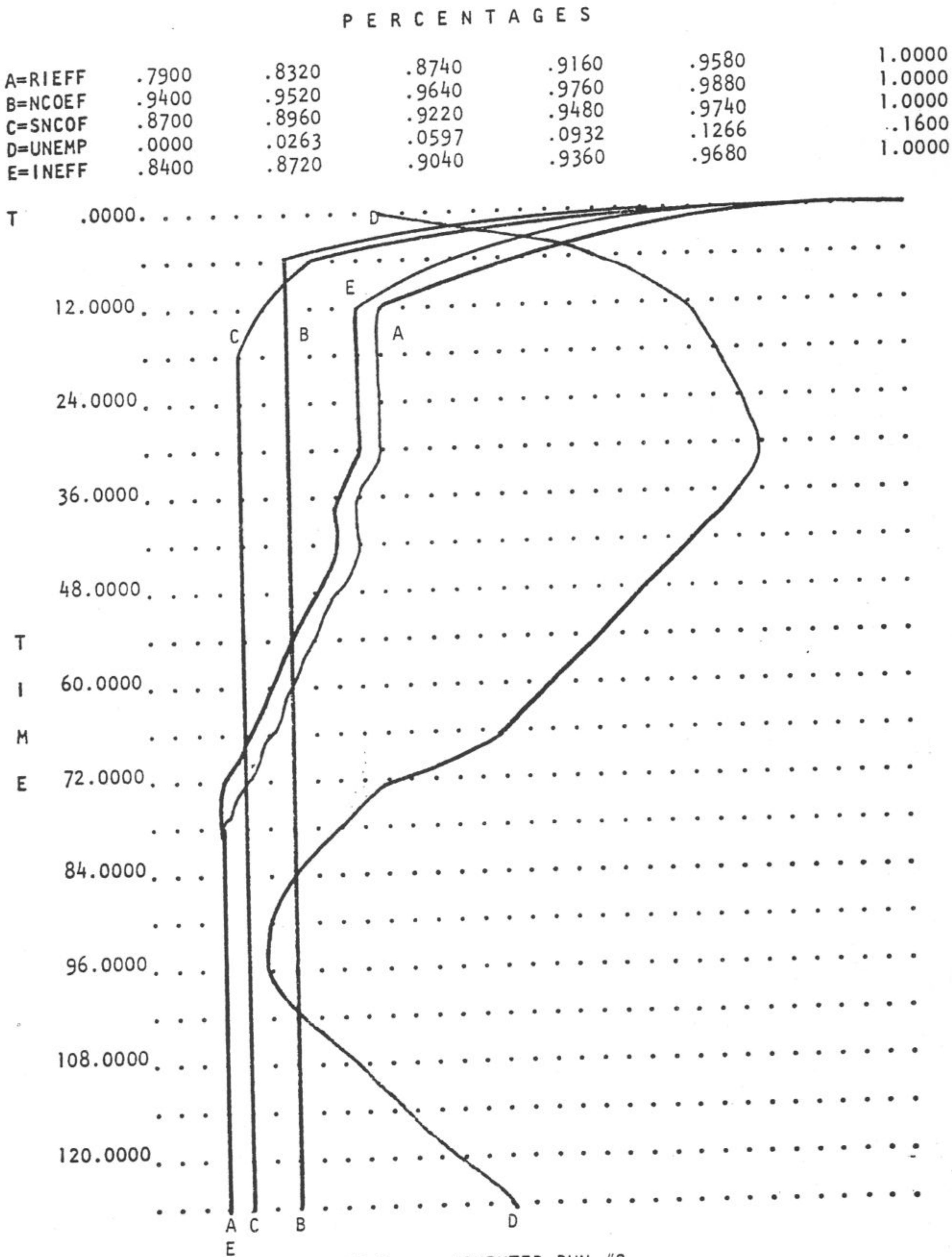


FIGURE 5 - COMPUTER RUN #2

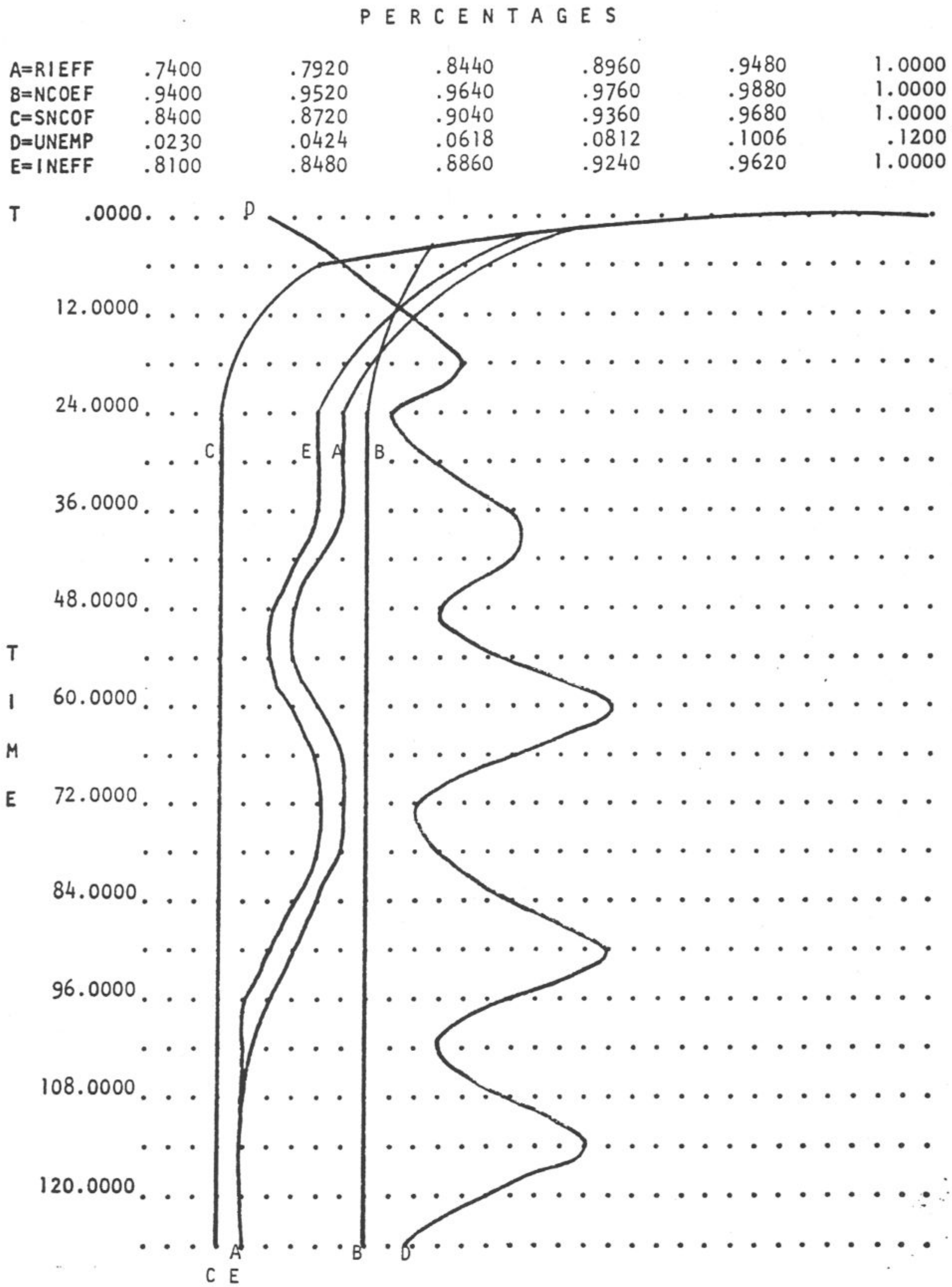


FIGURE 6 - COMPUTER RUN #3

P E R C E N T A G E S

A=RIEFF	.7300	.7840	.8380	.8920	.9460	1.0000
B=NCOEF	.9400	.9520	.9640	.9760	.9880	1.0000
C=SNCOF	.8400	.8720	.9040	.9360	.9680	1.0000
D=UNEMP	.0190	.0392	.0594	.0796	.0998	.1200
E=INEFF	.8000	.8400	.8800	.9200	.9600	1.0000

