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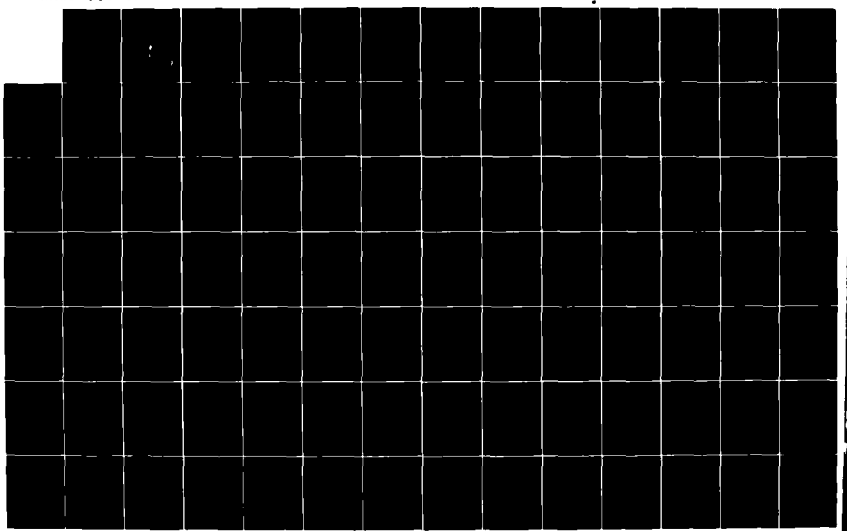

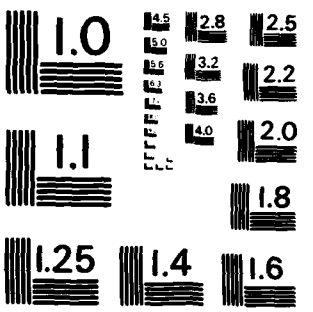


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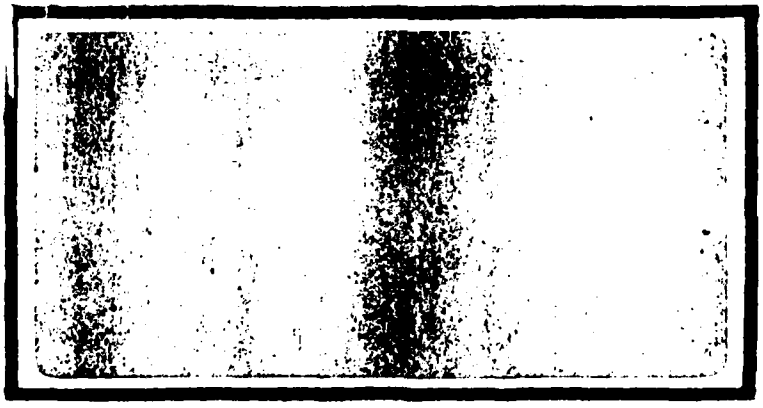






DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)

# AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GCS/EE/82D-24

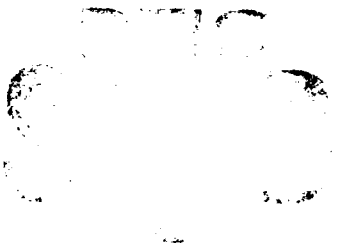
# TACTICAL AIR CONTROL SYSTEM

# SIMULATION PROGRAM

THESIS

AFIT/GCS/EE/82D-24

Donald P. McCanless
Captain USAF



AFIT/GCS/EE/82D-24

# TACTICAL AIR CONTROL SYSTEM SIMULATION PROGRAM

THESIS

Presented to the Faculty of the School of Engineering

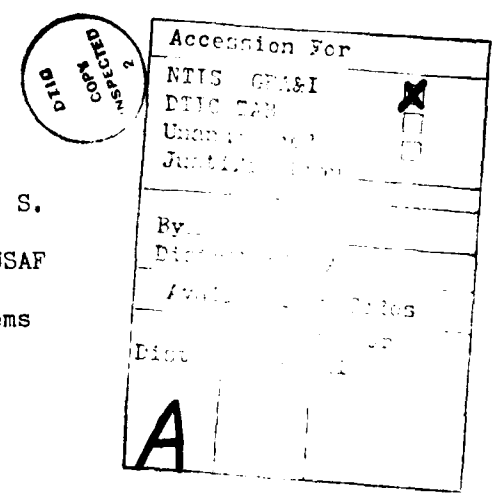
of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science




by

Donald P. McCanless, B. S.

Captain USAF

Graduate Computer Systems

December 1982

Approved for public release; distribution unlimited.

## Acknowledgements

I would like to acknowledge the assistance provided by my thesis advisor, Lieutenant Colonel Harold Carter. Without his patience and guidance this effort would not have been completed. I would also like to thank my readers, Major Walter Seward and Dr. David Barr, for finding the time in their busy schedules to read this document and provide suggestions for improvement. Lastly, I would like to thank Professor Dan Reynolds for all of the enthusiastic support he provided.

Contents

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## Abstract

The Tactical Air Force's Interoperability Group wants to be able to simulate communication networks. The simulation language for alternative modeling (SLAM) was proposed as the basis for the simulation. However, this language requires too much effort to make any changes to the network to be simulated. A Pre-Processor was written in FORTRAN 77 which allows the user to describe the network in a convenient manner, and produces the necessary SLAM source code to perform the simulation.

TACTICAL AIR CONTROL SYSTEM
SIMULATION PROGRAM

## I. Introduction

The Tactical Air Force Interoperability Group (TAFIG) located at Langley Air Force Base, Virginia, wishes to be able to simulate the flow of message traffic through the Tactical Air Control System. This simulation will allow TAFIG to determine the number of messages going across particular communication channels and statistics about the queues which may form at nodes (Morrison, 1981). Current models, concluded one study, are too broad and it was recommended that a specific set of problems be defined and selected model development be continued (Bennett, 1970: ix).

A simulation language for alternative modeling (SLAM) was selected as the basis for the simulation. However, every change to the communication network being modeled would require rewriting the SLAM source code. This constraint was not seen as being "user-friendly" enough for a production system.

In order to make the ease of input acceptable, a SLAM Pre-Processor was proposed. This Pre-Processor would take, as inputs, a description of the network to be simulated along with descriptions of the message traffic and produce, as output, the necessary SLAM source code to model the network. This SLAM source code would, in turn, be input into the SLAM program for the actual simulation.

## II. The Pre-Processor

### Introduction

In order to determine the feasability of such a system as the SLAM Pre-Processor (SLAMPP), a subset of the desired capabilities was selected and implemented. Following this evaluation, the system was expanded to include all of the desired capabilities.

### SLAMPP Capabilities

The SLAMPP was designed to allow the user to simulate communication networks. To the SLAMPP, a network consists of message creations and queues (processing locations), along with the path a message will follow through the various queues.

In order to describe a communication network, SLAMPP must allow the user to describe the network to be simulated. The items which may be described are listed below.

Nodes. A node, or queue, is a location at which a message will receive some type of handling. The maximum number of messages which may be waiting at a node at any given time can be specified. The name of an alternate node may (optionally) be supplied to which a message will "balk" should the node's capacity be exceeded, or "blocking" may be specified which causes messages to "back up" in the system when capacity is exceeded. If neither balking nor blocking is specified, the message will simply be lost (without any indication to the user) if capacity has been reached.

Two time durations are associated with a node. The first allows

the user to specify how long it takes to process a message at this node, while the second specifies how long transmission to the next node will take. If either of these two times are not specified, a default time of zero will be assumed.

Terminate Nodes. Terminate nodes are locations at which a message leaves the network.

Message Creation. The rate at which a message of a particular type is created can be specified. Additionally, the starting time for this message and the number of messages to be created are also specified.

Routing. Each message may be routed through the nodes following paths which the user supplies. Also, an alternate balk route can be supplied should a message be redirected to a balk node.

## Feasibility Study

In order to determine the feasibility of the SLAMPP, a subset of the capabilities was selected and implemented.

Selected Capabilities. Only the "bare" essential capabilities were selected for the feasibility study. Additionally, these capabilities were (in some cases) simplified.

Node definition was included; however, balk nodes were not implemented. Terminate nodes were included exactly as they would be included in the final version, as was message creation. Path definition did not support balk paths, nor blocking. Message processing times and transmit times between nodes were ignored.

Design Stages. Following the selection of the capabilities to be studied, the feasibility fell into several stages. First, a logical and easy-to-follow method was developed to input the network description to

the Pre-Processor. These input formats, with some modifications and additions, remained in the final version.

Next, a small network was designed and, using the input formats mentioned previously, a SLAMPP description of this network was coded.

A great deal of information was necessary to build even this simple implementation. Storing and manipulating this data quickly became confusing. In order to try and clarify this problem, the variables and data structures to store this information was designed. Although some modifications occurred during the course of the project, the basic design remained the same.

Now that the exact capabilities for the feasibility study were known, and the inputs and data structures were designed, flowcharts were produced which showed the steps necessary to implement the project. The flowcharts began at a very "high-level" and were iteratively refined until the detail necessary to design the program was obtained.

Using these flowcharts, the FORTRAN source code was written. Although some logic errors did exist, they proved to be relatively minor and easy to correct.

Program Evaluation. After the SLAMPP was written and debugged, the Pre-Processor output was examined for correctness. This examination included a visual inspection of the output file to verify the SLAM code produced by the Pre-Processor was as expected, and an execution of this code by the SLAM program to ensure the code would indeed be accepted by the SLAM system.

This examination showed that the SLAMPP output was valid and acceptable to the SLAM program. Additionally, it showed that the basic

concept behind the Pre-Processor was viable and continued development was warranted.

Completed Design

Following the feasibility study, the remaining capabilities were incorporated into the final SLAMPP. Due to modularity of design these additions were easily installed into the framework developed earlier (see Appendix A for a listing of the SLAMPP program).

The basic flow of the program is shown in Figure 1, while Appendix B contains detailed operating instructions. First, all of the nodes are defined, followed by all of the terminate nodes. After these definitions comes the start of the first message. Each message consists of one message definition, followed by an optional process and transmit time definition, followed by the name of the next node along the path. Successive steps in the path are indicated by repetition of process and transmit times and node name. Additional messages are input by placing another message definition into the data deck and repeating the above steps.

After all messages have been described, information about balk routes (if any are present) is input. This process is similar to message definition, however, the message definition card is replaced by a balk route definition card. The process and transmit time and path definitions are the same as above. One balk definition is included for each message that can possibly balk.

The validity of the inputs is verified prior to building the SLAM source code (a summary of the input errors which can be detected is

contained in Appendix C). If all inputs are valid, the SLAM source is constructed.

The SLAM source built by the Pre-Processor now serves as input to the SLAM program for the actual simulation. The outputs produced by the SLAM program are described in Appendix D.

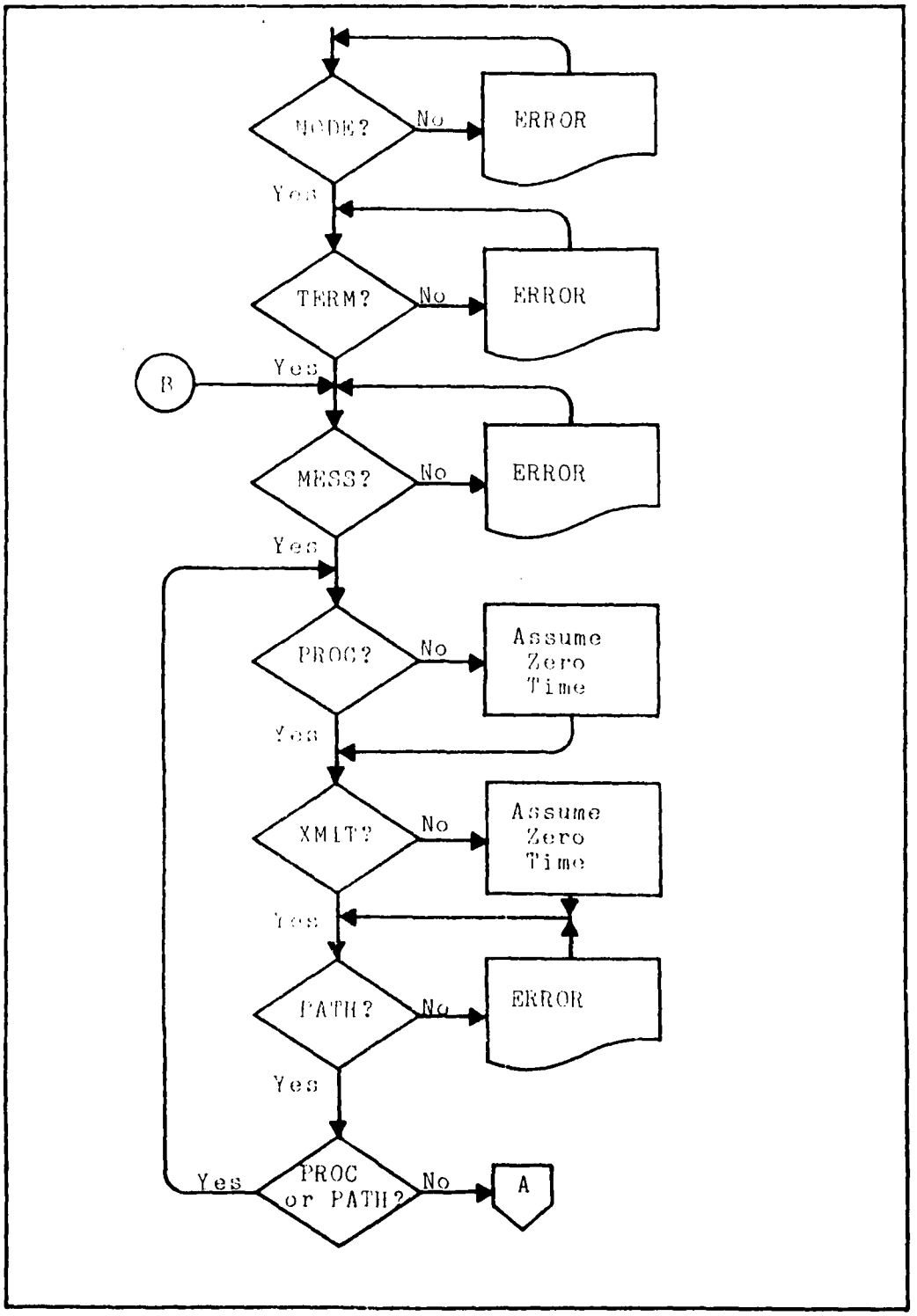


Figure 1. Program Flow (Part One)

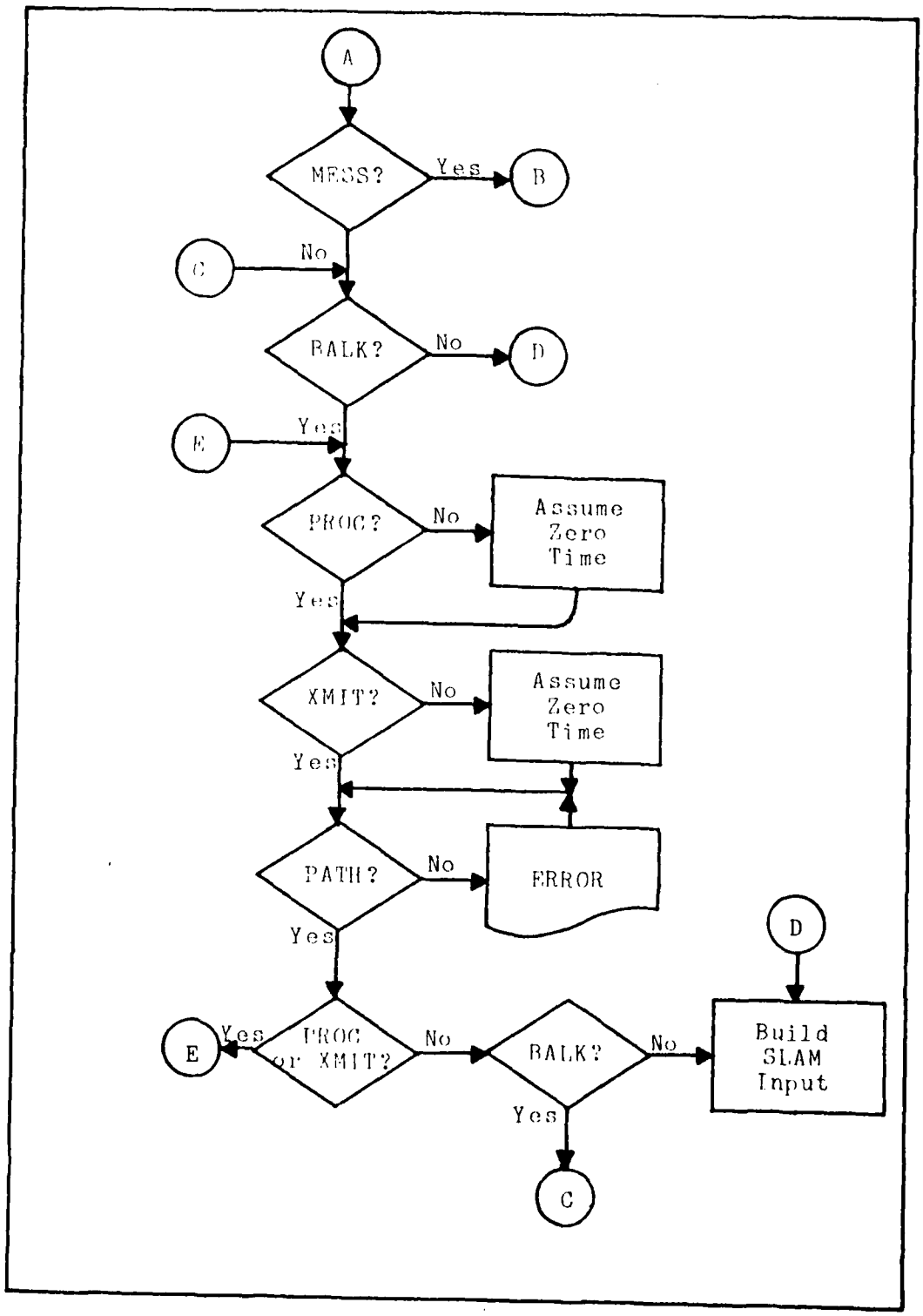


Figure 1. Program Flow (Part Two)

## III. Program Installation

### Introduction

Prior to execution of the SLAM Pre-Processor, the program must be compiled. To minimize the amount of computer memory required, certain changes can be made to the program to decrease array sizes.

### Array Size Selection

Due to the way SLAMPP is written, the user has the flexibility to vary the maximum number of messages (NOMSG) the Pre-Processor can handle, the maximum number of terminate nodes (NOTRM), and the maximum number of nodes (NONOD).

SLAMPP is written entirely in FORTRAN 77. To allow for variable dimension sizes for arrays, each subroutine and function contains a PARAMETER statement (Katzan, 1978: 77) which defines each of the three variables sizes. Prior to compilation, the user should decide on appropriate values for these parameters and change each PARAMETER statement accordingly.

