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A Computer Model for Simulation of Message Processing in Military Exercise Control and Evaluation Systems

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by

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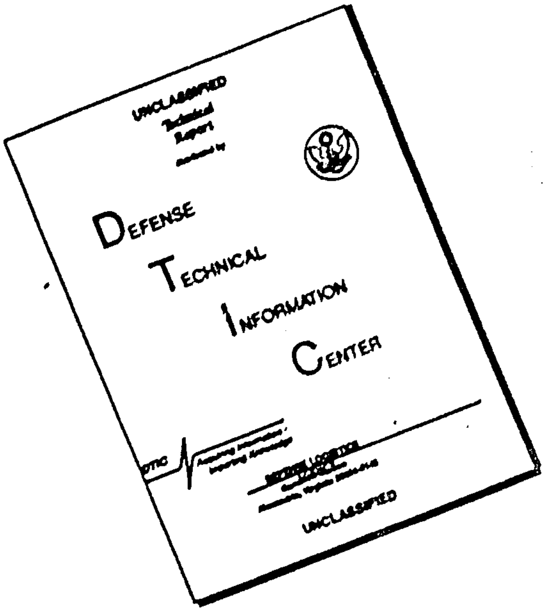

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This report describes a digital computer model, NETMAN, and its implementation for simulating the information processing in a semi-automated system with Army personnel during field exercises, using a computer based message handling system.

The NETMAN model was designed to allow simulation of message processing in a system composed of up to three networks. Each network may be composed of up to nine referees, up to nine radio operators, and one controller. →

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20. One computer is assumed to accommodate the three networks. As such, the model allows simulation and test of the effects on system effectiveness of varying such aspects as: number of referees, number of networks, task procedures, message arrival rate, message length, and operator skill.

The results of the simulation are interpretable in terms of a number of formal effectiveness measures (accuracy, thoroughness, responsiveness, completeness) and an overall effectiveness index. Additionally, the results are interpretable in terms of such model results as work time, stress imposed, message processing time, errors, number of messages processed, and fatigue.

The Appendices contain flowcharts, data item information, individual definitions for each model subroutine, and input-output formats. This information is organized to serve as a user's manual for those who wish to apply the model for simulation.

PREFACE

The computer model, NETMAN, described in the report that follows was developed by Applied Psychological Services, Inc. under contract DAHC 19-76-C-0013. The specific requirements for this effort were established by the Army Research Institute for the Behavioral and Social Sciences (ARI) within a continuing Army training project and in response to the special needs of the Army Combat Arms Training Board and the Training Device Requirements Office, now the Army Training Support Center, Fort Benning, GA.

Field training exercises (FTX) serve an important role in the training of units for the rapid transition from peacetime readiness to wartime effectiveness on the modern, highly lethal, dynamic battlefield. The current manual system[1] for conducting an FTX imposes costly demands on resources during the period necessary to form and train the exercise staff and to plan, conduct, and report on the exercise. In addition, the methods and techniques for maneuver control, casualty/damage assessment, and simulation of combat events are unwieldy and time consuming, degrading the training effectiveness. In order to improve the cost-training effectiveness of conducting an FTX, the Army has initiated a program to develop a computer *assisted exercise control support* system. This report describes a portion of ARI's efforts in support of this development--the development of a computer model, NETMAN, as a tool for analysis, design, and assessment of candidate systems. This development responds to needs which are established in HRN 76-132[2] and HRN 77-27[3].

Based on a general purpose model of information processing systems,[4] this model simulates operations (i.e., staff duties/functions and machine functions) as a joint function of the interactions between the exercise data flow, human information processing, and other sources of variance (e.g., personnel characteristics) to produce predictions of overall system performance. On-line inputs to the program permit simulation of candidate configurations that reflect changes in personnel/machine functions, the equipment/device complement (particularly at the man-machine interface), and level of personnel training for comparison of alternatives (i.e., the ability to ask "what if" questions on-line.

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[1] FM 105-5, Maneuver Control, 31 December 1973.

[2] HRN 76-132, "Improved control systems for field training exercises," submitted by U.S. Army Combat Arms Training Board; MAJ Robert Keivit, user point of contact.

[3] HRN 77-275, "A tool for the assessment of alternative command group training systems," submitted by U.S. Army Training Device Requirements Office; MAJ David Blodgett, user point of contact.

[4] Baker, J. D. Quantitative modeling of human performance in information systems. U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Research Note 232, June 1972.

In addition to an overall measure of performance, the system provides four component measures on-line with detailed printouts available off-line as system status snapshots.