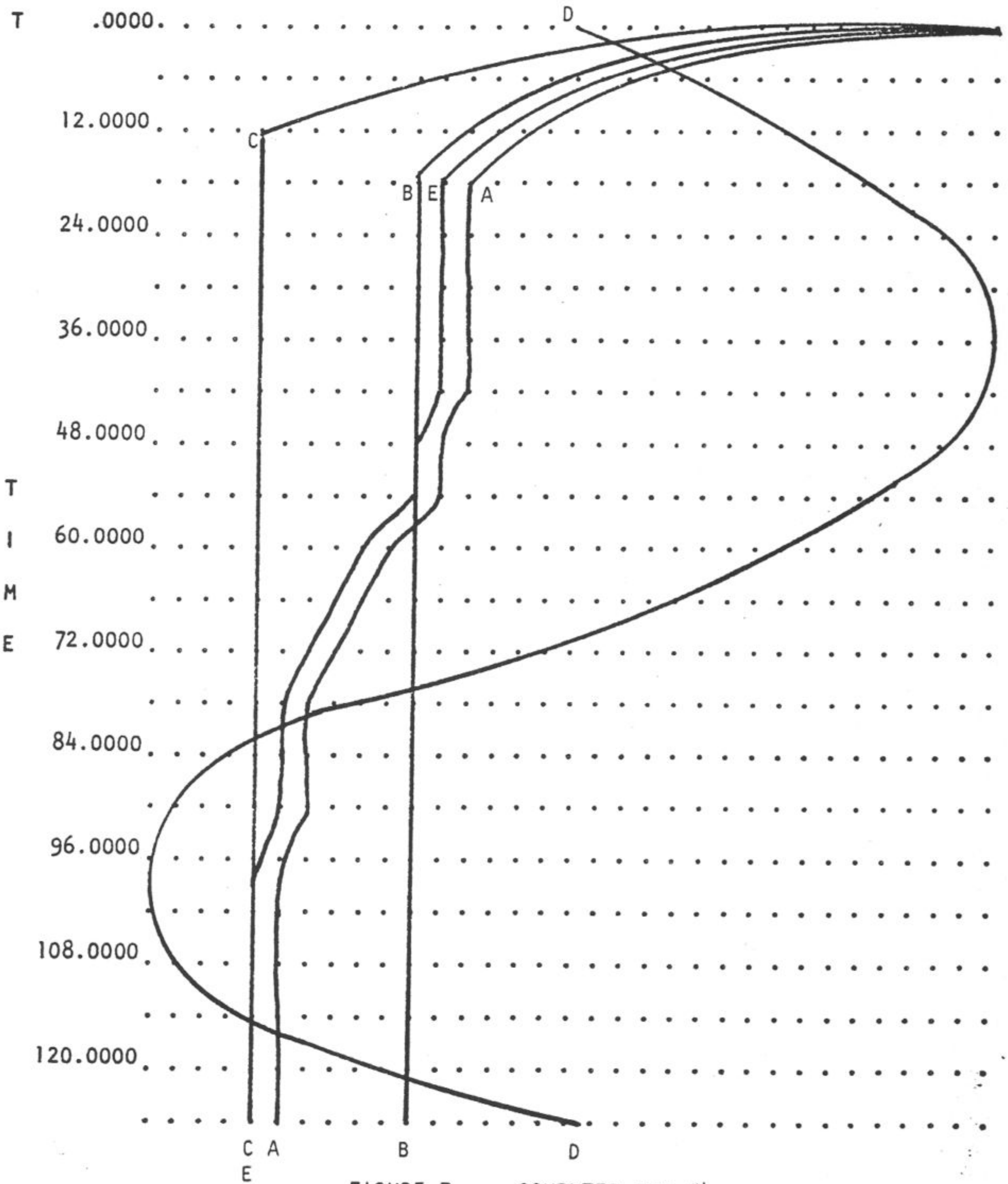


FIGURE 7 - COMPUTER RUN #4

(3) Increased turnover rates can be effectively dealt with by decreasing input rates. (4) The decline in the recruitable age population must be offset by increasing the relative benefits for joining the armed forces and by forecasting and planning for the ramification of economic growth.

This specific model developed could be extended in several possible ways. One approach would be to apply the model to the overall Marine Corps structure. With this concept, it may be rewarding to investigate the possibilities of having sub-programs that deal specifically with one occupational specialty. In this way, it might be possible to predict the probability of attaining the quality and quantity required by the simulation given the projected economic conditions and a specific population change. With such figures, recruiting budget requests could be substantiated.

The impact of recruiting more women in the U.S. Marine Corps could be explored in greater detail. The philosophy behind this particular idea is that women could perform a wider range of duties than presently performed, freeing their male counterparts to perform the stressful enterprise of combat. Even now this program is under consideration and implementation in the armed forces in general.

Another option under consideration would be to lower entrance requirements. However, this points out the problem in this program with respect to the infantry. The fact is that the lowest scores eligible for enlistment are often only eligible for a position in the combat arms, e.g. infantry. The real recruiting problem deals with attracting, and retaining intelligent, skilled young people.

Another modification would be to consider the impact of reinstituting the draft. This might be the least cost alternative, but one alternative that is politically very difficult to accomplish.

In summary, an important consideration is to establish the pros and cons of the two most likely recruiting strategies for the next several years. The present U.S. Marine Corps is the "requirements approach" see (7)) and involves recruiting within the constraints of a set quality and quantity standards. The alternative approach, and probably a more realistic strategy would be a "market approach', which uses flexible quality needs to meet manpower requirements (see (7)). The accession approach used in the computer model most closely resembles the "market approach" as it is tremendously complex to incorporate rejections rates at the recruiter level. Much more information concerning some of the population parameters in the model would have to be gathered and analyzed before such an approach could be implemented.