Since each of the three parameters are used to determine array sizes, the larger the parameter sizes, the larger the amount of computer memory required to execute SLAMPP. Therefore, care should be used to select values which are both realistic and conservative.

### Compilation

As mentioned previously, SLAMPP is written in FORTRAN 77. After any changes to the PARAMETER statements are made, the Pre-Processor is

ready to be compiled and saved using whatever installation dependent procedures are required.

Enlarging SLAM

Figure 2 shows the main driver for the SLAM program. Depending upon the size of the SLAMPP network to be simulated, certain changes may be necessary to the SLAM main routine to accommodate the network. Although these changes are part of the SLAM program itself, and not part of the Pre-Processor, they are listed here for the user's convenience.

Three items must be changed: the dimension sizes of NSET and QSET, and the value for NNSET. Each of these three values must be the same to ensure a successful SLAM run. Typically, the default value is 5,000.

```
      PROGRAM MAINRT (INPUT, OUTPUT, TAPE7, TAPE5=INPUT,
     &                TAPE6=OUTPUT)
C
C     THIS ROUTINE IS INCLUDED SO THAT THE ARRAY SIZE
C     FOR NNSET/QSET CAN BE CHANGED TO ACCOMODATE
C     LARGE SIMULATION RUNS.
C
      DIMENSION NSET(7000)
      COMMON /SCOM1/ ATRIB(100), DD(100), DDL(100),
     &  DTNOW, II, MFA, MSTOP, NCLNR, NCRDR, NPRNT,
     &  TNEXT, TNOW, XX(100)
      COMMON QSET(7000)
      EQUIVALENCE (NSET(1), QSET(1))
      NNSET = 7000
      NCRDR = 5
      NPRNT = 6
      NTAPE = 7
      CALL SLAM
      STOP
      END
```

Figure 2. SLAM Main Driver

# IV. SLAMPP Validation

## Introduction

In order to check the validity of the SLAMPP (that is, verify that SLAMPP produces a SLAM network which represents the intention of the inputs), a test case was designed and evaluated. In addition to this large test case, over 30 smaller networks were input to the Pre-Processor during development to assure a valid Pre-Processor was in fact produced. Also, tests were performed to ensure that invalid inputs would be detected.

## Test Case

The test case used for validation was designed to exercise every capability of SLAMPP. Specifically, nodes of all three types were used (some with balking, some with blocking, and some with neither). Nine different messages were included to demonstrate each of the nine valid distribution types (see Appendix B). Process and transit times included at least one example of each of the nine distributions also, plus examples of the zero default time which will be generated if not specified otherwise. Since balking was specified on two nodes, balk route descriptions were required in addition to regular route descriptions. See Appendix E for a listing of the SLAMPP inputs and the associated SLAM source which was generated.

## Test Case Validation

After the test network was designed, the SLAMPP description of the

network was written and input into the Pre-Processor. The SLAM source output was then carefully examined to ensure that a valid network representation had been produced. Also, the Pre-Processor output was executed through the SLAM program to verify it would execute successfully. Both the examination and the execution showed the SLAMPP output to contain no known discrepancies.

Error Detection

Given valid inputs, SLAMPP will produce a corresponding SLAM network; however, it is equally important that the Pre-Processor recognize invalid inputs to prevent the creation of a bad network.

Many types of input validations are performed by the Pre-Processor. The errors which may be detected are summarized in Appendix C. To be certain that each input validation point worked correctly, test cases were devised which intentionally (and unintentionally) exercised each point. Since the validity of any SLAM network created using invalid input data is questionable, no SLAM source is generated if any errors are detected.

## V. Summary

The Tactical Air Forces Interoperability Group needs to be able to simulate the flow of message traffic through the Tactical Air Control System. The simulation language for alternative modeling (SLAM) was used as the basis for the simulation. A Pre-Processor was constructed to permit a user-friendly operation.

The Pre-Processor was written in FORTRAN 77, and produced the source code to be used by the SLAM program. The Pre-Processor output was validated and found to be correct.

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Katzan, Harry Jr., FORTRAN 77. New York: Van Nostrand Reinhold, 1978.

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## Appendix A: Program Listing