This model capitalizes on earlier work by ARI in support of the U.S. Army's first developmental automated tactical operations system, TOS. The TOS modeling effort was characterized by a twofold interactive approach linking laboratory research and field studies as well as human performance and system performance. As the system design evolved, the need to verify and evaluate the man/machine interfaces and relate their performance to the overall system performance was recognized. The general purpose model was found to be a useful simulation and development tool. This evolution led to three computer versions of the model: batch processing,[5] on-line,[6] and interactive.[7] The interactive version can capture task performance data from operators serving in a simulated system context with an on-line experimenter to record the relevant ancillary activities/events. The resulting data store, when reduced and treated statistically, provides input parameters for the simulation. Additional features introduced during the course of development include a generalized error schema, interface options with a model of communication flow in multichannel systems (CASE), and a model of TOS computer system with ancillary equipment (TOS/SAM).[8]

ARI participation in this development of exercise control systems was initiated in response to a request for technical assistance from the Combined Arms Training Board (CATB). The Training and Doctrine Command (TRADOC) had tasked CATB to evaluate the Tactical Warfare Analysis and Evaluation System (TWAES), developed by the US Marine Corps, for potential use by the Army. TWAES is a computer-based aid to the exercise control staff conceived as an information processing system with design predicated on automation of those staff functions which were time consuming and error prone.

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[5] Siegel, A. I., Wolf, J. J., & Leahy, W. R. A digital simulation model of message handling in the tactical operations system: I. The model, its sensitivity and user's manual. U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Report TR-77-A23, October 1977.

[6] Leahy, W. R., Lautman, M. R., Wolf, J. J. Bearde, J. L., & Siegel, A. I. A digital simulation model of message handling in the tactical operations system: III. Further extension of the model for increased interaction. U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Report TR-77-A25, October 1977.

[7] Siegel A. I., Wolf, J. J., Leahy, W. R., & Bearde, J. L. A digital simulation model of message handling in the tactical operations system: II. Extensions of the model for interactivity with subjects and experimenters. U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Report TR-77-A24, October 1977.

[8] Leahy, W. R., Siegel, A. I., & Wolf, J. J. A digital simulation model of message handling in the tactical operations system: IV. Model integration with CASE and SAMTOS. In press.

The results of the TWAES evaluation supported the introduction of automation as a viable approach to improvement of field exercises but determined that the Army needs would best be satisfied by development of a "fully integrated system for control of field training exercises," to include current and projected advanced technology in engagement simulation, command and control, and training.[9] These findings were derived from the use of TWAES during an Army battalion level Operational Readiness Training Test (ORTT) at Ft. Lewis, Washington, September 1974, employing units of the 9th ID. The data collected included communication records of the exercise staff during the ORTT. This data, when reduced and treated statistically, will provide input parameters to this simulation program which, in turn, will provide the actual system performance--permitting comparison with estimates of a simulated system's performance. In this manner, the computer simulation may be calibrated with actual field operations. Future plans include the validation of the model and use of the simulation to explore alternative system configurations, equipment, procedures and allocation of function/tasks to achieve a design that satisfies the Army needs for development of a "fully integrated," cost-training effective exercise control system.

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[9] U.S. Army Combat Arms Training Board, Evaluation Report: Tactical Warfare Analysis and Evaluation System, December 1974.

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We are also indebted to Dr. Irving Alderman and Mr. James Baker of the U. S. Army Research Institute for the Behavioral and Social Sciences for their valuable advice and assistance in determining the scope, basic approach, and design objectives to which the model was developed.

Arthur I. Siegel
Wm. Rick Leahy
J. Jay Wolf

APPLIED PSYCHOLOGICAL SERVICES, INC.
September 1976

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I. INTRODUCTION AND BACKGROUND

General Overview

This report presents a description of a digital computer model and its implementation for simulating the information processing actions of Army personnel during field exercises using a computer based message handling system. These personnel include up to 27 referees, 27 radio operators, and 3 controllers interacting in a fixed network of communication lines while sharing time on a Central Computing Center (CCC). Messages introduced into the system are input by referee/ radio operator personnel, processed by the CCC, and then delivered to controllers for evaluation. The field exercise is simulated through random message generation based on pertinent values such as message length, type, and arrival time. Each generated message is then processed through a referee→radio operator→CCC→controller network, and processing time is determined along with a number of other descriptive indices.

The model is called NETMAN. During NETMAN's processing of message information, the model places particular emphasis on certain human performance features considered to be important in a field operational system of this sort. These include operator stress, speed, precision, and level of aspiration. In simulating each operator (and the CCC) in the handling of each message, the model requires as input an estimation of time related data for various operator tasks to be accomplished. These tasks include functions such as message scanning, data entry, and table lookup. The work of each operator is analyzed prior to simulation into these tasks and the probable sequence of their occurrence is determined. Data are prepared which provide a pertinent quantitative description of the tasks, and these data are entered into the computer in the form of procedures called task analyses.

NETMAN is programmed in FORTRAN IV for the Univac 1108 system. It is organized to allow the user to conduct various simulation experiments relative to the field exercises. Each computer run of the model represents a simulation of a field session up to 12 hours in duration conducted under conditions as specified by input parameters. Examples of exercise input parameters include the frequency of messages entered to the system, the number of operators, and the speed and aspiration levels of these operators.