APPENDIX I

LISTING OF MIMIC PROGRAM

MIMIC SOURCE-LANGUAGE PROGRAM

```
C
$DELETE
C SIMULATION OF COMBAT EFFECTIVENESS
C WITH RELATION TO MANPOWER AVAILABILITY
C IN POLITICAL AND ECONOMIC INSTABILITY
C
C        CONSTANTS
                        CON(DSRIF)
                        CON(INRFM)
                        CON(INNCO)
                        CON(DSNCO)
                        CON(RETRR)
                        CON(DBNCO)
                        CON(ISNCO)
                        CON(DNINF)
                        CON(PAJT)
                        CON(NORUM)
C
C TABLES
        ASFCT   =CFN(3.)
        PODEC   =CFN(3.0)
C
C       PARAMETERS
                        PAR(TOVRR,QAJT,VAR,UNAMP)
C
C  RIFLEMEN LEVEL
C       TOTAL RIFLEMEN STRENGTH
        RIFLM   =INT(INPUT-(RTRNR+RPROM),INRFM)
        INPUT   =((QUOTA*POMLT)*UNMLT)*(1.0/QAJT)
C FACTORS EFFECTING INPUT
C UNEMPLOYMENT RATE
        UNMLT   =FUN(ASFCT,UNEMP)
        UNVAR   =ZOH(RNG(0.,VAR),1.)
        UNEMP   =NORUM+UNVAR+OSCUN
C MARKET BASE  SHRINKAGE
        POMLT   =FUN(PODEC,T)
C OSCILLATION IN UNEMP.
        OSCUN   =UNAMP*SIN(6.283*T/120.)
C
C RATE OF TRANSFER
        RTRNR   =Z
        Z       =LSW(T-1.0,0.,(RIFLM*TOVRR))
C
C       NUMBER OF PROMOTIONS AMONG RIFLEMEN
        RPROM   =(DSNCO-NCOS)*(1.0/PAJT)
C
C  RIFLEMEN EFFECTIVENESS RATIO
        RIEFF   =RIFLM/DSRIF
C  QUOTA TO RECRUITERS
        QUOTA   =DSRIF-RIFLM
C
C NONCOMMISSIONED OFFICERS LEVEL
C
C  NCO STRENGTH LEVEL
        NCOS    =INT(RPROM-(NCOTR+NCOPM),INNCO)
C
C  NCO PROMOTIONS
        NCOPM   =(DBNCO-SNCO)*(1.0/QAJT)
C
C  NCO TRANSFER RATE
```

```
      Y         =LSW(T-1.0,0.,(NCOS*TOVRR))
C
C RESULTS OF EXOGENOUS EFFECTS
      EXFCT     =QUOTA-INPUT
C
C NCO EFFECTIVE STRENGTH
      NCOEF     =NCOS/DSNCO
C
C  STAFF NONCOMMISSIONED OFFICER LEVEL
C
C SNCO TOTAL STRENGTH
      SNCO      =INT(NCOPM-(SNCOT+SNCOR),ISNCO)
C
C  SNCO TRANSFERS
      SNCOT     =X
      X         =LSW(T-1.0,0.,(SNCO*TOVRR))
C
C  SNCO RETIREMENTS
      SNCOR     =E
      E         =LSW(T-1.0,0.,(SNCO*RETRR))
C
C  SNCO EFFECTIVENESS
      SNCOF     =SNCO/DBNCO
C
C TOTAL INFANTRY EFFECTIVENESS
      INEFF     =(RIFLM+NCOS+SNCO)/DNINF
C
      DT        =1.0
      DTMIN     =0.1
      DTMAX     =0.1
                FIN(T,120.)
                OUT(T,RIFLM,NCOS+SNCO,QUOTA)
                OUT(T,EXFCT,UNEMP)
                PLO(T,RIEFF,NCOEF,SNCOF,UNEMP,INEFF)
                TTY(PERCENTAGES)
                TTX(TIME)
                END
```

```
***** CONSTANTS INPUT *****

      DSRIF =    11664
      INRFM =    11664
      INNCO =   5616.0
      DSNCO =   5616.0
      RETRR =  5.41600E-03
      DBNCO =   648.00
      ISNCO =   648.00
      DNINF =    17930
      PAJT  =   1.0000
      NORUM =  7.00000E-02
```

***** CONSTANT FUNCTION ASFCT   3 = NO. OF POINTS.

X	Y	SLOPE/Z
6.00000E-02	.90000	.0
7.00000E-02	1.0000	10.000
8.00000E-02	1.1000	10.0000

***** CONSTANT FUNCTION PODEC   3 = NO. OF POINTS.

X	Y	SLOPE/Z
1.0000	1.0000	.0
96.000	.85000	-1.57895E-03
180.00	.75000	-1.19048E-03

**TOTAL ELAPSED TIME FOR INPUT, SORT, AND ASSEMBLY IS 2.570 SECONDS.

***** EXECUTION *****

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