Following is the FORTRAN 77 listing of the source code for the SLAM Pre-Processor.

```
      PROGRAM SLAMPP
C
C     THIS PROGRAM ACCEPTS (FROM FILE 10) INPUT CARDS DESCRIBING THE
C     NETWORK TO BE SIMULATED, CHECKS THEIR VALIDITY, AND (IF NO
C     ERRORS ARE DETECTED) PRODUCES THE CORRESPONDING SLAM SOURCE
C     CODE ON FILE 20.
C
C     SUBROUTINES CALLED:
C        BLDOUT--BUILD THE SLAM OUTPUT
C        CHKBLK--VALIDATE BALK ROUTES
C        CHKUSD--ENSURE ALL NODES ARE USED
C        BALK--PROCESS BALK CARDS
C        MESS--PROCESS MESS CARDS
C        NODE--PROCESS NODE CARDS
C        PROC--PROCESS PROC CARDS
C        PATH--PROCESS PATH CARDS
C        TERM--PROCESS TERM CARDS
C        XMIT--PROCESS XMIT CARDS
C        READ--READ INPUT FILE
C     FUNCTIONS CALLED:
C        NUMNOD--RETURNS THE NODE'S NUMBER
C        NUMTRM--RETURNS THE TERM'S NUMBER
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        NXTTRM
C        NXTMSG
C        PARM1
C        PARM2
C        PARM3
C        PARM4
C        PARM5
C        CRDTYP
C        LABEL
C        LABEL2
C        DSTNAM
C     OUTPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        NXTTRM
C        NXTMSG
C        MAXNOD
C        MAXTRM
C        MAXMSG
C        PTHMAT
C        NODNAM
C        TRMNAM
C        DSTNAM
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
```

```
C         ISAVMS--TEMPORARY STORAGE OF MESSAGE COUNT
C         ISAVND--TEMPORARY STORAGE OF NODE COUNT
C         J--DO LOOP COUNTER
C
C
C      PARAMETERS FOR DIMENSION SIZES:
C        NONOD--MAXIMUM NUMBER OF NODES
C        NOTRM--MAXIMUM NUMBER OF TERMINATE NODES
C        NOMSG--MAXIMUM NUMBER OF MESSAGES
C
       PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
       CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
      &  BALKS*4, DSTNAM*5
C      DESCRIPTION OF COMMON BLOCK /COM1/:
C
C      IFATAL--NUMBER OF FATAL ERRORS DETECTED
C      NXTNOD--CURRENT NODE NUMBER
C      NXTTRM--CURRENT TERMINATE NODE NUMBER
C      NXTMSG--CURRENT MESSAGE NUMBER
C      MAXNOD--MAXIMUM NUMBER OF NODES
C      MAXTRM--MAXIMUM NUMBER OF TERMINATE NODES
C      MAXMSG--MAXIMUM NUMBER OF MESSAGES
C      NODCAP(1,I)--MAXIMUM CAPACITY OF NODE I
C      NODCAP(2,I)--NUMBER OF SERVERS AT NODE I
C      PTHMAT(I,J)--
C         IF > 0, NODE NUMBER OF NEXT NODE THAT MESSAGE J
C           WILL FOLLOW AFTER NODE I
C         IF = 0, MESSAGE J DOES NOT USE NODE I
C         IF < 0, NEGATIVE OF THE TERMINATE NODE NUMBER THAT
C           MESSAGE J WILL FOLLOW AFTER NODE I
C      CREATE(1,I)--PARAMETER 1 OF DISTRIBUTION RATE FOR
C           MESSAGE I
C      CREATE(2,I)--PARAMETER 2 OF DISTRIBUTION RATE FOR
C           MESSAGE I
C      CREATE(3,I)--PARAMETER 3 OF DISTRIBUTION RATE FOR
C           MESSAGE I
C      CREATE(4,I)--STARTING TIME FOR MESSAGE I
C      CREATE(5,I)--NUMBER OF MESSAGE RELEASES
C      LASNOD(I)--THE PREVIOUS NODE NUMBER IN THE PATH FOR
C           MESSAGE I
C      NODSTR(I)--THE FIRST NODE NUMBER IN THE PATH FOR
C           MESSAGE I
C      PARM1--1ST NUMERIC DATA FIELD READ FROM INPUT DECK
C      PARM2--2ND NUMERIC DATA FIELD READ FROM INPUT DECK
C      PARM3--3RD NUMERIC DATA FIELD READ FROM INPUT DECK
C      PARM4--4TH NUMERIC DATA FIELD READ FROM INPUT DECK
C      PARM5--5TH NUMERIC DATA FIELD READ FROM INPUT DECK
C      DSTPRC(I,J,1)--DISTRIBUTION NUMBER FOR THE PROCESSING
C           TIME FOLLOWING NODE J FROM MESSAGE I
C      DSTPRC(I,J,2)--PARAMETER 1 OF PROCESSING DISTRIBUTION
C      DSTPRC(I,J,3)--PARAMETER 2 OF PROCESSING DISTRIBUTION
C      DSTPRC(I,J,4)--PARAMETER 3 OF PROCESSING DISTRIBUTION
C      DSTXMT(I,J,1)--DISTRIBUTION NUMBER FOR THE TRANSMIT
C           TIME FOLLOWING NODE J FROM MESSAGE I
```

```
C      DSTXMT(I,J,2)--PARAMETER 1 OF TRANSMIT DISTRIBUTION
C      DSTXMT(I,J,4)--PARAMETER 2 OF TRANSMIT DISTRIBUTION
C      DSTXMT(I,J,4)--PARAMETER 3 OF TRANSMIT DISTRIBUTION
C
       COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
      &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
      &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
      &  PARM1, PARM2, PARM3, PARM4, PARM5,
      &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
C      DESCRIPTION OF COMMON BLOCK /COM2/:
C
C      NODNAM(I)--NAME OF NODE I
C      DIST(I)--NAME OF THE MESSAGE DISTRIBUTION FOR MESSAGE I
C      TRMNAM(I)--NAME OF TERMINATE NODE I
C      CRDTYP--CARD TYPE READ FROM INPUT DECK
C      LABEL--1ST CHARACTER DATA FIELD READ FROM INPUT DECK
C      LABEL2--2ND CHARACTER DATA FIELD READ FROM INPUT DECK
C      BALKS(I)--
C         IF BLANK, NODE I DOES NOT BLOCK OR BALK
C         IF 'BLOK', NODE I IS BLOCKED
C         OTHERWISE, NODE NAME THAT NODE I BALKS TO
C      DSTNAM--LIST OF VALID DISTRIBUTION NAMES
C
       COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
      &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C      PREPARE INPUT FILE
       REWIND 10
C      INITIAL VALUES
       IFATAL = 0
       NXTNOD = 0
       NXTTRM = 0
       NXTMSG = 0
       MAXNOD = NONOD
       MAXTRM = NOTRM
       MAXMSG = NOMSG
C      VALID DISTRIBUTION NAMES
       DSTNAM(1) = 'EXPON'
       DSTNAM(2) = 'NPSSN'
       DSTNAM(3) = 'BETA '
       DSTNAM(4) = 'GAMA '
       DSTNAM(5) = 'RLOGN'
       DSTNAM(6) = 'RNORM'
       DSTNAM(7) = 'UNFRM'
       DSTNAM(8) = 'TRIAG'
       DSTNAM(9) = 'CONST'
       DO 1 I = 1, MAXMSG
       DO 1 J = 1, MAXNOD
C      ZERO OUT PTHMAT (I.E., ESTABLISH NO PATHS EXIST FOR ANY
C      MESSAGE).
1      PTHMAT(J, I) = 0.0
       DO 2, I = 1, MAXTRM
C      INITIALIZE ALL TERMINATE NODES TO BLANK (UNUSED).
2      TRMNAM(I) = '    '
       DO 3, I = 1, MAXNOD
```

```
C     INITIALIZE ALL NODES TO BLANK (UNUSED).
3     NODNAM(I) = '    '
      PRINT *, ' '
      PRINT *, ' '
      PRINT *, '         SLAM PRE-PROCESSOR'
      PRINT *, ' '
      PRINT *, '    SUMMARY OF PROGRAM INPUTS:'
C
C - - - PROCESS NODE CARDS - - - - - - - - - - - - - - - - - - - - - - - -
C
      PRINT *, ' '
20    CALL READ
C     NODE CARDS MUST BE FIRST.
      IF (CRDTYP .EQ. 'NODE') THEN
C        A NODE CARD WAS FOUND--PROCESS IT.
10       CALL NODE (LABEL, PARM2, PARM3)
         CALL READ
C        ANOTHER NODE CARD?
         IF (CRDTYP .EQ. 'NODE') THEN
            GO TO 10
         ENDIF
      ELSE
C        SOMETHING OTHER THAN A NODE CARD WAS FIRST.
         PRINT *, 'ERROR--NODE CARDS MUST BE FIRST.'
         IFATAL = IFATAL + 1
         GO TO 20
C
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C - - - PROCESS TERM CARDS - - - - - - - - - - - - - - - - - - - - - - - -
C
      ENDIF
30    CONTINUE
C     FOLLOWING NODE CARDS MUST BE TERM CARDS.
      IF (CRDTYP .EQ. 'TERM') THEN
C        A TERM CARD WAS FOUND--PROCESS IT.
40       CALL TERM(LABEL)
         CALL READ
C        ANOTHER TERM CARD?
         IF (CRDTYP .EQ. 'TERM') THEN
            GO TO 40
         ENDIF
      ELSE
C        SOMETHING OTHER THAN A TERM CARD WAS FOUND.
         PRINT *, 'ERROR--TERM CARDS MUST FOLLOW NODE CARDS.'
         IFATAL = IFATAL + 1
         CALL READ
         GO TO 30
      ENDIF
C
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C - - - PROCESS MESSAGES - - - - - - - - - - - - - - - - - - - - - - - - -
C
```

```
C  EACH MESSAGE CONSISTS OF A MESS CARD, FOLLOWED BY A PROC (OPTIONAL),
C  AN XMIT (OPTIONAL), AND A PATH CARD. CONTINUE PROCESSING MESSAGES
C  UNTIL A NON-MESS, PROC, XMIT OR PATH CARD IS FOUND.
C
C     FOLLOWING TERM CARDS MUST BE A MESS CARD.
50    IF (CRDTYP .NE. 'MESS') THEN
C        SOMETHING OTHER THAN A MESS CARD WAS FOUND.
         PRINT *, 'ERROR--MESS CARD MUST FOLLOW TERM CARDS.'
         IFATAL = IFATAL + 1
         CALL READ
         GO TO 50
      ELSE
C        A MESS CARD WAS FOUND--PROCESS IT.
60       CALL MESS(LABEL, PARM1, PARM2, PARM3, PARM4, PARM5, LABEL2)
         CALL READ
C        FOLLOWING A MESS CARD CAN BE A PATH CARD, A PROC
C        CARD, OR AN XMIT CARD.
         IF (CRDTYP .EQ. 'PROC') THEN
C           A PROC CARD WAS FOUND--PROCESS IT.
            CALL PROC (LABEL, PARM3, PARM4, PARM1)
            CALL READ
         ELSE
C           NO PROC CARD WAS FOUND--ESTABLISH DEFAULT PROCESS TIME
            CALL PROC('CONST', 0.0, 0.0, 0.0)
         ENDIF
         IF (CRDTYP .EQ. 'XMIT') THEN
C           AN XMIT CARD WAS FOUND--PROCESS IT.
            CALL XMIT(LABEL, PARM3, PARM4, PARM1)
            CALL READ
         ELSE
C           NO XMIT CARD WAS FOUND--ESTABLISH DEFAULT TRANSMIT TIME
            CALL XMIT('CONST', 0.0, 0.0, 0.0)
         ENDIF
C        A PATH CARD MUST BE NEXT.
         IF (CRDTYP .NE. 'PATH') THEN
C           NO PATH CARD FOUND.
            NXTMSG = NXTMSG - 1
            PRINT *, 'ERROR--MISSING PATH CARD. SKIPPING TO NEXT MESS.'
70          CALL READ
C           GO TO BEGINNING OF NEXT MESSAGE.
            IF (CRDTYP .EQ. 'MESS') THEN
               GO TO 60
            ELSE
               GO TO 70
            ENDIF
         ELSE
C           A PATH CARD WAS FOUND--PROCESS IT.
80          CALL PATH
C           IF NUMTRM(LABEL) = 0, THEN THE LAST NODE SPECIFIED
C           WAS NOT A TERMINATE NODE.  THEREFORE, THE NEXT CARD
C           MUST BE EITHER PROC, XMIT OR PATH TO CONTINUE
C           DESCRIBING THIS MESSAGE PATH.
            IF (NUMTRM(LABEL) .EQ. 0) THEN
C              LAST NODE WAS NOT A TERMINATE NODE.
```

```
                  CALL READ
                  IF (CRDTYP .EQ. 'PROC') THEN
C                    A PROC CARD WAS FOUND--PROCESS IT.
                     CALL PROC(LABEL, PARM3, PARM4, PARM1)
                     CALL READ
                  ELSE
C                    NO PROC CARD WAS FOUND--ESTABLISH DEFAULT PROCESS TIM
                     CALL PROC('CONST', 0.0, 0.0, 0.0)
                  ENDIF
                  IF (CRDTYP .EQ. 'XMIT') THEN
C                    AN XMIT CARD WAS FOUND--PROCESS IT.
                     CALL XMIT(LABEL, PARM3, PARM4, PARM1)
                     CALL READ
                  ELSE
C                    NO XMIT CARD WAS FOUND--ESTABLISH DEFAULT TRANSMIT
C                    TIME.
                     CALL XMIT('CONST', 0.0, 0.0, 0.0)
                  ENDIF
                  IF (CRDTYP .EQ. 'PATH') THEN
C                    A PATH CARD WAS FOUND--PROCESS IT.
                     GO TO 80
                  ENDIF
C                 NO PATH CARD WAS FOUND.
                  PRINT *, 'ERROR--MESSAGE MUST END ON A TERMINATE NODE.'
                  IFATAL = IFATAL + 1
               ELSE
C                 THE LAST NODE WAS A TERMINATE NODE.
                  CALL READ
               ENDIF
            ENDIF
         ENDIF
C        FOLLOWING THE LAST PATH CARD OF A MESSAGE MAY BE ANOTHER
C        MESS CARD, A BALK CARD, OR AN END CARD.
         IF (CRDTYP .EQ. 'MESS') THEN
C           ANOTHER MESSAGE IS BEING DEFINED.
            GO TO 50
C
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
         ENDIF
C        SAVE NXTNOD AND NXTMSG FOR LATER USE.
         ISAVND = NXTNOD
         ISAVMS = NXTMSG
         IF (CRDTYP .NE. 'BALK') THEN
C           A BALK ROUTE IS NOT BEING DEFINED.
            GO TO 500
         ENDIF
C
C - - - PROCESS BALK ROUTES - - - - - - - - - - - - - - - - - - - - - -
C
C  EACH BALK ROUTE CONSISTS OF A BALK CARD, FOLLOWED BY A PROC(OPTIONAL
C  AN XMIT (OPTIONAL), AND A PATH CARD.  CONTINUE PROCESSING BALK ROUTE
C  UNTIL A NON-BALK, PROC, XMIT ORPATH CARD IS FOUND
C
```

```
C     ESTABLISH THE NXTNOD NUMBER FOR THIS BALK ROUTE.
400   NXTNOD = NUMNOD(LABEL)
      IF (NXTNOD .EQ. 0) THEN
         PRINT *, 'ERROR--INVALID BALK NODE (SKIPPING TO NEXT BALK.)'
         PRINT *, '       CORRECT NODE NAME OR INSERT CORRESPONDING ',
     &      'TERM CARD.'
         IFATAL = IFATAL + 1
402      CALL READ
         IF (CRDTYP .EQ. 'BALK') THEN
            GO TO 400
         ELSE
            GO TO 402
         ENDIF
      ENDIF
C     ESTABLISH THE NXTMSG NUMBER FOR THIS BALK ROUTE.
C     NXTMSG IS THE MESSAGE NUMBER OF THE MESSAGE FOR WHOM A BALK
C     ROUTE IS BEING DEFINED.
      NXTMSG = PARM1
      IF (NXTMSG .GT. ISAVMS .OR. NXTMSG .LE. 0) THEN
         PRINT *, 'ERROR--INVALID MESSAGE NUMBER (SKIPPING TO NEXT ',
     &     'BALK).'
         IFATAL = IFATAL + 1
401      CALL READ
         IF (CRDTYP .EQ. 'BALK') THEN
            GO TO 400
         ELSE
            GO TO 401
         ENDIF
      ENDIF
C     A VALID BALK CARD WAS FOUND--PROCESS IT.
      CALL BALK
      CALL READ
C     FOLLOWING A BALK CARD MAY BE EITHER A PROC CARD, XMIT
C     CARD, OR PATH CARD.
410   IF (CRDTYP .EQ. 'PROC') THEN
C        A PROC CARD WAS FOUND--PROCESS IT.
         CALL PROC(LABEL, PARM3, PARM4, PARM1)
         CALL READ
      ELSE
C        NO PROC CARD WAS FOUND--ESTABLISH DEFAULT PROCESS TIME.
         CALL PROC ('CONST', 0.0, 0.0, 0.0)
      ENDIF
      IF (CRDTYP .EQ. 'XMIT') THEN
C        AN XMIT CARD WAS FOUND--PROCESS IT.
         CALL XMIT(LABEL, PARM3, PARM4, PARM1)
         CALL READ
      ELSE
C        NO XMIT CARD WAS FOUND--ESTABLISH DEFAULT TRANSMIT TIME.
         CALL XMIT('CONST', 0.0, 0.0, 0.0)
      ENDIF
      IF (CRDTYP .NE. 'PATH') THEN
C        THIS BALK ROUTE CONTAINED NO PATH.
         PRINT *, 'ERROR--MISSING BALK PATH CARD. SKIPPING TO NEXT ',
     &     'BALK.'
```

```
            IFATAL = IFATAL + 1
C           SKIP TO NEXT BALK CARD.
600         CALL READ
C           ANOTHER BALK?
            IF (CRDTYP .EQ. 'BALK') THEN
               GO TO 400
            ELSE
               GO TO 600
            ENDIF
         ELSE
C           A PATH CARD WAS FOUND--PROCESS IT.
            CALL PATH
         ENDIF
         CALL READ
C        IS THE NEXT CARD A PROC OR PATH OR XMIT (I.E., A CONTINUATION
C        OF THIS BALK PATH)?
         IF (CRDTYP .EQ. 'PROC' .OR. CRDTYP .EQ. 'XMIT' .OR.
        &  CRDTYP .EQ. 'PATH') THEN
            GO TO 410
         ENDIF
C        FOLLOWING THE LAST PATH CARD OF A BALK ROUTE MAY BE
C        ANOTHER BALK CARD OR AN END CARD.
         IF (CRDTYP .EQ. 'BALK') THEN
C           ANOTHER BALK CARD WAS FOUND.
            GO TO 400
C
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C - - - END OF DATA--VALIDATE AND PRODUCE SLAM OUTPUT - - - - - - - -
C
         ENDIF
500      CONTINUE
C        THE NEXT CARD MUST BE AN END.
         IF (CRDTYP .NE. 'END ') THEN
            PRINT *, 'ERROR--END CARD EXPECTED.'
            IFATAL = IFATAL + 1
         ENDIF
C        RESTORE NXTMSG AND NXTNOD TO THEIR PREVIOUS VALUES.
         NXTMSG = ISAVMS
         NXTNOD = ISAVND
C        VERIFY BALK ROUTES.
         IF (IFATAL .EQ. 0) THEN
            CALL CHKBLK
         ELSE
            PRINT *, 'WARNING--BALK ROUTE VERIFICATION NOT ATTEMPTED DUE',
        &      ' TO PREVIOUS ERRORS.'
         ENDIF
         CALL CHKUSD
         IF (IFATAL .EQ. 0) THEN
C           IF NO ERRORS DETECTED, PRODUCE SLAM OUTPUT.
            PRINT *, 'NO ERRORS DETECTED. SLAM SOURCE WILL BE CONSTRUCTED.
            CALL BLDOUT
         ELSE
            PRINT *, IFATAL, ' ERRORS DETECTED.  SLAM SOURCE WILL NOT BE '.
```

```
     &       'CONSTRUCTED.'
C
C -----------------------------------------------------------------
C
      ENDIF
      RETURN
      END
```

```
      SUBROUTINE BALK
C
C     THIS SUBROUTINE HANDLES BALK CARDS.  WHEN A BALK IS ENCOUNTERED,
C     LASNOD (THE PREVIOUS NODE NUMBER) IS INITIALIZED TO THE FIRST
C     NODE IN THE BALK PATH.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMNOD
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        LABEL
C     OUTPUT VIA COMMON:
C        IFATAL
C        LASNOD
C     WORKING VARIABLES:
C        NUMN--NODE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     FIND THE NODE NUMBER OF THE BALK NODE (NUMN MUST BE > 0 TO
C     BE VALID).
      NUMN = NUMNOD(LABEL)
      IF (NUMN .GT. 0) THEN
C        INITIALIZE LASNOD TO THE 1ST NODE IN THIS BALK PATH.
         LASNOD(NXTMSG) = NUMN
      ELSE
         PRINT *, 'ERROR--ILLEGAL BALK NODE NAME.'
         IFATAL = IFATAL + 1
      ENDIF
      RETURN
      END
```

```
      SUBROUTINE BLDOUT
C
C     THIS SUBROUTINE PRODUCES THE SLAM SOURCE CODE, WHICH IS
C     WRITTEN TO FILE 20.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMDST
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        NXTNOD
C        NXTTRM
C        NXTMSG
C        NODCAP
C        PTHMAT
C        CREATE
C        NODSTR
C        DSTPRC
C        DSTXMT
C        NODNAM
C        DIST
C        TRMNAM
C        BALKS
C        DSTNAM
C     OUTPUTS VIA COMMON:
C        NONE
C     WORKING VARIABLES:
C        BRNAME--BRANCH NODE NAME
C        I--DO LOOP COUNTER
C        ICNT--GENERATED LINE LABEL NUMBER
C        IMAX--INTEGER REPRESENTATION OF STARTING TIME OF MESSAGE
C        IMIN--INTEGER REPRESENTATION OF NUMBER OF MESSAGE RELEASES
C        ISTRT--LINE LABEL NUMBER
C        J--DO LOOP COUNTER
C        NUM--THE NEXT NODE NUMBER IN THE PATH
C        NUMD--DISTRIBUTION NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER BRNAME*4
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
```

```
      REWIND 20
C     WRITE SLAM GEN CARD.
      WRITE (20, 10)
10    FORMAT ('GEN,SLAMPP,SLAM,09/19/1982,1,,,,,,72;')
      WRITE (20, 15) NXTNOD
C     WRITE LIM CARD.
15    FORMAT ('LIM,',I4,',2,500;')
      WRITE (20,20)
20    FORMAT ('NETWORK;')
C     WRITE RESOURCE CARD FOR EACH NODE.
      DO 300, I = 1, NXTNOD
300   WRITE (20, 301) NODNAM(I), NODCAP(2, I), I
301   FORMAT ('      RESOURCE/', A4, '(', I4, '),', I4, ';')
C     WRITE MESSAGE CREATION CARDS.  EACH MESSAGE CONSISTS OF A
C     CREATE CARD, ASSIGN CARD, AND AN ACT CARD.
      DO 900 I = 1, NXTMSG
C     STARTING TIME FOR THIS MESSAGE.
      IMIN = CREATE (4, I)
C     NUMBER OF MESSAGE RELEASES.
      IMAX = CREATE (5, I)
C     NUMBER OF THE CREATION DISTRIBUTION RATE.
      NUMD = NUMDST(DIST(I))
C     EACH DISTRIBUTION RATE REQUIRES A CERTAIN NUMBER OF INPUT
C     PARAMETERS.  THE FOLLOWING SELECTS THE APPROPRIATE WRITE
C     STATEMENT FOR THE DISTRIBUTION.
      IF (NUMD .EQ. 9) THEN
C        CONSTANT CREATION RATE.
         WRITE (20, 800) CREATE(1, I), IMIN, IMAX
800      FORMAT ('      CREATE,', F10.5, ',', I5, ',1,',
     &         I5, ';')
      ELSE IF (NUMD .LE. 2) THEN
C        FOR EXPON AND NPSSN (REQUIRING ONE PARAMETER).
         WRITE (20, 805) DIST(I), CREATE(1, I), IMIN, IMAX
805      FORMAT ('      CREATE,', A5, '(', F10.5, '),',
     &       I5, ',1,', I5, ';')
      ELSE IF (NUMD .LE. 7) THEN
C        FOR BETA,  GAMA, RLOGN, RNORM AND UNFRM (REQUIRING TWO
C          PARAMETERS).
         WRITE (20, 810) DIST(I), CREATE(1, I), CREATE(2, I),
     &         IMIN, IMAX
810      FORMAT ('      CREATE,', A5, '(', F10.5, ',', F10.5,
     &         '),', I5,',1,', I5, ';')
      ELSE
C        FOR TRIAG (REQUIRING THREE PARAMETERS).
         WRITE (20, 820) DIST(I), CREATE(1, I), CREATE(2, I),
     &         CREATE(3, I), IMIN, IMAX
820      FORMAT ('      CREATE,', A5, '(', 2(F10.5, ','),
     &         F10.5, '),', I5, ',1,', I5, ';')
      ENDIF
C     EACH MESSAGE IS ASSIGNED A SEQUENTIAL MESSAGE NUMBER SO
C     THAT DIFFERENT MESSAGES CAN BE DISTINGUISHED FROM EACH
C     OTHER THROUGHOUT THE NETWORK.
      WRITE (20, 30) I
30    FORMAT ('      ASSIGN,ATRIB(2)=',I4,';')
```

```
C       ACT TO BRANCH TO 1ST NODE IN THE PATH.
        WRITE (20, 35) NODNAM(NODSTR(I))
35      FORMAT ('       ACT,,,',A4,';')
900     CONTINUE
C       ESTABLISH BEGINNING LABEL NUMBER FOR PROGRAM GENERATED LABELS.
        ICNT = 101
C       GENERATE THE SLAM OUTPUT NECESSARY TO DESCRIBE EACH NODE.
C       THIS WILL CONSIST OF AN AWAIT CARD, BRANCH CARDS (ACT) FOR
C       EACH MESSAGE, PLUS A SET OF PROCESS AND TRANSMIT ACTIVITIES
C       FOR EACH MESSAGE USING THIS NODE.
        DO 950 I = 1, NXTNOD
C       THREE TYPES OF AWAIT STATEMENTS ARE POSSIBLE:  AN AWAIT WITHOUT
C       ANY BLOCKING OR BALKING, AN AWAIT WITH BLOCKING, OR AN AWAIT
C       WITH BALKING.
        IF (BALKS(I) .EQ. '    ') THEN
C          NO BLOCKING OR BALKING.
           WRITE (20, 40) NODNAM(I), I, NODCAP(1, I), NODNAM(I)
40         FORMAT (A4, 2X, 'AWAIT(', I4, '/', I4, '),', A4, ';')
        ELSE IF (BALKS(I) .EQ. 'BLOK') THEN
C          BLOCKING.
           WRITE (20,  41) NODNAM(I), I, NODCAP(1, I), NODNAM(I)
41         FORMAT (A4, 2X, 'AWAIT(', I4, '/', I4, '),', A4, ',BLOCK;')
        ELSE
C          BALKING.
           WRITE (20, 42) NODNAM(I), I, NODCAP(1, I), NODNAM(I),
     &          BALKS(I)
42         FORMAT (A4, 2X, 'AWAIT(', I4, '/', I4, '),', A4, ',BALK(',
     &       A4, ');')
        ENDIF
C       PLACE A DUMMY ACTIVITY FOLLOWING THE AWAIT.
38      FORMAT ('       ACT;')
        WRITE (20,29)
C       GOON TO SPECIFY ONLY ONE BRANCH TO BE TAKEN.
29      FORMAT ('       GOON,1;')
C       SAVE THE NUMBER OF THE FIRST PROGRAM GENERATED LABEL.
        ISTRT = ICNT
        DO 925 J = 1, NXTMSG
C       GET THE NODE NUMBER OF THE I-TH NODE IN PATH J.
        NUM = PTHMAT (I, J)
C       IF 0, MESSAGE I DOES NOT USE PATH J.
        IF (NUM .NE. 0) THEN
C          CONSTRUCT SLAM BRANCH TO THAT PORTION OF THE SLAM CODE
C          WHICH WILL HANDLE THE PROCESS AND TRANSMIT TIMES FOR THIS
C          MESSAGE.
           WRITE (20, 500) J, ICNT
500        FORMAT ('       ACT,,ATRIB(2).EQ.',I4,',L',I3,';')
C          INCREMENT PROGRAM GENERATED LABEL NUMBER.
           ICNT = ICNT + 1
        ENDIF
925     CONTINUE
C       GENERATE A PROCESS AND TRANSMIT ACTIVITY PAIR FOR EACH MESSAGE
C       THAT USES NODE J.
        DO 926 J = 1, NXTMSG
C       GET THE NODE NUMBER OF THE I-TH NODE IN PATH J.
```

```
      NUM = PTHMAT(I, J)
C     IF 0, MESSAGE I DOES NOT USE PATH J.
      IF (NUM .NE. 0) THEN
         WRITE (20, 501) ISTRT
C        CONSTRUCT DUMMY GOON WITH PROGRAM GENERATED LABEL.
501      FORMAT ('L', I3, '  GOON;')
C        INCREMENT PROGRAM GENERATED LABEL NUMBER.
         ISTRT = ISTRT + 1
C        EACH DISTRIBUTION RATE REQUIRES A CERTAIN NUMBER OF INPUT
C        PARAMETERS.  THE FOLLOWING SELECTS THE APPROPRIATE WRITE
C        STATEMENT FOR THE DISTRIBUTION.
C
C        IF THE DISTRIBUTION IS A CONSTANT ZERO, DO NOT WRITE ANYTHING.
         IF (DSTPRC(J, I, 1) .EQ. 9.0 .AND.
     &       DSTPRC(J, I, 2) .EQ. 0.0) THEN
            GO TO 600
         ENDIF
         IF (DSTPRC(J, I, 1) .EQ. 9.0) THEN
C           CONSTANT PROCESS TIME.
            WRITE (20, 502) DSTPRC(J, I, 2)
502         FORMAT (6X,'ACT,' ,F10.5,';')
         ELSE IF (DSTPRC(J, I, 1) .LE. 2.0) THEN
C           FOR EXPON AND NPSSN (REQUIRING ONE PARAMETER).
            WRITE (20, 503) DSTNAM(INT(DSTPRC(J, I, 1))),
     &           DSTPRC(J, I, 2)
503         FORMAT (6X, 'ACT,', A5, '(',
     &           F10.5, ');')
         ELSE IF (DSTPRC(J, I, 1) .LE. 7.0) THEN
C           FOR BETA, GAMA, RLOGN, RNORM AND UNFRM (REQUIRING TWO
C           PARAMETERS).
            WRITE (20, 504) DSTNAM(INT(DSTPRC(J, I, 1))),
     &           DSTPRC(J, I, 2), DSTPRC(J, I, 3)
504         FORMAT (6X, 'ACT,', A5, '(',
     &           F10.5, ',', F10.5, ');')
         ELSE
C           FOR TRIAG (REQUIRING THREE PARAMETERS).
            WRITE (20, 505) DSTNAM(INT(DSTPRC(J, I, 1))),
     &           DSTPRC(J, I, 2), DSTPRC(J, I, 3), DSTPRC(J, I, 4)
505         FORMAT (6X, 'ACT,', A5, '(',
     &           2(F10.5, ','), F10.5, ');')
         ENDIF
C        PLACE A DUMMY GOON BETWEEN PROCESS AND TRANSMIT ACTIVITIES.
         WRITE (20, 506)
506      FORMAT ('      GOON;')
600      CONTINUE
C        FIND THE NODE NAME OF THE NEXT NODE IN THE PATH.  IF
C        NUM > 0, THEN THE NEXT NODE IS A NODE.  IF < 0, THEN THE
C        NEXT NODE IS A TERMINATE NODE.
         IF (NUM .GT. 0) THEN
            BRNAME = NODNAM(NUM)
         ELSE
            BRNAME = TRMNAM(-NUM)
         ENDIF
C        OBTAIN THE NUMBER OF SERVERS FOR THIS TRANSMIT ACTIVITY.
```

```
C         EACH DISTRIBUTION RATE REQUIRES A CERTAIN NUMBER OF INPUT
C         PARAMETERS.  THE FOLLOWING SELECTS THE APPROPRIATE WRITE
C         STATEMENT FOR THE DISTRIBUTION.
C         IF THE DISTRIBUTION IS A CONSTANT ZERO, DO NOT WRITE ANYTHING.
          IF (DSTXMT(J, I, 1) .EQ. 9.0 .AND.
     &        DSTXMT(J, I, 2) .EQ. 0.0) THEN
              GO TO 601
          ENDIF
          IF (DSTXMT(J, I, 1) .EQ. 9.0) THEN
C             CONSTANT PROCESS TIME.
              WRITE (20, 502) DSTXMT(J, I, 2)
          ELSE IF (DSTXMT(J, I, 1) .LE. 2.0) THEN
C             FOR EXPON AND NPSSN (REQUIRING ONE PARAMETER).
              WRITE (20, 503) DSTNAM(INT(DSTXMT(J, I, 1))),
     &              DSTXMT(J, I, 2)
          ELSE IF (DSTXMT(J, I, 1) .LE. 7.0) THEN
C             FOR BETA, GAMA, RLOGN, RNORM AND UNFRM (REQUIRING TWO
C             PARAMETERS).
              WRITE (20, 504) DSTNAM(INT(DSTXMT(J, I, 1))),
     &              DSTXMT(J, I, 2), DSTXMT(J, I, 3)
          ELSE
C             FOR TRIAG (REQUIRING THREE PARAMETERS).
              WRITE (20,505) DSTNAM(INT(DSTXMT(J, I, 1))),
     &              DSTXMT(J, I, 2), DSTXMT(J, I, 3), DSTXMT(J, I, 4)
          ENDIF
601       CONTINUE
          WRITE (20, 303) NODNAM(I)
303       FORMAT ('       FREE,', A4, ';')
          WRITE (20, 35) BRNAME
        ENDIF
926     CONTINUE
950     CONTINUE
        DO 960 I = 1, NXTTRM
C       PRINT EACH OF THE TERMINATE NODE CARDS.
        WRITE (20, 50) TRMNAM(I), TRMNAM(I)
50      FORMAT (A4, 2X, 'COLCT,INT(1),EXIT INTRVL ', A4, ';')
        WRITE (20, 55)
55      FORMAT ('       TERM;')
960     CONTINUE
        WRITE (20, 59)
59      FORMAT ('       END;')
        WRITE (20, 60)
60      FORMAT ('INIT,0;')
        WRITE (20, 65)
65      FORMAT ('FIN;')
        RETURN
        END
```

```
      SUBROUTINE CHKBLK
C
C     THIS SUBROUTINE VERIFIES THAT ALL BALK PATHS ARE VALID, I.E.,
C     ALL PATHS END AT A TERMINATE NODE AND NO PATH CONTAINS A CYCLE.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMNOD
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        NXTMSG
C        PTHMAT
C        NODNAM
C        BALKS
C     OUTPUTS VIA COMMON:
C        IFATAL
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
C        J--DO LOOP COUNTER
C        NEXT--NEXT NODE NUMBER ON THE PATH
C        NOSTEP--COUNT OF THE NUMBER OF NODES IN A PATH
C        NUM--BALK NODE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
      DO 10 I = 1, NXTNOD
C     IF BALK(I) IS BLANK OR 'BLOK', THEN A BALK ROUTE WAS NOT
C     SPECIFIED FOR NODE I AND, THEREFORE, NEED NOT BE CHECKED.
      IF (BALKS(I) .NE. '    ' .AND. BALKS(I) .NE. 'BLOK') THEN
C        FIND THE NODE NUMBER THAT NODE I WILL BALK TO.
         NUM = NUMNOD(BALKS(I))
         DO 20 J = 1, NXTMSG
C        IF PTHMAT(I,J) = 0, THEN MESSAGE J DOES NOT USE NODE I AND
C        CAN BE IGNORED.  OTHERWISE, FOR EACH MESSAGE J IN NODE I
C        INSURE THAT BALK NODE NUM HAS A PATH FOR MESSAGE J (I.E.,
C        IF MESSAGE J APPEARS IN NODE I, MESSAGE J MUST ALSO APPEAR
C        IN NODE NUM).
         IF (PTHMAT(I, J) .NE. 0) THEN
```

```
C            NOSTEP WILL COUNT HOW MANY NODES ARE IN THE MESSAGE'S PATH.
             NOSTEP = 0
C            FIND THE NEXT NODE NUMBER IN THE BALK PATH FOR MESSAGE J.
             NEXT = PTHMAT(NUM, J)
30           IF (NEXT .EQ. 0) THEN
C               BALK PATH FOR MESSAGE J WAS NOT SPECIFIED OR WAS
C               INCOMPLETE (DID NOT END ON A TERMINATE NODE).
                PRINT 50, J, NODNAM(I)
                PRINT *, '        SUPPLY BALK PATH, OR MAKE SURE PATH ',
     &             'ENDS AT A TERMINATE NODE.'
                IFATAL = IFATAL + 1
             ELSE
C               IF > 0, NEXT NODE IS A REGULAR NODE.  IF < 0, NEXT
C               NODE IS A TERMINATE NODE (MEANING THIS PATH IS
C               SUCCESSFULLY COMPLETED).
                IF (NEXT .GT. 0) THEN
C                  FIND THE NEXT NODE NUMBER IN THE BALK PATH FOR MESSAGE
C                  J.
                   NEXT = PTHMAT(NEXT, J)
C                  INCREMENT THE NUMBER OF NODES IN THIS BALK PATH.
                   NOSTEP = NOSTEP + 1
C                  IF MORE STEPS IN THE PATH WAS USED THAN NODES WERE
C                  DEFINED, THEN A CYCLE MUST EXIST FOR THIS PATH
C                  (MESSAGE J LOOPS BACK UPON ITSELF).
                   IF (NOSTEP .GT. NXTNOD) THEN
                      PRINT 55, J, NODNAM(I)
                      IFATAL = IFATAL + 1
                      GO TO 20
                   ENDIF
                   GO TO 30
                ENDIF
             ENDIF
          ENDIF
20        CONTINUE
       ENDIF
10     CONTINUE
50     FORMAT (' ERROR--INCOMPLETE BALK PATH FOR MESSAGE ', I4,
     &   ' FROM NODE ', A4, '.')
55     FORMAT (' ERROR--THE BALK PATH FOR MESSAGE ', I4,
     &   ' CONTAINS A CYCLE FROM NODE ', A4, '.')
       RETURN
       END
```

```
      SUBROUTINE CHKUSD
C
C     THIS SUBROUTINE VERIFIES THAT EACH NODE SPECIFIED
C     BY A NODE CARD IS USED IN AT LEAST ONE PATH.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NONE
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        NXTMSG
C        PTHMAT
C        NODNAM
C     OUTPUTS VIA COMMON:
C        IFATAL
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
C        J--DO LOOP COUNTER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     SEARCH EACH NODE I LOOKING FOR A MESSAGE J THAT USES NODE I
C     (I.E., PTHMAT(I,J) .NE. 0).
      DO 20, I = 1, NXTNOD
      DO 10, J = 1, NXTMSG
      IF (PTHMAT(I, J) .NE. 0.0) THEN
C        THE NODE WAS USED.
         GO TO 20
      ENDIF
10    CONTINUE
      PRINT *, 'ERROR--NODE ', NODNAM(I), ' IS NOT USED IN A PATH.'
      PRINT *, '        REMOVE CORRESPONDING NODE CARD.'
      IFATAL = IFATAL + 1
20    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MESS (LABL, PRM1, PRM2, PRM3, PRM4,
     &  PRM5, LABL2)
C
C     THIS SUBROUTINE HANDLES MESS CARDS BY SAVING THE NECESSARY
C     MESSAGE INFORMATION.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMDST
C        NUMNOD
C     INPUT ARGUMENTS:
C        LABL--MESSAGE DISTRIBUTION NAME
C        PRM1--DISTRIBUTION PARAMETER 1
C        PRM2--DISTRIBUTION PARAMETER 2
C        PRM3--DISTRIBUTION PARAMETER 3
C        PRM4--MESSAGE START TIME
C        PRM5--NUMBER OF MESSAGE RELEASES
C        LABL2--NAME OF FIRST NODE IN PATH
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        MAXMSG
C     OUTPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        CREATE
C        LASNOD
C        NODSTR
C        DIST
C     WORKING VARIABLES:
C        NUMN--NODE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER LABL*5, LABL2*4
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     INCREMENT MESSAGE COUNT.
      NXTMSG = NXTMSG + 1
C     INSURE NXTMSG STILL IN RANGE.
      IF (NXTMSG .GT. MAXMSG) THEN
         PRINT *, 'ERROR--TOO MANY MESSAGES DEFINED.'
         IFATAL = IFATAL + 1
```

```
            NXTMSG = MAXMSG
            LASNOD(NXTMSG) = 1
            GO TO 999
         ENDIF
C        VERIFY LABL IS A VALID DISTRIBUTION NAME.
         IF (NUMDST(LABL) .GT. 0) THEN
C           VALID NAME, SAVE IT.
            DIST(NXTMSG) = LABL
         ELSE
            PRINT *, 'ERROR--ILLEGAL DISTRIBUTION SPECIFIED.'
            IFATAL = IFATAL + 1
         ENDIF
C        SAVE 1ST PARAMETER OF DISTRIBUTION
         CREATE(1, NXTMSG) = PRM1
C        SAVE 2ND PARAMETER OF DISTRIBUTION.
         CREATE(2, NXTMSG) = PRM2
C        SAVE 3RD PARAMETER OF DISTRIBUTION.
         CREATE(3, NXTMSG) = PRM3
C        SAVE STARTING TIME OF THIS MESSAGE.
         CREATE(4, NXTMSG) = PRM4
C        SAVE THE NUMBER OF MESSAGE RELEASES.
         CREATE(5, NXTMSG) = PRM5
C        FIND THE NODE NUMBER OF THE FIRST NODE IN THIS MESSAGE.
         NUMN = NUMNOD(LABL2)
         IF (NUMN .GT. 0) THEN
C           VALID NODE NUMBER--INITIALIZE THE LAST NODE IN THE PATH
C           (LASNOD) AND THE FIRST NODE IN THE PATH (NODSTR) TO NUMN.
            LASNOD(NXTMSG) = NUMN
            NODSTR(NXTMSG) = NUMN
         ELSE
            PRINT *, 'ERROR--UNDEFINED NODE.'
            PRINT *, '       CORRECT NODE NAME OR INSERT CORRESPONDING ',
     &         'NODE CARD.'
            LASNOD(NXTMSG) = 1
            IFATAL = IFATAL + 1
         ENDIF
999      RETURN
         END
```

```
      SUBROUTINE NODE (LABL, PRM1, PRM2)
C
C     THIS SUBROUTINE HANDLES NODE CARDS BY SAVING THE NODE INFORMATION
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMNOD
C     INPUT ARGUMENTS:
C        LABL--NAME OF NODE BEING DEFINED.
C        PRM1--MAXIMUM CAPACITY OF NODE
C        PRM2--NUMBER OF SERVERS
C     OUTPUT PARAMETERS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        MAXNOD
C        LABEL2
C     OUTPUTS VIA COMMON:
C        IFATAL
C        NXTNOD
C        NODCAP
C        NODNAM
C        BALKS
C     WORKING VARIABLES:
C        NONE
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER LABL*5
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     HAS THIS NODE BEEN PREVIOUSLY DEFINED (AS INDICATED BY A
C     VALUE > 0)?
      IF (NUMNOD(LABL) .GT. 0) THEN
         PRINT *, 'ERROR--NODE PREVIOUSLY DEFINED.'
         IFATAL = IFATAL + 1
         GO TO 999
      ENDIF
C     INCREMENT NODE COUNT.
      NXTNOD = NXTNOD + 1
C     VERIFY NODE COUNT STILL IN RANGE.
      IF (NXTNOD .GT. MAXNOD) THEN
         PRINT *, 'ERROR--TOO MANY NODES DEFINED (IGNORED).'
         NXTNOD = MAXNOD
```

```
            IFATAL = IFATAL + 1
            NXTNOD = MAXNOD
            GO TO 999
         ENDIF
C        SAVE NODE NAME.
         NODNAM(NXTNOD) = LABL
C        VERIFY VALIDITY OF MAXIMUM CAPACITY.
         IF (PRM1 .LE. 0.0) THEN
            PRINT *, 'ERROR--MAXIMUM CAPACITY MUST BE GREATER THAN 0.'
            IFATAL = IFATAL + 1
         ELSE
            NODCAP(1, NXTNOD) = PRM1
         ENDIF
C        NUMBER OF SERVERS MUST BE GREATER THAN 0.
         IF (PRM2 .GT. 0.0) THEN
C           SAVE THE NUMBER OF SERVERS.
            NODCAP(2, NXTNOD) = PRM2
         ELSE
            PRINT *, 'ERROR--NUMBER OF SERVERS MUST BE GREATER THAN 0.'
            IFATAL = IFATAL + 1
         ENDIF
C        IS THIS NODE BLOCKED OR NO BALK NODE SPECIFIED?
         IF (LABEL2 .EQ. 'BLOK' .OR. LABEL2 .EQ. '    ') THEN
C           ITS BLOCKED OR NO BALK NODE SPECIFIED.
            BALKS(NXTNOD) = LABEL2
         ELSE
C           IS THE BALK NODE NAME VALID?
            IF (NUMNOD(LABEL2) .GT. 0) THEN
C              ITS VALID--SAVE IT.
               BALKS(NXTNOD) = LABEL2
            ELSE
C              ERROR--ITS NOT VALID.
               PRINT *, 'ERROR--ILLEGAL BALK NODE.'
               PRINT *, '       CORRECT THE NAME OR INSERT ',
     &            'CORRESPONDING NODE CARD.'
               IFATAL = IFATAL + 1
            ENDIF
         ENDIF
999      RETURN
         END
```

```
      SUBROUTINE PATH
C
C     THIS SUBROUTINE HANDLES PATH CARDS BY SAVING THE INFORMATION
C     NECESSARY TO CONSTRUCT A PATH.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMNOD
C        NUMTRM
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        PTHMAT
C        LASNOD
C        LABEL
C     OUTPUTS VIA COMMON:
C        IFATAL
C        PTHMAT
C        LASNOD
C     WORKING VARIABLES:
C        NUMN--NODE NUMBER
C        NUMT--TERMINATE NODE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     FIND NODE NUMBER FOR THIS LABEL.
      NUMN = NUMNOD(LABEL)
C     FIND TERMINATE NODE NUMBER FOR THIS LABEL.
      NUMT = NUMTRM(LABEL)
C     IF BOTH NUMN AND NUMT ARE 0, THEN THIS LABEL IS NEITHER A
C     TERMINATE NOR A REGULAR NODE.
      IF (NUMN .EQ. 0 .AND. NUMT .EQ. 0) THEN
         PRINT *, 'ERROR--UNDEFINED NODE.'
         PRINT *, '        CORRECT NODE NAME OR INSERT CORRESPONDING ',
     &      'NODE OR TERM CARD.'
         IFATAL = IFATAL + 1
      ELSE
C        VERIFY A PATH HAS NOT BEEN PREVIOUSLY DEFINED AT THIS LOCATION
         IF (PTHMAT(LASNOD(NXTMSG), NXTMSG) .NE. 0.0) THEN
```

```
            PRINT *, 'ERROR--DUPLICATE PATH DEFINITION.'.
            PRINT *, '       (A PATH FOR THIS MESSAGE AT THIS NODE WAS
     &       , 'PREVIOUSLY SPECIFIED.)'
            IFATAL = IFATAL + 1
         ELSE
            IF (NUMN .GT. 0) THEN
C              A REGULAR NODE--MOVE THIS NODE NUMBER INTO THE PATH
C              MATRIX (PTHMAT).
               PTHMAT(LASNOD(NXTMSG), NXTMSG) = NUMN
C              THIS NODE NOW BECOMES THE PREVIOUS (LAST) NODE IN THIS
C              PATH.
               LASNOD(NXTMSG) = NUMN
            ELSE
C              A TERMINATE NODE--MOVE THE NEGATIVE OF THE TERMINATE NOD
C              NUMBER INTO THE PATH MATRIX (PTHMAT).
               PTHMAT(LASNOD(NXTMSG), NXTMSG) = -NUMT
C              THE TERMINATE NODE NOW BECOMES THE PREVIOUS (LAST) NODE
C              IN THIS PATH.
               LASNOD(NXTMSG) = -NUMT
            ENDIF
         ENDIF
      ENDIF
      RETURN
      END
```

```
      SUBROUTINE PROC(LBL, PRM1, PRM2, PRM3)
C
C     THIS SUBROUTINE HANDLES PROC CARDS BY SAVING THE INFORMATION
C     NECESSARY FOR PROCESSING TIMES.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMDST
C     INPUT ARGUMENTS:
C        LBL--PROCESSING TIME DISTRIBUTION NAME
C        PRM1--1ST PARAMETER OF DISTRIBUTION
C        PRM2--2ND PARAMETER OF DISTRIBUTION
C        PRM3--3RD PARAMETER OF DISTRIBUTION
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        LASNOD
C     OUTPUTS VIA COMMON:
C        IFATAL
C        DSTPRC
C     WORKING VARIABLES:
C        NUM--DISTRIBUTION RATE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER LBL*5
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     FIND THE DISTRIBUTION NUMBER.
      NUM = NUMDST(LBL)
C     IS DISTRIBUTION VALID (I.E., > 0)?
      IF (NUM .EQ. 0) THEN
         PRINT *, 'ERROR--ILLEGAL DISTRIBUTION SPECIFIED.'
         IFATAL = IFATAL + 1
      ELSE
C        VALID, SAVE DISTRIBUTION NUMBER.
         DSTPRC(NXTMSG, LASNOD(NXTMSG), 1) = NUM
C        SAVE DISTRIBUTION PARAMETER 1.
         DSTPRC(NXTMSG, LASNOD(NXTMSG), 2) = PRM1
C        SAVE DISTRIBUTION PARAMETER 2.
         DSTPRC(NXTMSG, LASNOD(NXTMSG), 3) = PRM2
C        SAVE DISTRIBUTION PARAMETER 3.
         DSTPRC(NXTMSG, LASNOD(NXTMSG), 4) = PRM3
```

```
      ENDIF
      RETURN
      END
```

C

```
      SUBROUTINE READ
C
C        THIS SUBROUTINE READS THE INPUT DATA DECK FROM FILE 20.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NONE
C     INPUT ARGUMENTS:
C        NONE
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C     OUTPUTS VIA COMMON:
C        IFATAL
C        PARM1
C        PARM2
C        PARM3
C        PARM4
C        PARM5
C        CRDTYP
C        LABEL
C        LABEL2
C     WORKING VARIABLES:
C        CARD67--CARD COLUMNS 6-72 OF THE INPUT CARD
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER CARD67*67
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     READ A CARD.
      READ (10, 10, END=999) CRDTYP, CARD67
      PRINT 30, CRDTYP, CARD67
C     RE-READ EACH CARD BASED UPON THE CARD TYPE TO OBTAIN THE NECESSARY
C     INFORMATION FOR THAT PARTICULAR CARD TYPE.
      IF (CRDTYP .EQ. 'NODE') THEN
         BACKSPACE 10
         READ (10, 20, ERR=888) LABEL, PARM2, PARM3,
     &     LABEL2
      ELSE IF (CRDTYP .EQ. 'TERM' .OR. CRDTYP .EQ. 'PATH') THEN
         BACKSPACE 10
         READ (10, 40, ERR=888) LABEL
      ELSE IF (CRDTYP .EQ. 'MESS') THEN
         BACKSPACE 10
```

```
          READ (10, 50, ERR=888) LABEL, PARM1, PARM2, PARM3,
     &         PARM4, PARM5, LABEL2
         ELSE IF (CRDTYP .EQ. 'PROC' .OR. CRDTYP .EQ. 'XMIT') THEN
          BACKSPACE 10
          READ (10, 70, ERR=888) LABEL, PARM3, PARM4, PARM1
         ELSE IF (CRDTYP .EQ. 'BALK') THEN
          BACKSPACE 10
          READ (10, 90, ERR=888) LABEL, PARM1
         ELSE IF (CRDTYP .NE. 'END ') THEN
C         AN INVALID CARD TYPE WAS SPECIFIED.
          PRINT 100
          IFATAL = IFATAL + 1
         ENDIF
         GO TO 1000
888      PRINT 110
         CRDTYP = 'ERR '
         IFATAL = IFATAL + 1
1000     RETURN
999      PRINT 120
         STOP
10       FORMAT (A4, A67)
20       FORMAT (5X, A5, 2F10.5, A4)
30       FORMAT (1X,A4, A67)
40       FORMAT (5X, A5)
50       FORMAT (5X, A5, 5F10.5, A4)
70       FORMAT (5X, A5, 3F10.5)
90       FORMAT (5X, A5, F10.5)
100      FORMAT (' ERROR--INVALID CARD TYPE.')
110      FORMAT (' ERROR--CONVERSION ERRORS OCCURRED.', /,
     &    7X, 'CHECK INPUT FORMATS.')
120      FORMAT (' UNEXPECTED END-OF-FILE.  JOB TERMINATED.')
         END
```

```
      SUBROUTINE TERM (LABL)
C
C     THIS SUBROUTINE HANDLES TERM CARDS BY SAVING THE TERMINATE NODE
C     NAME.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMTRM
C     INPUT ARGUMENTS:
C        LABL--TERMINATE NODE NAME
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTTRM
C        MAXTRM
C     OUTPUTS VIA COMMON:
C        IFATAL
C        NXTTRM
C        TRMNAM
C     WORKING VARIABLES:
C        NONE
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER LABL*5
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     HAS THIS TERMINATE NODE BEEN PREVIOUSLY DEFINED?
      IF (NUMTRM(LABL) .GT. 0) THEN
         PRINT *, 'ERROR--TERM PREVIOUSLY DEFINED.'
         IFATAL = IFATAL + 1
      ELSE
C        INCREMENT TERMINATE NODE COUNT.
         NXTTRM = NXTTRM + 1
C        IS COUNT STILL IN RANGE?
         IF (NXTTRM .GT. MAXTRM) THEN
            PRINT *, 'ERROR--TOO MANY TERMS DEFINED (IGNORED).'
            IFATAL = IFATAL + 1
            NXTTRM = MAXTRM
         ELSE
C           SAVE THIS TERMINATE NODE NAME.
            TRMNAM(NXTTRM) = LABL
         ENDIF
      ENDIF
```

```
RETURN
END
```

```
      SUBROUTINE XMIT (LBL, PRM1, PRM2, PRM3)
C
C     THIS SUBROUTINE HANDLES XMIT CARDS BY SAVING THE INFORMATION
C     NECESSARY FOR TRANSMIT TIME.
C
C     CALLED BY:
C        MAIN
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NUMDST
C     INPUT ARGUMENTS:
C        LBL--TRANSMIT TIME DISTRIBUTION NAME
C        PRM1--1ST PARAMETER OF DISTRIBUTION
C        PRM2--2ND PARAMETER OF DISTRIBUTION
C        PRM3--3RD PARAMETER OF DISTRIBUTION
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        IFATAL
C        NXTMSG
C        LASNOD
C     OUTPUTS VIA COMMON:
C        IFATAL
C        DSTXMT
C     WORKING VARIABLES:
C        NUM--DISTRIBUTION RATE NUMBER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER LBL*5
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4,
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     FIND THE DISTRIBUTION NUMBER.
      NUM = NUMDST(LBL)
C     IS DISTRIBUTION NUMBER VALID?
      IF (NUM .EQ. 0) THEN
         PRINT *, 'ERROR--ILLEGAL DISTRIBUTION SPECIFIED.'
         IFATAL = IFATAL + 1
      ELSE
C        SAVE THE DISTRIBUTION NUMBER.
         DSTXMT(NXTMSG, LASNOD(NXTMSG), 1) = NUM
C        SAVE PARAMETER 1 OF THE DISTRIBUTION.
         DSTXMT(NXTMSG, LASNOD(NXTMSG), 2) = PRM1
C        SAVE PARAMETER 2 OF THE DISTRIBUTION.
         DSTXMT(NXTMSG, LASNOD(NXTMSG), 3) = PRM2
C        SAVE PARAMETER 3 OF THE DISTRIBUTION.
         DSTXMT(NXTMSG, LASNOD(NXTMSG), 4) = PRM3
```

```
ENDIF
RETURN
END
```

```
      FUNCTION NUMDST(NAME)
C
C     THIS FUNCTION RETURNS THE DISTRIBUTION NUMBER FOR NAME (IF
C     A VALID DISTRIBUTION NAME) OR 0 (IF INVALID).
C
C     CALLED BY:
C        BLDOUT
C        MESS
C        PROC
C        XMIT
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NONE
C     INPUT ARGUMENTS:
C        NAME--DISTRIBUTION NAME
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        DSTNAM
C     OUTPUTS VIA COMMON:
C        NONE
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER NAME*5
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     ESTABLISH DEFAULT RETURN VALUE.
      NUMDST = 0
      DO 10 I = 1, 9
C     IF FOUND, RETURN I.
      IF (NAME .EQ. DSTNAM(I)) THEN
         NUMDST = I
         GO TO 20
      ENDIF
10    CONTINUE
20    RETURN
      END
```

```
      FUNCTION NUMNOD(NODE)
C
C     THIS FUNCTION RETURNS THE NODE NUMBER FOR NODE (IF THE NODE HAS
C     BEEN PREVIOUSLY DEFINED) OR 0 (IF UNDEFINED).
C
C     CALLED BY:
C        MAIN
C        CHEELK
C        BALK
C        MESS
C        NODE
C        PATH
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NONE
C     INPUT ARGUMENTS:
C        NODE--NODE NAME
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        MAXNOD
C        NODNAM
C     OUTPUTS VIA COMMON:
C        NONE
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER NODE*4
      CHARACTER CRDTYP*4, LABEL*4, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*4
     &  BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     &  MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     &  CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     &  PARM1, PARM2, PARM3, PARM4, PARM5,
     &  DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     &  LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     ESTABLISH DEFAULT RETURN VALUE.
      NUMNOD = 0
      DO 10, I = 1, MAXNOD
C     IF FOUND, RETURN I.
      IF (NODE .EQ. NODNAM(I)) THEN
         NUMNOD = I
         GO TO 20
      ENDIF
10    CONTINUE
20    RETURN
      END
```

```
      FUNCTION NUMTRM (NODE)
C
C     THIS FUNCTION RETURNS THE TERMINATE NODE NUMBER FOR NODE (IF
C     THE TERMINATE NODE HAS BEEN DEFINED) OR 0 (IF UNDEFINED).
C
C     CALLED BY:
C        MAIN
C        PATH
C        TERM
C     SUBROUTINES CALLED:
C        NONE
C     FUNCTIONS CALLED:
C        NONE
C     INPUT ARGUMENTS:
C        NODE--TERMINATE NODE NAME
C     OUTPUT ARGUMENTS:
C        NONE
C     INPUTS VIA COMMON:
C        MAXTRM
C        TRMNAM
C     OUTPUTS VIA COMMON:
C        NONE
C     WORKING VARIABLES:
C        I--DO LOOP COUNTER
C
      PARAMETER (NONOD=10,NOTRM=10,NOMSG=10)
      CHARACTER NODE*4
      CHARACTER CRDTYP*4, LABEL*5, LABEL2*4, NODNAM*4, DIST*5, TRMNAM*
     & BALKS*4, DSTNAM*5
      COMMON /COM1/ IFATAL, NXTNOD, NXTTRM, NXTMSG, MAXNOD, MAXTRM,
     & MAXMSG, NODCAP(2, NONOD), PTHMAT(NONOD, NOMSG),
     & CREATE(6, NOMSG), LASNOD(NOMSG), NODSTR(NOMSG),
     & PARM1, PARM2, PARM3, PARM4, PARM5,
     & DSTPRC(NOMSG, NONOD, 4), DSTXMT(NOMSG, NONOD, 4)
      COMMON /COM2/ NODNAM(NONOD), DIST(NOMSG), TRMNAM(NOTRM), CRDTYP,
     & LABEL, LABEL2, BALKS(NONOD), DSTNAM(9)
C     ESTABLISH DEFAULT RETURN VALUE.
      NUMTRM = 0
      DO 10 I = 1, MAXTRM
C     IF FOUND, RETURN I.
      IF (NODE .EQ. TRMNAM(I)) THEN
         NUMTRM = I
         GO TO 20
      ENDIF
10    CONTINUE
20    RETURN
      END
```

## Appendix B: Operating Instructions

### Introduction

The SLAM Pre-Processor is designed to operate in a batch mode, with card or card image inputs from file 10. Eight legal card types describe the network to be simulated, and the flow of messages through the network.

### Card Types

The eight legal card types are BALK, END, MESS, NODE, PATH, PROC, TERM, and XMIT. Each of these are described in more detail below. Samples of each card type may be found in Appendix E.

BALK Card. When the capacity of a node has been exceeded, a balk node may be specified (more details concerning balking may be found in the description of the NODE card). A BALK card is used to define the beginning of a balk route specification (the route to be taken should a node's capacity be exceeeded) by specifying the name of the node for which a balk route is being provided, and the message number for which the route applies.

END Card. An END card marks the end of the SLAMPP input deck.

MESS Card. A MESS card marks the beginning of a message description and defines the message arrival rate, the time of the first message arrival, the number of message releases (number of messages to be created), and the name of the first node on the message path.

NODE Card. A NODE card defines a node (by name), its maximum capacity, the number of servers (the number of messages which may be

processed at the same time) at this node, and balking or blocking information.

When a message arrives at a node whose queue is at its maximum capacity, one of three actions may occur: the message may balk, the message may block, or the message may be lost. If balking is specified, the message will go to an alternate (balk) node. If blocking is specified, the message "backs up" in the network prior to the node and waits until a message leaves the node, at which time it moves into the node. If neither balking nor blocking is specified, the message will simply be lost.

PATH Card. A PATH card specifies the name of the node which is next in the path.

PROC Card. A PROC card describes the amount of time a message takes to be processed prior to leaving a node.

TERM Card. A TERM card defines (by name) those nodes at which a message may leave the network, called "terminate nodes."

XMIT Card. An XMIT card describes the amount of time it takes to transmit a message to the next node on the path after a message has been processed.

## Distribution Rates

Three card types (MESS, PROC, and XMIT) allow the user to specify a time duration. In the case of the MESS card, the time is the time between message creations while, for PROC and XMIT, it is the time for processing and transmitting a message, respectively.

SLAMPP will recognize nine distributions as valid. Each

distribution requires from one to three parameters, which should be input in the order given. These are described below (Pritsker, 1979: 528-534).

BETA. Beta distribution with two parameters: Theta and phi.

CONST. Constant duration with one parameter: length.

EXPON. Exponential distribution with one parameter: mean.

GAMA. Gamma distribution with two parameters: Beta and alpha.

NPSSN. Poisson distribution with one parameter: mean.

RLOGN. Lognormal distribution with two parameters: mean and standard deviation.

RNORM. Normal distribution with two parameters: mean and standard deviation.

TRIAG. Triagonal distribution with three parameters: interval low value, mode, and interval high value.

UNFRM. Uniform distribution with two parameters: interval low value and interval high value.

## Input Formats

Each input card consists of a card type, plus (depending upon card type) up to seven additional data areas. Regardless of card type, each data area (or field) is located in the same card columns. Field one is in columns 1-4 and field two in 6-10, while the remaining fields begin in columns 11, 21, 31, 41, 51, and 61, and are each 10 columns wide.

Two types of data may be placed within each field: alphanumeric or numeric. Alphanumeric data must be left justified within the field. All numeric data is input as real values, and may fall any place within

a field; however, a decimal point must be explicitly included with the number. Thus, the number "1" should be entered as "1." or "1.0". Only the first five decimal places are significant.

Although each numeric field should be entered as a real value (to keep all data field formats consistant for all card types), some values are internally converted to integers by truncation. Therefore, if the data item is listed as "integer," ensure that no decimal places are included.

The format for each of the eight card types is shown below. The number within parenthesis is the field number associated with that data item.

BALK. (1) Card type key word "BALK". (2) Name of the node (not a terminate node) for which a balk route is being specified. This node name should have appeared as a balk node on a NODE card. (3) The integer message number for which a balk route is being specified. Message numbers are assigned sequentially (beginning with one) in the order found in the SLAMPP input deck (see the section on message numbering later).

END. (1) Card type keyword "END".

MESS. (1) Card type keyword "MESS". (2) Distribution name for the message creation rate. (3) Parameter one of the distribution. (4) Parameter two of the distribution (if only one parameter is required, enter zero). (5) Parameter three of the distribution (if only one or two parameters are required, enter zero). (6) The integer time of creation of the first message. (7) The integer number of messages to be created. (8) The name of the first node in this message's path.

NODE. (1) Card type keyword "NODE". (2) The name of the node being defined (four or fewer characters). (3) The integer maximum capacity of this node (the maximum number of messages which may be waiting at this node at any one time). (4) The integer number of servers at this node (the maximum number of messages which may be processed concurrently). (5) Balking or blocking information. If balking is to occur, place the name of the node to which messages should balk if maximum capacity is exceeded. If blocking is to occur, place the keyword "BLOK" into this field. If neither balking or blocking is desired (meaning that an arriving message will be lost if maximum capacity has been reached), leave this field blank.

PATH. (1) Card type keyword "PATH". (2) The name of the next node along this message or balk route's path.

PROC. (1) Card type keyword "PROC". (2) The distribution name for the processing time at this node. (3) Parameter one of the distribution. (4) Parameter two of the distribution (if only one parameter is required, enter zero). (5) Parameter three of the distribution (if only one or two parameters are required, enter zero).

TERM. (1) Card type keyword "TERM". (2) The name (four or fewer characters) of the terminated node being declared.

XMIT. (1) Card type keyword "XMIT". (2) The distribution name for the transmission time at this node. (3) Parameter one of the distribution. (4) Parameter two of the distribution (if only one parameter is required, enter zero). (5) Parameter three of the distribution (if only one or two parameters are required, enter zero).

Building the Input Deck

The input deck can be divided into four catagories, which are described below. The order of these descriptions is the same as the order in which these catagories must fall within the SLAMPP input deck.

Declarations. Before any message can be defined, all nodes within the network must be defined. Each node must be described and defined (using NODE cards). Following the node declarations comes the declaration of all terminate nodes (using TERM cards).

Message Descriptions. Following the declaration portion of the SLAMPP input is the message description area. A message description may involve up to four card types: MESS, PROC, XMIT and PATH.

The first card in the description of any message is a MESS card specifying the creation rate for this message and the first node along the path. In essence, this card specifies when and how often this message will arrive, and the name of the node where the message will first arrive.

While at a node, a message may be processed in some manner which requires time. This processing time can be expressed by using a PROC card. If processing is not required, this card may be omitted.

After all processing is complete, this message is ready to be transmitted to the next node along the path. This transmission may require time, and can be defined using an XMIT card. If no transmission time is needed, this card may be omitted.

The next node along this message's path (that is, the node to which the message is being transmitted) is defined by a PATH card. This PROC, PATH and XMIT pattern is repeated until the entire path of the message

has been described. The last node of every message's path must be a terminate node.

Subsequent messages are described by inserting another MESS card and following the above instructions again.

Balk Route Descriptions. One of the items specified on a NODE card is whether balking will occur or not. If balking is specified, there is a possibiity that every message that uses this node could be redirected to the balk node. Therefore, a path must exist for every message which could possibly enter a balk node. If a path already exists for a message at the balk node from the message's original description, nothing more need be done for this message. However, if a path does not exist, one must be supplied by means of a BALK card. All balk route descriptions (if any are present) follow the last message description.

The BALK card specifies the balk node name and the message number for which a balk route is being provided. Following the BALK card, PROC, XMIT and PATH cards are repeated (just as in a message description) until the entire balk path is defined. As with a regular message path, balk paths must end at a terminate node.

Additional balk routes may be supplied by inserting another BALK card and repeating the above steps.

End of Deck. The last card of the input deck must be an END card. No additional data will be read beyond the END card.

## Design Considerations

Designing the SLAMPP Network. Experience has shown that even the most simple network can become confusing unless a systematic method is

used to translate that network into SLAMPP inputs. In order to minimize the number of input errors, a few simple guidelines are suggested.

First, determine exactly which nodes and terminate nodes will be required for the network. In the case of nodes, also determine the number of servers, maximum capacity, and balking or blocking characteristics. Translate this information into the appropriate NODE or TERM cards.

Second, determine exactly which messages are to be included. A good method to follow is to "outline" the message directly into SLAMPP inputs. That is, code the appropriate MESS card for the message, and follow this with the applicable PROC, XMIT and PATH cards to describe the message. After the first message is completely defined, begin defining the second, then the third, etc., until all messages have been defined.

Third, define any balk routes which may be required. To do this, examine each node, in succession, which has a balk node specified on its NODE card. Then, for every message which uses this node, ensure a route exists for this message from the balk node. This route may already exist if the message originally was routed using this balk node as part of its path. For example, as might occur if a message went from N1 to N2 to N3 to N4, and N1 balked to N3. In this case, if N1 was at maximum capacity the message would skip N1 and N2 and go directly to N3. If a route does not already exist for this message, then a route must be defined by using a BALK card. As with a message, follow the BALK card with the necessary PROC, XMIT and PATH cards to describe the route.

Fourth, make sure that any routes added in step three that use a

node which can balk has its own balk routes specified. Repeat this step until all routes and all necessary balk routes are specified.

Lastly, supply an END card to the input deck.

Message Numbering. Balk routes are specified using the number of the message for which a route is being supplied. It is, therefore, important to know how messages are numbered.

Messages are numbered consecutively (beginning at one) in the order they appear in the input deck. Thus, the first message found is message number one; the second, number two, etc.

When additional messages are being added to the network, always add the new message(s) after the end of the last message of the network. In this manner, any balk routes which may have been previously defined will not need any changes. Otherwise, the BALK cards will need changing to reflect the new message numbers.

Balk Route Considerations. Balk route design provides the user with several methods which may be used. To familiarize the user with these methods, they are described below.

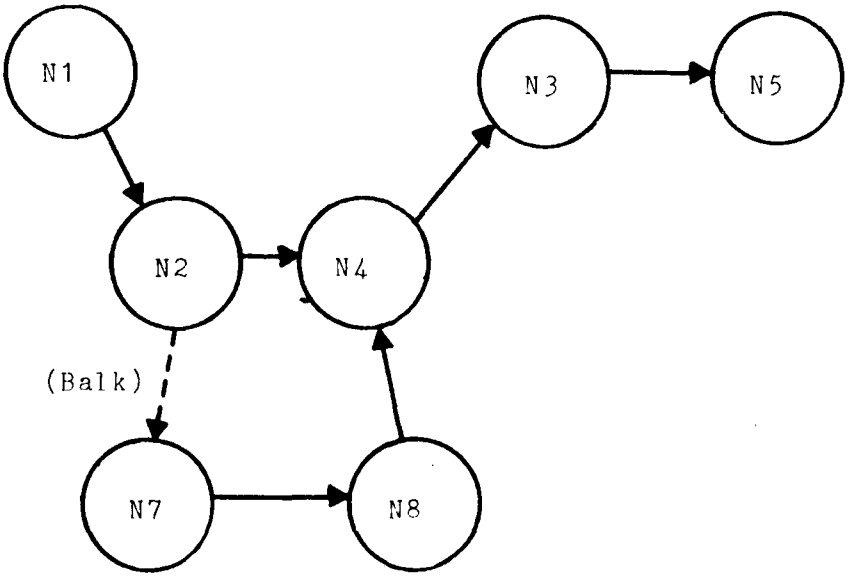
First, no balk route may be necessary and therefore, the user need not do anything. However, this is only applicable to nodes which do not have a balk node specified.

Second, the balk route may be an entirely different route from the path defined for the message (by the MESS card). The primary consideration here is to ensure that this balk route ends on a terminate node.

Third, the balk node may have been included within the message's original path. In this case, a route already exists for this message

from the balk node, and the user need not (in fact, cannot) provide another route.

Fourth, the balk route may merge back into the message route. This means that a portion of the balk route is entirely different from the message path; however, at some point in the balk route a node defined in the message path is used. From this node forward, the balk route is the same as the message path. To illustrate this, assume a message has path N1, N2, N4, N3 and N5 (in that order). If N2 balks to N7, then a merging balk route might be N7, N8 and N4. In this example, a message would balk from N2 to N7 and then traverse N8 and N4. The remainder of the path from N4 would be the same as the message path. In essence, the balk route would be N7, N8, N4, N3 and N5. Diagramatically, this could be viewed as:



All messages which arrive at a node are required to balk to the same balk node. Occasionally, however, different balk nodes may be desired for each different message. This can be accomplished by using a "dummy" balk node whose only function is to redirect messages to their appropriate nodes. The recommended procedure is to define this dummy balk node as having a very large capacity (9999) and a large number of servers (9999). Since this node does not represent a real node within the network, following this definition prevents this node from becoming a "bottleneck" in the system and affecting statistics. Immediately following the BALK cards for the messages to be redirected, insert a PATH card to the desired node. This causes the message to balk to the dummy node and then be transmitted to the appropriate node. However, since both balking and transmitting (in this case) use zero time, the net result is that the message goes directly to its appropriate node.

## Appendix C: Input Errors

The validity of the SLAM Pre-Processor input is verified at several points. Should any errors be detected, an error message is printed and the SLAM input source code is not created. Below is a list of the error messages which may be produced, along with an explaination and a possible cause or correction.

CONVERSION ERRORS OCCURRED. A conversion error occurred trying to read the input file. The most likely cause is failure to follow the correct input format for the card type involved. Correct the format.

DUPLICATE PATH DEFINITION. An attempt was made to define a path for a particular message using a node already defined on that message's path. Frequently caused by trying to define a balk path for a message which overlaps the message's path.

END CARD EXPECTED. Additional input data followed the end of the last balk route or, if no balk routes are specified, the end of the last message. Either this data is incorrect (and should be removed), or a problem exists in the last message or balk route to be specified.

INCOMPLETE BALK PATH FOR MESSAGE n FROM NODE name. The balk path for message number n (which balks from node name) does not end on a terminate node. Either the path is incorrect (and should be corrected) or the balk route was not supplied as required.

ILLEGAL BALK NODE. The balk node name specified was not defined in a NODE statement. Either supply a corresponding NODE statement, or correct the node name.

ILLEGAL BALK NODE NAME. The balk node name specified on the BALK

card is incorrect and should be corrected.

ILLEGAL DISTRIBUTION SPECIFIED. The distribution name specified is not valid in the SLAMPP (see Appendix B). Correct to a valid name.

INVALID BALK NODE (SKIPPING TO NEXT BALK). The balk node name is incorrect and should be corrected. The remainder of this balk path is ignored.

INVALID CARD TYPE. The card type specified is not a valid SLAMPP card type (see Appendix B). Correct the card type or remove from the input deck.

INVALID MESSAGE NUMBER (SKIPPING TO NEXT BALK). The message number specified on the BALK card is invalid (either zero, negative, or greater than the number of messages input to SLAMPP). Correct the number. The remainder of this balk path is ignored.

MAXIMUM CAPACITY MUST BE GREATER THAN 0. The maximum capacity specified for this node was either zero or negative. Correct to a positive value.

MESS CARD MUST FOLLOW TERM CARDS. A card type other than MESS was found following the last TERM card. The input deck is out of order (and should be reordered).

MESSAGE MUST END ON A TERMINATE NODE. The message path being defined did not end on a terminate node, leaving this path incomplete. Complete the path.

MISSING BALK PATH CARD. SKIPPING TO NEXT BALK. The path for this balk route did not contain a PATH card. The remainder of this path is ignored.

MISSING PATH CARD. SKIPPING TO NEXT MESS. The path for this

message route did not contain a PATH card. The remainder of this message is ignored.

NODE CARDS MUST BE FIRST. The first card type found was not a NODE card. Inputs are out of order and should be reordered.

NODE name IS NOT USED IN A PATH. The node name, which was defined in a NODE card, was not used in any path. Either place name in a path, or remove the corresponding NODE card.

NODE PREVIOUSLY DEFINED. The node being defined by this NODE card has appeared previously on a NODE card. Renove one of the NODE cards.

NUMBER OF SERVERS MUST BE GREATER THAN 0. The number of servers specified for this node was either zero or negative. Correct to a positive value.

TERM CARDS MUST FOLLOW NODE CARDS. The first card type found following the last NODE card was not a TERM card. Inputs are out of order and should be reordered.

TERM PREVIOUSLY DEFINED. The terminate node being defined by this TERM card has appeared previously on a TERM card. Remove one of the TERM cards.

THE BALK PATH FOR MESSAGE n CONTAINS A CYCLE FROM NODE name. The balk route specified for message number n from node name loops back upon itself. Correct the path to remove the cycle.

TOO MANY MESSAGES DEFINED. The number of messages input to the SLAMPP exceeds the program capacity. Either remove the excess messages, or recompile the Pre-Processor with an increased value for NOMSG (see Chapter III).

TOO MANY NODES DEFINED (IGNORED). The number of nodes input to the

SLAMPP exceeds the program capacity. This node declaration is ignored. Either remove the excess nodes, or recompile the Pre-Processor with an increased value for NONOD (see Chapter III).

TOO MANY TERMS DEFINED (IGNORED). The number of terminate nodes input to the SLAMPP exceeds the program capacity. This terminate node declaration is ignored. Either remove the excess terminate nodes, or recompile the Pre-Processor with an increased value for NOTRM (see Chapter III).

UNDEFINED NODE. The node specified was not declared in a NODE or TERM statement. Insert the corresponding declaration.

UNEXPECTED END-OF-FILE. JOB TERMINATED. The end of the input data was encountered when SLAMPP expected additional data, usually caused by a missing END card or previous errors. Insert an END card or correct the other errors.

## Appendix D: Interpreting the SLAM Output

### Introduction

Upon successful completion of a network simulation, the user must be able to interpret the SLAM output. Summarized here is a description of the outputs. Refer to the sample SLAM output at the end of this appendix for examples.

### SLAM Output

The output of interest to the user begins on the page labelled "SLAM SUMMARY REPORT." The first item to notice is the "Current Time." The time shown is the time the last message left the network, leaving the network empty.

### Terminate Nodes

Following this is the "Statistics for Variables Based on Observations." Statistics are produced for each terminate node within the network and are identified by terminate node name. The statistics are based upon the time interval between message arrivals at the terminate node. The mean, standard deviation, and coefficient of variation of the time between message arrivals are listed. Also, the minimum and maximum arrival intervals and the number of messages to arrive at this terminate node are shown.

### Queues

File statistics are printed next. These statistics deal with the

queues for each of the nodes in the network. The queue statistics are listed in the same order as their NODE cards in the SLAMPP network. An easier way, perhaps, to identify the node's name is to look at the next section of the SLAM output titled "Resource Statistics." The "Resource Number" for a particular node name (listed under "Resource Label") is the same as that node's "File Number." Note that the last file number listed is a SLAM work file and should be ignored.

The statistics shown include the average length, standard deviation and maximum length of each queue. The average time a message waited to be processed at a queue is also presented. Note that messages may have been lost at nodes which do not have balking nor blocking specified if the maximum length of that node's queue is the same as that node's maximum capacity.

Service and Transmission

The "Resource Statistics" represents statistics dealing with the service and transmission time at each node. The first group of data represents node utilization while the second group represents node availability.

In the utilization group, "Current Capacity" is the number of servers available at this node. The "Average Utilization" is the average number of servers to be used. The maximum number of servers used concurrently and the current number of servers being used (at end of simulation) are also shown.

In the available group, the average number of servers available, plus the minimum and maximum number available are shown.

# S L A M  S U M M A R Y  R E P O R T

SIMULATION PROJECT SLAM  BY SLAMPP

DATE 9/19/1982  RUN NUMBER 1 OF 1

CURRENT TIME .3235E+04
STATISTICAL ARRAYS CLEARED AT TIME 0.

**STATISTICS FOR VARIABLES BASED ON OBSERVATION**

| | MEAN VALUE | STANDARD DEVIATION | COEFF. OF VARIATION | MINIMUM VALUE | MAXIMUM VALUE | NO.OF OBS |
|---|---|---|---|---|---|---|
| EXIT INTRVL TRM1 | .563E+02 | .158E+03 | .280E+01 | .172E+01 | .113E+04 | 295 |
| EXIT INTRVL TRM2 | .381E+03 | .356E+03 | .934E+00 | .903E+01 | .115E+04 | 74 |
| EXIT INTRVL TRM3 | .119E+03 | .131E+03 | .110E+01 | .938E+01 | .764E+03 | 238 |

**FILE STATISTICS**

| FILE NUMBER | ASSOCIATED NODE TYPE | AVERAGE LENGTH | STANDARD DEVIATION | MAXIMUM LENGTH | CURRENT LENGTH | AVERAGE WAIT TIME |
|---|---|---|---|---|---|---|
| 1 | AWAIT | 0.000 | 0.000 | 1 | 0 | 0.000 |
| 2 | AWAIT | .001 | .045 | 3 | 0 | .113 |
| 3 | AWAIT | 2.991 | 10.750 | 61 | 0 | 92.125 |
| 4 | AWAIT | 9.904 | 17.473 | 50 | 0 | 152.550 |
| 5 | AWAIT | 0.000 | 0.000 | 1 | 0 | 0.000 |
| 6 | AWAIT | 4.399 | 12.353 | 50 | 0 | 28.399 |
| 7 | AWAIT | .181 | 1.249 | 10 | 0 | 6.967 |
| 8 | AWAIT | 9.869 | 13.005 | 30 | 0 | 570.047 |
| 9 | AWAIT | .628 | 2.909 | 15 | 0 | 3.790 |
| 10 | | 4.118 | 3.395 | 19 | 0 | 1.162 |

**RESOURCE STATISTICS**

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT CAPACITY | AVERAGE UTIL | STANDARD DEVIATION | MAXIMUM UTIL | CURRENT UTIL |
|---|---|---|---|---|---|---|
| 1 | ALFA | 1 | .18 | .381 | 1 | 0 |
| 2 | BLK1 | 1 | .00 | .052 | 1 | 0 |
| 3 | BLK2 | 1 | .10 | .298 | 1 | 0 |
| 4 | BETA | 1 | .29 | .451 | 1 | 0 |
| 5 | DLTA | 5 | .05 | .294 | 4 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | PI | 1 | .46 | .498 | 1 | 0 |
| 7 | RHO | 1 | .03 | .179 | 1 | 0 |
| 8 | ZETA | 1 | .39 | .489 | 1 | 0 |
| 9 | GAMA | 2 | .17 | .481 | 2 | 0 |

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT AVAILABLE | AVERAGE AVAILABLE | MINIMUM AVAILABLE | MAXIMUM AVAILABLE |
|---|---|---|---|---|---|
| 1 | ALFA | 1 | .8241 | 0 | 1 |
| 2 | BLK1 | 1 | .9973 | 0 | 1 |
| 3 | BLK2 | 1 | .9016 | 0 | 1 |
| 4 | BETA | 1 | .7149 | 0 | 1 |
| 5 | DLTA | 5 | 4.9460 | 1 | 5 |
| 6 | PI | 1 | .5389 | 0 | 1 |
| 7 | RHO | 1 | .9668 | 0 | 1 |
| 8 | ZETA | 1 | .6066 | 0 | 1 |
| 9 | GAMA | 2 | 1.8349 | 0 | 2 |

## Appendix E: Test and Evaluation

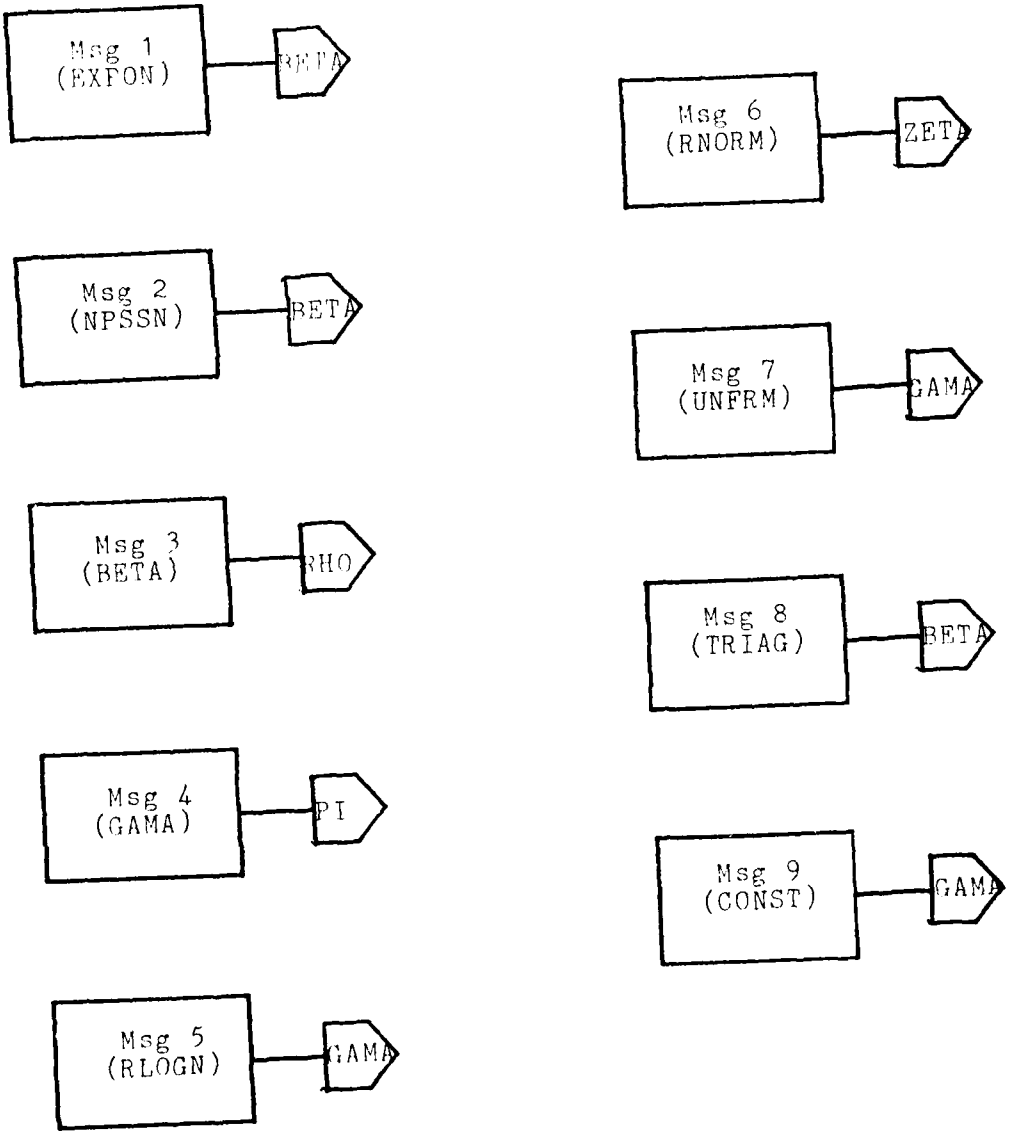
In order to check the validity of the SLAMPP, a test case was designed and evaluated. This test case was designed to use at least once every capability of SLAMPP. Specifically, nodes with balking, nodes with blocking and nodes with neither were used. Each of the nine valid distribution types found in Appendix B was used in each of their legal positions, that is, on the message creation card (MESS), process card (PROC) and the transmit card (XMIT). The default process and transmit time of zero was also demonstrated. Since balking was specified on two nodes, balk route descriptions were required in addition to regular route descriptions.

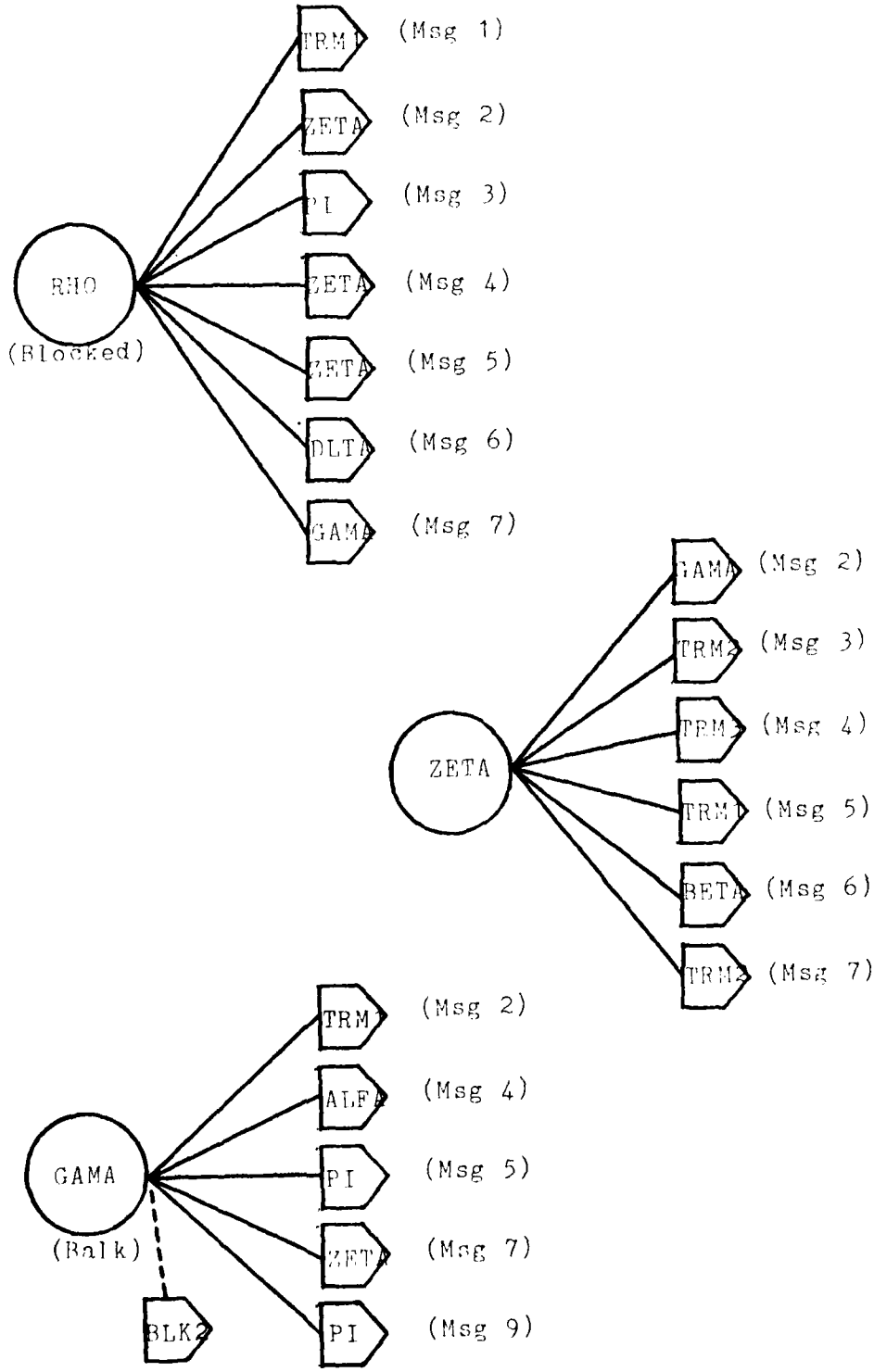
This test case was developed using the design considerations found in Appendix B. All of the nodes to be included were first determined and translated into NODE and TERM cards (a listing of the SLAMPP inputs may be found later in this appendix). The messages to be included were determined and placed into the SLAMPP input deck. Lastly, all balk routes which were necessary were supplied. The message creations and routings are diagramatically illustrated on the following pages.

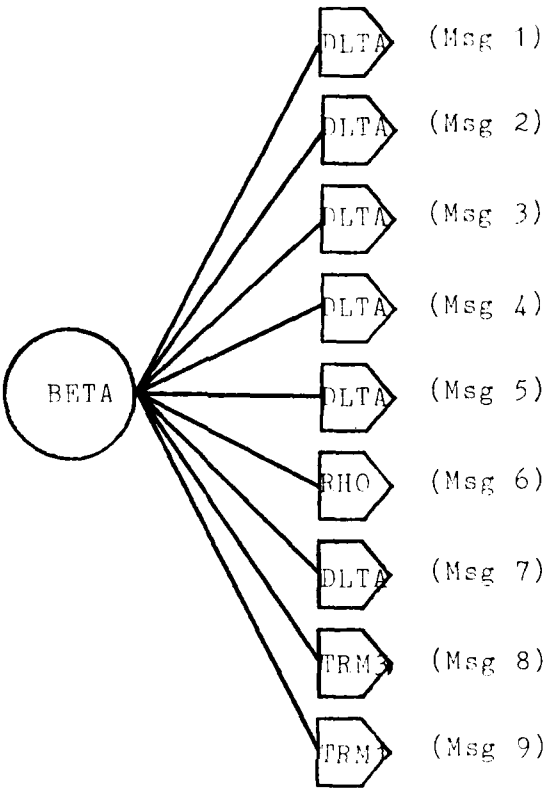
After all SLAMPP inputs were completed, the SLAMPP program was executed to produce the SLAM source code, a copy of which is at the end of this appendix. This source code was manually inspected to ensure that the source was an accurate representation of the network to be modeled. After acceptance, the source code was executed by SLAM to verify that SLAM would indeed accept the code. The SLAM execution listing is also included in this appendix.

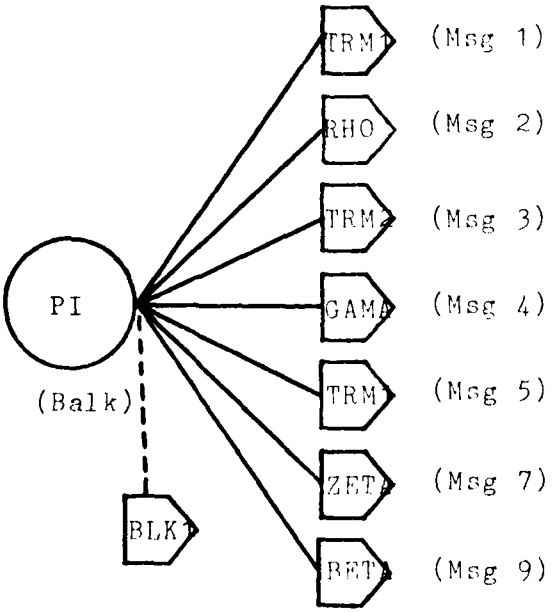
After repeated executions of SLAMPP, no errors could be detected and the program was accepted.

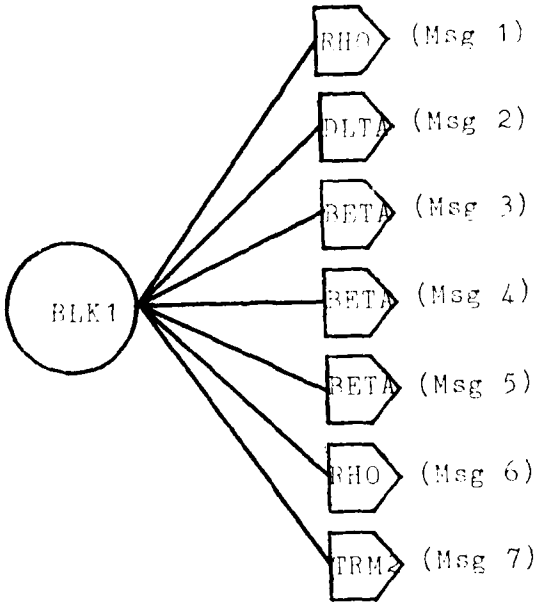
MESSAGE CREATIONS

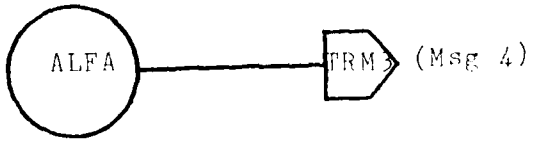


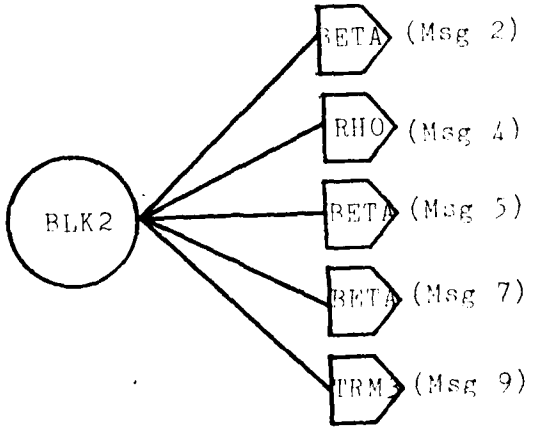

RHO
(Blocked)
TRM1
(Msg 1)
ZETA
(Msg 2)
PI
(Msg 3)
ZETA
(Msg 4)
ZETA
(Msg 5)
DLTA
(Msg 6)
GAMA
(Msg 7)
ZETA
GAMA
(Msg 2)
TRM2
(Msg 3)
TRM2
(Msg 4)
TRM1
(Msg 5)
BETA
(Msg 6)
TRM2
(Msg 7)
GAMA
(Balk)
TRM1
(Msg 2)
ALFA
(Msg 4)
PI
(Msg 5)
ZETA
(Msg 7)
PI
(Msg 9)
BLK2

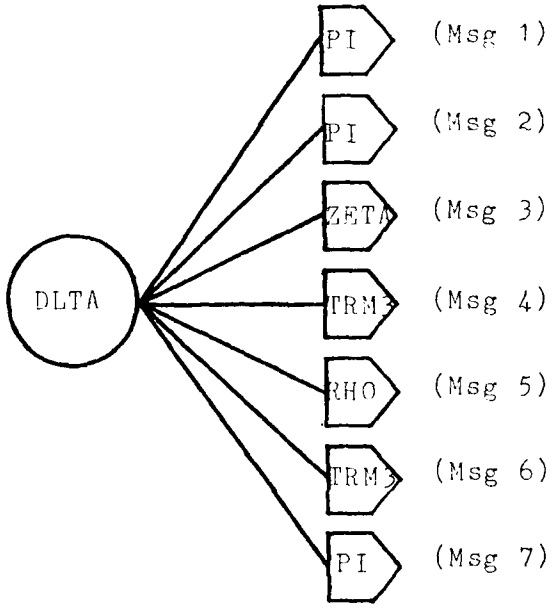

BETA
DLTA
DLTA
DLTA
DLTA
DLTA
RHO
DLTA
TRM3
TRM1
(Msg 1)
(Msg 2)
(Msg 3)
(Msg 4)
(Msg 5)
(Msg 6)
(Msg 7)
(Msg 8)
(Msg 9)


PI
(Balk)
BLK1
TRM1
RHO
TRM2
GAMA
TRM3
ZETA
BETA
(Msg 1)
(Msg 2)
(Msg 3)
(Msg 4)
(Msg 5)
(Msg 7)
(Msg 9)


BLK1
RHO
(Msg 1)
DLTA
(Msg 2)
BETA
(Msg 3)
BETA
(Msg 4)
BETA
(Msg 5)
RHO
(Msg 6)
TRM2
(Msg 7)


ALFA
TRM3
(Msg 4)


BLK2
BETA
(Msg 2)
RHO
(Msg 4)
BETA
(Msg 5)
BETA
(Msg 7)
TRM3
(Msg 9)


DLTA
PI
PI
ZETA
TRM
RHO
TRM
PI
(Msg 1)
(Msg 2)
(Msg 3)
(Msg 4)
(Msg 5)
(Msg 6)
(Msg 7)

SLAM PRE-PROCESSOR

SUMMARY OF PROGRAM INPUTS:

```
NODE  ALFA 50.0       1.0
NODE  BLK1 9999.0     1.0
NODE  BLK2 9999.0     1.0
NODE  BETA 50.0       1.0
NODE  DLTA 20.0       5.0
NODE  PI   50.0       1.0         BLK1
NODE  RHO  10.0       1.0         BLOK
NODE  ZETA 30.0       1.0
NODE  GAMA 15.0       2.0         BLK2
TERM  TRM1
TERM  TRM2
TERM  TRM3
MESS  EXPON2.0        0.0         0.0         0.0         50.0        BETA
PROC  TRIAG2.0        7.0         9.
PATH  DLTA
XMIT  CONST1.7
PATH  PI
PROC  EXPON0.75
XMIT  BETA 3.12       6.14
PATH  TRM1
MESS  NPSSN3.2        0.0         0.0         20.0        100.0       BETA
PATH  DLTA
PROC  GAMA 2.17       .95
XMIT  CONST0.5
PATH  PI
XMIT  RLOGN1.333      .888
PATH  RHO
PROC  EXPON.23175
XMIT  NPSSN.103
PATH  ZETA
PROC  RNORM2.1        .44
PATH  GAMA
PROC  CONST2.0
XMIT  CONST1.1
PATH  TRM1
MESS  BETA 2.0        1.0         0.0         10.0        75.0        RHO
PROC  UNFRM2.1        3.6
PATH  PI
XMIT  CONST6.55
PATH  TRM2
MESS  GAMA 6.2        5.1         0.0         0.0         100.0       PI
PROC  CONST9.75
XMIT  NPSSN0.223
PATH  GAMA
PATH  ALFA
PROC  CONST3.1
XMIT  RLOGN2.7        .334
PATH  TRM3
```

```
MESS RLOGN9.1       1.3         0.0         150.0       250.0       GAMA
PROC CONST0.0001
XMIT TRIAG.85       .88         .9
PATH PI
PROC CONST.0001
XMIT TRIAG.85       .88         .91
PATH TRM1
MESS RNORM4.1       2.6         0.0         500.0       63.0        ZETA
PATH BETA
PROC NPSSN.667
XMIT NPSSN.668
PATH RHO
XMIT GAMA .45       .23
PATH DLTA
PROC RNORM.382      .125
XMIT RLOGN.543      .321
PATH TRM3
MESS UNFRM.75       1.5         0.0         0.0         200.0       GAMA
PATH ZETA
PROC CONST25.0
XMIT CONST5.0
PATH TRM2
MESS TRIAG2.0       5.0         10.0        15.0        125.        BETA
XMIT TRIAG3.00      6.          11.0
PATH TRM3
MESS CONST1.5       0.0         0.0         1.0         85.0        GAMA
PROC UNFRM4.2       6.5
XMIT CONST1.621
PATH PI
PROC BETA .5        .1
PATH BETA
PATH TRM1
BALK BLK1 1.0
XMIT CONST.5
PATH RHO
PROC NPSSN1.6
XMIT EXPON.0002
PATH TRM1
BALK BLK1 2.0
PATH DLTA
BALK BLK2 2.0
XMIT GAMA 1.234     2.345
PATH BETA
BALK BLK1 3.0
PROC RNORM.45       .21
XMIT CONST2.678
PATH BETA
PATH DLTA
PROC RLOGN1.2       .7654
PATH ZETA
XMIT BETA 6.1       3.7
PATH TRM2
BALK BLK1 4.0
XMIT UNFRM.99       2.1
```

```
PATH BETA
PATH DLTA
PROC GAMA 1.1          .87654
XMIT CONST2.3
PATH TRM3
BALK BLK2 4.0
PATH RHO
PROC NPSSN.7
XMIT EXPON.7
PATH ZETA
PATH TRM3
BALK BLK1 5.0
PROC CONST.0009
XMIT CONST.00099
PATH BETA
PATH DLTA
XMIT RNORM4.675        1.304
PATH RHO
XMIT RLOCN.999         .888
PATH ZETA
PROC UNFRM.54          .62
XMIT TRIAG.0003        2.5          15.0
PATH TRM1
BALK BLK2 7.0
XMIT RNORM5.223        .162
PATH BETA
PROC TRIAG3.56         4.0          5.0
XMIT CONST.4
PATH DLTA
PATH PI
XMIT EXPON.1
PATH ZETA
BALK BLK1 7.0
PATH RHO
PATH GAMA
BALK BLK1 9.0
XMIT CONST.7
PATH TRM2
BALK BLK2 9.0
PATH TRM3
BALK BLK2 5.0
PATH BETA
END
NO ERRORS DETECTED. SLAM SOURCE WILL BE CONSTRUCTED.
```

```
1   GEN,SLAMPP,SLAM,09/19/1982,1,,,,,,72;
2   LIM,    9,2,500;
3   NETWORK;
4         RESOURCE/ALFA(    1),    1;
5         RESOURCE/BLK1(    1),    2;
6         RESOURCE/BLK2(    1),    3;
7         RESOURCE/BETA(    1),    4;
8         RESOURCE/DLTA(    5),    5;
9         RESOURCE/PI   (    1),    6;
10        RESOURCE/RHO  (    1),    7;
11        RESOURCE/ZETA(    1),    8;
12        RESOURCE/GAMA(    2),    9;
13        CREATE,EXPON(    2.00000),     0,1,    50;
14        ASSIGN,ATRIB(2)=    1;
15        ACT,,,BETA;
16        CREATE,NPSSN(    3.20000),    20,1,   100;
17        ASSIGN,ATRIB(2)=    2;
18        ACT,,,BETA;
19        CREATE,BETA (    2.00000,    1.00000),    10,1,    75;
20        ASSIGN,ATRIB(2)=    3;
21        ACT,,,RHO  ;
22        CREATE,GAMA (    6.20000,    5.10000),     0,1,   100;
23        ASSIGN,ATRIB(2)=    4;
24        ACT,,,PI   ;
25        CREATE,RLOGN(    9.10000,    1.30000),   150,1,   250;
26        ASSIGN,ATRIB(2)=    5;
27        ACT,,,GAMA;
28        CREATE,RNORM(    4.10000,    2.60000),   500,1,    63;
29        ASSIGN,ATRIB(2)=    6;
30        ACT,,,ZETA;
31        CREATE,UNFRM(     .75000,    1.50000),     0,1,   200;
32        ASSIGN,ATRIB(2)=    7;
33        ACT,,,GAMA;
34        CREATE,TRIAG(    2.00000,    5.00000,   10.00000),    15,1,
35        ASSIGN,ATRIB(2)=    8;
36        ACT,,,BETA;
37        CREATE,    1.50000,     1,1,    85;
38        ASSIGN,ATRIB(2)=    9;
39        ACT,,,GAMA;
40  ALFA  AWAIT(    1/  50),ALFA;
41        GOON,1;
42        ACT,,ATRIB(2).EQ.    4,L101;
43  L101  GOON;
44        ACT,    3.10000;
45        GOON;
46        ACT,RLOGN(    2.70000,     .33400);
47        FREE,ALFA;
48        ACT,,,TRM3;
49  BLK1  AWAIT(    2/9999),BLK1;
50        GOON,1;
51        ACT,,ATRIB(2).EQ.    1,L102;
52        ACT,,ATRIB(2).EQ.    2,L103;
53        ACT,,ATRIB(2).EQ.    3,L104;
```

```
54          ACT,,ATRIB(2).EQ.    4,L105;
55          ACT,,ATRIB(2).EQ.    5,L106;
56          ACT,,ATRIB(2).EQ.    7,L107;
57          ACT,,ATRIB(2).EQ.    9,L108;
58    L102  GOON;
59          ACT,     .50000;
60          FREE,BLK1;
61          ACT,,,RHO ;
62    L103  GOON;
63          FREE,BLK1;
64          ACT,,,DLTA;
65    L104  GOON;
66          ACT,RNORM(     .45000,     .21000);
67          GOON;
68          ACT,    2.67800;
69          FREE,BLK1;
70          ACT,,,BETA;
71    L105  GOON;
72          ACT,UNFRM(     .99000,    2.10000);
73          FREE,BLK1;
74          ACT,,,BETA;
75    L106  GOON;
76          ACT,     .00090;
77          GOON;
78          ACT,     .00099;
79          FREE,BLK1;
80          ACT,,,BETA;
81    L107  GOON;
82          FREE,BLK1;
83          ACT,,,RHO ;
84    L108  GOON;
85          ACT,     .70000;
86          FREE,BLK1;
87          ACT,,,TRM2;
88    BLK2  AWAIT(    3/9999),BLK2;
89          GOON,1;
90          ACT,,ATRIB(2).EQ.    2,L109;
91          ACT,,ATRIB(2).EQ.    4,L110;
92          ACT,,ATRIB(2).EQ.    5,L111;
93          ACT,,ATRIB(2).EQ.    7,L112;
94          ACT,,ATRIB(2).EQ.    9,L113;
95    L109  GOON;
96          ACT,GAMA (    1.23400,    2.34500);
97          FREE,BLK2;
98          ACT,,,BETA;
99    L110  GOON;
100         FREE,BLK2;
101         ACT,,,RHO ;
102   L111  GOON;
103         FREE,BLK2;
104         ACT,,,BETA;
105   L112  GOON;
106         ACT,PNORM(    5.22300,     .16200);
107         FREE,BLK2;
```

```
108             ACT,,,BETA;
109     L113    GOON;
110             FREE,BLK2;
111             ACT,,,TRM3;
112     BETA    AWAIT(    4/   50),BETA;
113             GOON,1;
114             ACT,,ATRIB(2).EQ.    1,L114;
115             ACT,,ATRIB(2).EQ.    2,L115;
116             ACT,,ATRIB(2).EQ.    3,L116;
117             ACT,,ATRIB(2).EQ.    4,L117;
118             ACT,,ATRIB(2).EQ.    5,L118;
119             ACT,,ATRIB(2).EQ.    6,L119;
120             ACT,,ATRIB(2).EQ.    7,L120;
121             ACT,,ATRIB(2).EQ.    8,L121;
122             ACT,,ATRIB(2).EQ.    9,L122;
123     L114    GOON;
124             ACT,TRIAG(    2.00000,    7.00000,    9.00000);
125             GOON;
126             FREE,BETA;
127             ACT,,,DLTA;
128     L115    GOON;
129             FREE,BETA;
130             ACT,,,DLTA;
131     L116    GOON;
132             FREE,BETA;
133             ACT,,,DLTA;
134     L117    GOON;
135             FREE,BETA;
136             ACT,,,DLTA;
137     L118    GOON;
138             FREE,BETA;
139             ACT,,,DLTA;
140     L119    GOON;
141             ACT,NPSSN(     .66700);
142             GOON;
143             ACT,NPSSN(     .66800);
144             FREE,BETA;
145             ACT,,,RHO ;
146     L120    GOON;
147             ACT,TRIAG(    3.56000,    4.00000,    5.00000);
148             GOON;
149             ACT,     .40000;
150             FREE,BETA;
151             ACT,,,DLTA;
152     L121    GOON;
153             ACT,TRIAG(    3.00000,    6.00000,   11.00000);
154             FREE,BETA;
155             ACT,,,TRM3;
156     L122    GOON;
157             FREE,BETA;
158             ACT,,,TRM1;
159     DLTA    AWAIT(    5/   20),DLTA;
160             GOON,1;
161             ACT,,ATRIB(2).EQ.    1,L123;
```

```
162          ACT,,ATRIB(2).EQ.    2,L124;
163          ACT,,ATRIB(2).EQ.    3,L125;
164          ACT,,ATRIB(2).EQ.    4,L126;
165          ACT,,ATRIB(2).EQ.    5,L127;
166          ACT,,ATRIB(2).EQ.    6,L128;
167          ACT,,ATRIB(2).EQ.    7,L129;
168  L123    GOON;
169          ACT,    1.70000;
170          FREE,DLTA;
171          ACT,,,PI   ;
172  L124    GOON;
173          ACT,GAMA (    2.17000,     .95000);
174          GOON;
175          ACT,     .50000;
176          FREE,DLTA;
177          ACT,,,PI   ;
178  L125    GOON;
179          ACT,RLOGN(    1.20000,     .76540);
180          GOON;
181          FREE,DLTA;
182          ACT,,,ZETA;
183  L126    GOON;
184          ACT,GAMA (    1.10000,     .87654);
185          GOON;
186          ACT,    2.30000;
187          FREE,DLTA;
188          ACT,,,TRM3;
189  L127    GOON;
190          ACT,RNORM(    4.67500,    1.30400);
191          FREE,DLTA;
192          ACT,,,RHO  ;
193  L128    GOON;
194          ACT,RNORM(     .38200,     .12500);
195          GOON;
196          ACT,RLOGN(     .54300,     .32100);
197          FREE,DLTA;
198          ACT,,,TRM3;
199  L129    GOON;
200          FREE,DLTA;
201          ACT,,,PI   ;
202  PI      AWAIT(   6/  50),PI   ,BALK(BLK1);
203          GOON,1;
204          ACT,,ATRIB(2).EQ.    1,L130;
205          ACT,,ATRIB(2).EQ.    2,L131;
206          ACT,,ATRIB(2).EQ.    3,L132;
207          ACT,,ATRIB(2).EQ.    4,L133;
208          ACT,,ATRIB(2).EQ.    5,L134;
209          ACT,,ATRIB(2).EQ.    7,L135;
210          ACT,,ATRIB(2).EQ.    9,L136;
211  L130    GOON;
212          ACT,EXPON(     .75000);
213          GOON;
214          ACT,BETA (    3.12000,    6.14000);
215          FREE,PI   ;
```

```
216          ACT,,,TRM1;
217   L131   GOON;
218          ACT,PLOGN(    1.33300,     .88800);
219          FREE,PI   ;
220          ACT,,,RHO ;
221   L132   GOON;
222          ACT,    6.55000;
223          FREE,PI   ;
224          ACT,,,TRM2;
225   L133   GOON;
226          ACT,    9.75000;
227          GOON;
228          ACT,NPSSN(     .22300);
229          FREE,PI   ;
230          ACT,,,GAMA;
231   L134   GOON;
232          ACT,     .00010;
233          GOON;
234          ACT,TRIAG(     .85000,     .88000,     .91000);
235          FREE,PI   ;
236          ACT,,,TRM1;
237   L135   GOON;
238          ACT,EXPON(     .10000);
239          FREE,PI   ;
240          ACT,,,ZETA;
241   L136   GOON;
242          ACT,BETA (     .50000,     .10000);
243          GOON;
244          FREE,PI   ;
245          ACT,,,BETA;
246   RHO    AWAIT(   7/  10),RHO ,BLOCK;
247          GOON,1;
248          ACT,,ATRIB(2).EQ.    1,L137;
249          ACT,,ATRIB(2).EQ.    2,L138;
250          ACT,,ATRIB(2).EQ.    3,L139;
251          ACT,,ATRIB(2).EQ.    4,L140;
252          ACT,,ATRIB(2).EQ.    5,L141;
253          ACT,,ATRIB(2).EQ.    6,L142;
254          ACT,,ATRIB(2).EQ.    7,L143;
255   L137   GOON;
256          ACT,NPSSN(    1.60000);
257          GOON;
258          ACT,EXPON(     .00020);
259          FREE,RHO ;
260          ACT,,,TRM1;
261   L138   GOON;
262          ACT,EXPON(     .23175);
263          GOON;
264          ACT,NPSSN(     .10300);
265          FREE,RHO ;
266          ACT,,,ZETA;
267   L139   GOON;
268          ACT,UNFRM(    2.10000,    3.60000);
269          GOON;
```

```
270           FREE,RHO ;
271           ACT,,,PI  ;
272   L140    GOON;
273           ACT,NPSSN(     .70000);
274           GOON;
275           ACT,EXPON(     .70000);
276           FREE,RHO ;
277           ACT,,,ZETA;
278   L141    GOON;
279           ACT,RLOGN(     .99900,     .88800);
280           FREE,RHO ;
281           ACT,,,ZETA;
282   L142    GOON;
283           ACT,GAMA (     .45000,     .23000);
284           FREE,RHO ;
285           ACT,,,DLTA;
286   L143    GOON;
287           FREE,RHO ;
288           ACT,,,GAMA;
289   ZETA    AWAIT(    8/   30),ZETA;
290           GOON,1;
291           ACT,,ATRIB(2).EQ.    2,L144;
292           ACT,,ATRIB(2).EQ.    3,L145;
293           ACT,,ATRIB(2).EQ.    4,L146;
294           ACT,,ATRIB(2).EQ.    5,L147;
295           ACT,,ATRIB(2).EQ.    6,L148;
296           ACT,,ATRIB(2).EQ.    7,L149;
297   L144    GOON;
298           ACT,RNORM(    2.10000,     .44000);
299           GOON;
300           FREE,ZETA;
301           ACT,,,GAMA;
302   L145    GOON;
303           ACT,BETA (    6.10000,    3.70000);
304           FREE,ZETA;
305           ACT,,,TRM2;
306   L146    GOON;
307           FREE,ZETA;
308           ACT,,,TRM3;
309   L147    GOON;
310           ACT,UNFRM(     .54000,     .62000);
311           GOON;
312           ACT,TRIAG(     .00030,    2.50000,   15.00000);
313           FREE,ZETA;
314           ACT,,,TRM1;
315   L148    GOON;
316           FREE,ZETA;
317           ACT,,,BETA;
318   L149    GOON;
319           ACT,   25.00000;
320           GOON;
321           ACT,    5.00000;
322           FREE,ZETA;
323           ACT,,,TRM2;
```

```
324  GAMA   AWAIT(    9/   15),GAMA,BALK(BLK2);
325         GOON,1;
326         ACT,,ATRIB(2).EQ.    2,L150;
327         ACT,,ATRIB(2).EQ.    4,L151;
328         ACT,,ATRIB(2).EQ.    5,L152;
329         ACT,,ATRIB(2).EQ.    7,L153;
330         ACT,,ATRIB(2).EQ.    9,L154;
331  L150   GOON;
332         ACT,    2.00000;
333         GOON;
334         ACT,    1.10000;
335         FREE,GAMA;
336         ACT,,,TRM1;
337  L151   GOON;
338         FREE,GAMA;
339         ACT,,,ALFA;
340  L152   GOON;
341         ACT,     .00010;
342         GOON;
343         ACT,TRIAG(     .85000,     .88000,     .90000);
344         FREE,GAMA;
345         ACT,,,PI   ;
346  L153   GOON;
347         FREE,GAMA;
348         ACT,,,ZETA;
349  L154   GOON;
350         ACT,UNFRM(    4.20000,    6.50000);
351         GOON;
352         ACT,    1.62100;
353         FREE,GAMA;
354         ACT,,,PI   ;
355  TRM1   COLCT,INT(1),EXIT INTRVL TRM1;
356         TERM;
357  TRM2   COLCT,INT(1),EXIT INTRVL TRM2;
358         TERM;
359  TRM3   COLCT,INT(1),EXIT INTRVL TRM3;
360         TERM;
361         END;
362  INIT,0;
363  FIN;
```

# S L A M  E C H O  R E P O R T

SIMULATION PROJECT SLAM  BY SLAMPP

DATE 9/19/1982  RUN NUMBER 1 OF 1

SLAM VERSION JAN 79

GENERAL OPTIONS

| | |
|---|---|
| PRINT INPUT STATEMENTS (ILIST): | YES |
| PRINT ECHO REPORT (IECHO): | YES |
| EXECUTE SIMULATIONS (IXQT): | YES |
| PRINT INTERMEDIATE RESULTS HEADING (IPIRH): | YES |
| PRINT SUMMARY REPORT (ISMRY): | YES |

LIMITS ON FILES

| | |
|---|---|
| MAXIMUM NUMBER OF USER FILES (MFILS): | 9 |
| MAXIMUM NUMBER OF USER ATTRIBUTES (MATR): | 2 |
| MAXIMUM NUMBER OF CONCURRENT ENTRIES (MNTRY): | 500 |

FILE SUMMARY

| FILE NUMBER | INITIAL ENTRIES | RANKING CRITERION |
|---|---|---|
| 1 | 0 | FIFO |
| 2 | 0 | FIFO |
| 3 | 0 | FIFO |
| 4 | 0 | FIFO |
| 5 | 0 | FIFO |
| 6 | 0 | FIFO |
| 7 | 0 | FIFO |
| 8 | 0 | FIFO |
| 9 | 0 | FIFO |

STATISTICS BASED ON OBSERVATIONS

| COLCT NUMBER | COLLECTION MODE | IDENTIFIER | HISTOGRAM SPECIFICATIONS NCEL | HLOW | HWID |
|---|---|---|---|---|---|
| 1 | NETWORK | EXIT INTRVL TRM 1 | | | |
| 2 | NETWORK | EXIT INTRVL TRM 2 | | | |
| 3 | NETWORK | EXIT INTRVL TRM 3 | | | |

RANDOM NUMBER STREAMS

| STREAM NUMBER | SEED VALUE | REINITIALIZATION OF STREAM |
|---|---|---|
| 1 | 1243978229109 57 | NO |
| 2 | 3467133363389 | NO |
| 3 | 7965446961439 1 | NO |
| 4 | 1841702321368 13 | NO |
| 5 | 2800330299350 85 | NO |
| 6 | 1479595129639 49 | NO |
| 7 | 1258945838548 29 | NO |
| 8 | 1504777756637 25 | NO |
| 9 | 2278747467279 17 | NO |
| 10 | 8217407794622 1 | NO |

INITIALIZATION OPTIONS

BEGINNING TIME OF SIMULATION (TTBEG): 0.
ENDING TIME OF SIMULATION (TTFIN): .1000E+21
STATISTICAL ARRAYS CLEARED (JJCLR): YES
VARIABLES INITIALIZED (JJVAR): YES
FILES INITIALIZED (JJFIL): YES

NSET/QSET STORAGE ALLOCATION

| | |
|---|---|
| DIMENSION OF NSET/QSET (NNSET): | 7000 |
| WORDS ALLOCATED TO FILING SYSTEM: | 3000 |
| WORDS ALLOCATED TO INDEXED LIST TAGS: | 0 |
| WORDS ALLOCATED TO NETWORK: | 3042 |
| WORDS AVAILABLE FOR PLOTS/TABLES: | 958 |

INPUT ERRORS DETECTED: 0

EXECUTION WILL BE ATTEMPTED

# S L A M  S U M M A R Y  R E P O R T

SIMULATION PROJECT SLAM  BY SLAMPP

DATE 9/19/1982  RUN NUMBER 1 OF 1

CURRENT TIME .3235E+04
STATISTICAL ARRAYS CLEARED AT TIME 0.

**STATISTICS FOR VARIABLES BASED ON OBSERVATION**

| | MEAN VALUE | STANDARD DEVIATION | COEFF. OF VARIATION | MINIMUM VALUE | MAXIMUM VALUE | NO.OF OBS |
|---|---|---|---|---|---|---|
| EXIT INTRVL TRM1 | .563E+02 | .158E+03 | .280E+01 | .172E+01 | .113E+04 | 295 |
| EXIT INTRVL TRM2 | .381E+03 | .356E+03 | .934E+00 | .903E+01 | .115E+04 | 74 |
| EXIT INTRVL TRM3 | .119E+03 | .131E+03 | .110E+01 | .938E+01 | .764E+03 | 238 |

**FILE STATISTICS**

| FILE NUMBER | ASSOCIATED NODE TYPE | AVERAGE LENGTH | STANDARD DEVIATION | MAXIMUM LENGTH | CURRENT LENGTH | AVERAGE WAIT TIME |
|---|---|---|---|---|---|---|
| 1 | AWAIT | 0.000 | 0.000 | 1 | 0 | 0.000 |
| 2 | AWAIT | .001 | .045 | 3 | 0 | .113 |
| 3 | AWAIT | 2.991 | 10.750 | 61 | 0 | 92.125 |
| 4 | AWAIT | 9.904 | 17.473 | 50 | 0 | 152.550 |
| 5 | AWAIT | 0.000 | 0.000 | 1 | 0 | 0.000 |
| 6 | AWAIT | 4.399 | 12.353 | 50 | 0 | 28.399 |
| 7 | AWAIT | .181 | 1.249 | 10 | 0 | 6.967 |
| 8 | AWAIT | 9.869 | 13.005 | 30 | 0 | 570.047 |
| 9 | AWAIT | .628 | 2.909 | 15 | 0 | 3.790 |
| 10 | | 4.118 | 3.395 | 19 | 0 | 1.162 |

**RESOURCE STATISTICS**

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT CAPACITY | AVERAGE UTIL | STANDARD DEVIATION | MAXIMUM UTIL | CURRENT UTIL |
|---|---|---|---|---|---|---|
| 1 | ALFA | 1 | .18 | .381 | 1 | 0 |
| 2 | BLK1 | 1 | .00 | .052 | 1 | 0 |
| 3 | BLK2 | 1 | .10 | .298 | 1 | 0 |
| 4 | BETA | 1 | .29 | .451 | 1 | 0 |
| 5 | DLTA | 5 | .05 | .294 | 4 | 0 |

AD-A124 789 TACTICAL AIR CONTROL SYTEM SIMULATION PROGRAM(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING D P MCCANLESS DEC 82 AFIT/GCS/EE/82D-24 2/2

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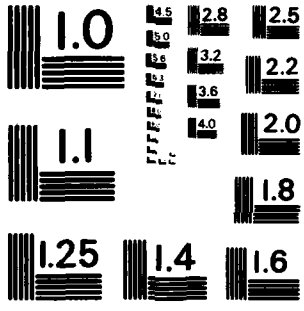

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | PI | 1 | .46 | .498 | 1 | 0 |
| 7 | RHO | 1 | .03 | .179 | 1 | 0 |
| 8 | ZETA | 1 | .39 | .489 | 1 | 0 |
| 9 | GAMA | 2 | .17 | .481 | 2 | 0 |

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT AVAILABLE | AVERAGE AVAILABLE | MINIMUM AVAILABLE | MAXIMUM AVAILABLE |
|---|---|---|---|---|---|
| 1 | ALFA | 1 | .8241 | 0 | 1 |
| 2 | BLK1 | 1 | .9973 | 0 | 1 |
| 3 | BLK2 | 1 | .9016 | 0 | 1 |
| 4 | BETA | 1 | .7149 | 0 | 1 |
| 5 | DLTA | 5 | 4.9460 | 1 | 5 |
| 6 | PI | 1 | .5389 | 0 | 1 |
| 7 | RHO | 1 | .9668 | 0 | 1 |
| 8 | ZETA | 1 | .6066 | 0 | 1 |
| 9 | GAMA | 2 | 1.8349 | 0 | 2 |

# VITA

Donald Paul McCanless was born on 31 March 1954 in San Antonio, Texas. He graduated from Highlands High School in 1972 and attended Trinity University where he received a Bachelor of Science degree in computer science in 1976. Following his commission in the United States Air Force from Officers Training School in August, 1977, he served as a programmer/analyst at Headquarters, Strategic Air Command at Offutt Air Force Base, Nebraska. In May, 1981, he entered the School of Engineering, Air Force Institute of Technology at Wright Patterson Air Force Base, Ohio.

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## REPORT DOCUMENTATION PAGE

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|---|---|
| 1. REPORT NUMBER: AFIT/GCS/EE/82D-24 | 2. GOVT ACCESSION NO.: AD-A124789 |
| 3. RECIPIENT'S CATALOG NUMBER: | |
| 4. TITLE (and Subtitle): TACTICAL AIR CONTROL SYSTEM SIMULATION PROGRAM | 5. TYPE OF REPORT & PERIOD COVERED: MS THESIS |
| | 6. PERFORMING ORG. REPORT NUMBER: |
| 7. AUTHOR(s): Donald P. McCandless, Captain, USAF | 8. CONTRACT OR GRANT NUMBER(s): |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: AIR FORCE INSTITUTE OF TECHNOLOGY DEPARTMENT OF ELECTRICAL ENGINEERING WRIGHT PATTERSON AFB, OH 45433 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: | 12. REPORT DATE: December 1982 |
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LYNN E. WOLAVER
Dean for Research and Professional Development
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4 JAN 1983

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computerized Simulation
SLAM
Communications Networks

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Tactical Air Force Interoperability Group wants to be able to simulate communication networks. The simulation language for alternative modeling (SLAM) was proposed as the basis for the simulation. However, this language requires too much effort to make any changes to the network to be simulated. A Pre-Processor was written in FORTRAN 77 which allows the user to describe the network in a convenient manner, and produces the necessary SLAM source code to perform the simulation.

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