The overall man-machine performance measure, effectiveness, is calculated for the simulated exercise and summarized over the total exercise. It is composed of four independent factors--thoroughness, completeness, accuracy, and responsiveness.

Goals of the Model

Output from the model is presented in the form of computer tabulations. These tabulations provide data which promote insight in evaluating alternatives both in terms of absolute and relative value. The printed output is designed and organized so as to provide results that answer questions of practical importance, such as the following:

1. What is the average processing time for a message through the network as a function of the frequency of input messages, operator capabilities, and network configuration?

2. How do changes of input parameters affect predicted total man-machine effectiveness values?

3. What is the loading situation relative to idle vs. busy time for referees, radio operators, the CCC, and the controller?

4. How great a stress is placed on the average operator of each type and what is the fatigue profile over the mission for each type of personnel?

5. Would changes in the task analysis of one or more operators materially affect average processing time and system effectiveness?

6. What are some effects of operator failures under various conditions?

7. How would increased personnel training or improved personnel selection affect system performance?

The program presents detailed message processing listings, if desired, as well as hourly summary and run summary outputs. The detailed message processing output shows the fine grain of the results of the simulation of each task in the processing of messages.

The hourly summary presents a consolidation of the results of a simulated hour's work across all iterations and includes items such as: number of messages completed, time spent working, end of hour stress level, performance and aspiration, time spent performing various processes, and average time per message.

The simulation run summary, produced after N iterations of the exercise, includes manpower utilization, message processing times, effectiveness indicators, and workload summary information.

Prior Message Processing Models

The NETMAN model represents a new model and computer program. Yet, many of the approaches and techniques are taken from, or are extensions of, a prior (operational) model, developed by Applied Psychological Services in collaboration with the U. S Army Research Institute for the Behavioral and Social Sciences, for simulating the U. S. Army's Tactical Operations System (TOS). The earlier model, called MANMOD, simulates the behavior and performance of up to six men who function as action officers and input-output device operators in the TOS system. These men perform tasks similar to those simulated in NETMAN and which were also organized for computer processing into task analysis tables. The mechanism for task-by-task performance evaluation in MANMOD is basically the same as is used in NETMAN.

MANMOD was originally designed for batch run processing in FORTRAN IV on the CDC 3300 computer. In this form, original sensitivity runs were followed by validation runs. In the validation, a high degree of correspondence was found between the model's output and a set of error data collected from an independent source.

In a follow-on effort, the MANMOD model was modified to operate in an interactive time-sharing mode. This feature allows the experimenter (mission analyst) to interact in a "conversational" mode with the model and to enter data "on line." This interaction is performed through a terminal and greatly increases the ease with which simulations can be performed. NETMAN possesses the same interactive capabilities.

A variant of the MANMOD was also developed which allowed collection of data during an experiment in which one or more actual operators performed a part of the process and the computer simulated the remainder of the TOS activity.

More recently, MANMOD was adapted for the Univac 1108 computer and several new capabilities were added which increase the realism of the simulation. It was modified to exchange data with two other independent computer models in such a way as to maximize the strong points of each of the models.

The above efforts are the subjects of the following technical reports: Siegel, Wolf, and Leahy (1973); Siegel, Wolf, Leahy, Bearde, and Baker (1973); Leahy, Lautman, Bearde, and Siegel (1974); and Leahy, Siegel, and Wolf (1975).

Other areas of similarity between MANMOD and NETMAN are:

1. the message generation technique is similar.
2. the operator performance and aspiration determination technique is the same.
3. some of the parameters and two of the four effectiveness factors are the same.
4. the basic nature of both models is stochastic. As a result, a number of repetitions is required to produce a stable result.
5. both models provide lists of inputs, optional detailed output, hourly summaries, and run summaries.

Scope of This Report

The primary features of the NETMAN model are presented in narrative and summary flow logic form in the next chapter. This includes a graphic presentation and description of the field communications network simulated and the procedures implemented in the model.

Chapter III shows the results of the computer runs made to determine the acceptability of the sensitivity of model outputs based on input variation. Both magnitude and direction of output are analyzed for reasonableness in selected categories of input changes for operator skill levels and message sizes.

The last chapter discusses the developed model and its use.

The Appendices contain flowcharts, data item information, individual definitions for each model subroutine, and input-output formats. This information is organized so as to serve the function of a user's manual for those who wish to apply the model for simulation.

II. THE SYSTEM SIMULATED AND THE NETMAN MODEL

Message Processing Flow

The field exercise situation simulated may be viewed as a message processing network configured as shown in Figure 2-1. This figure symbolically displays 27 simulated referees (R_1 through R_{27}) receiving simulated symbolic input messages from independent sources as well as from one of three simulated controllers (CON 1, CON 2, or CON 3). Messages are indicated by the symbol ∿.

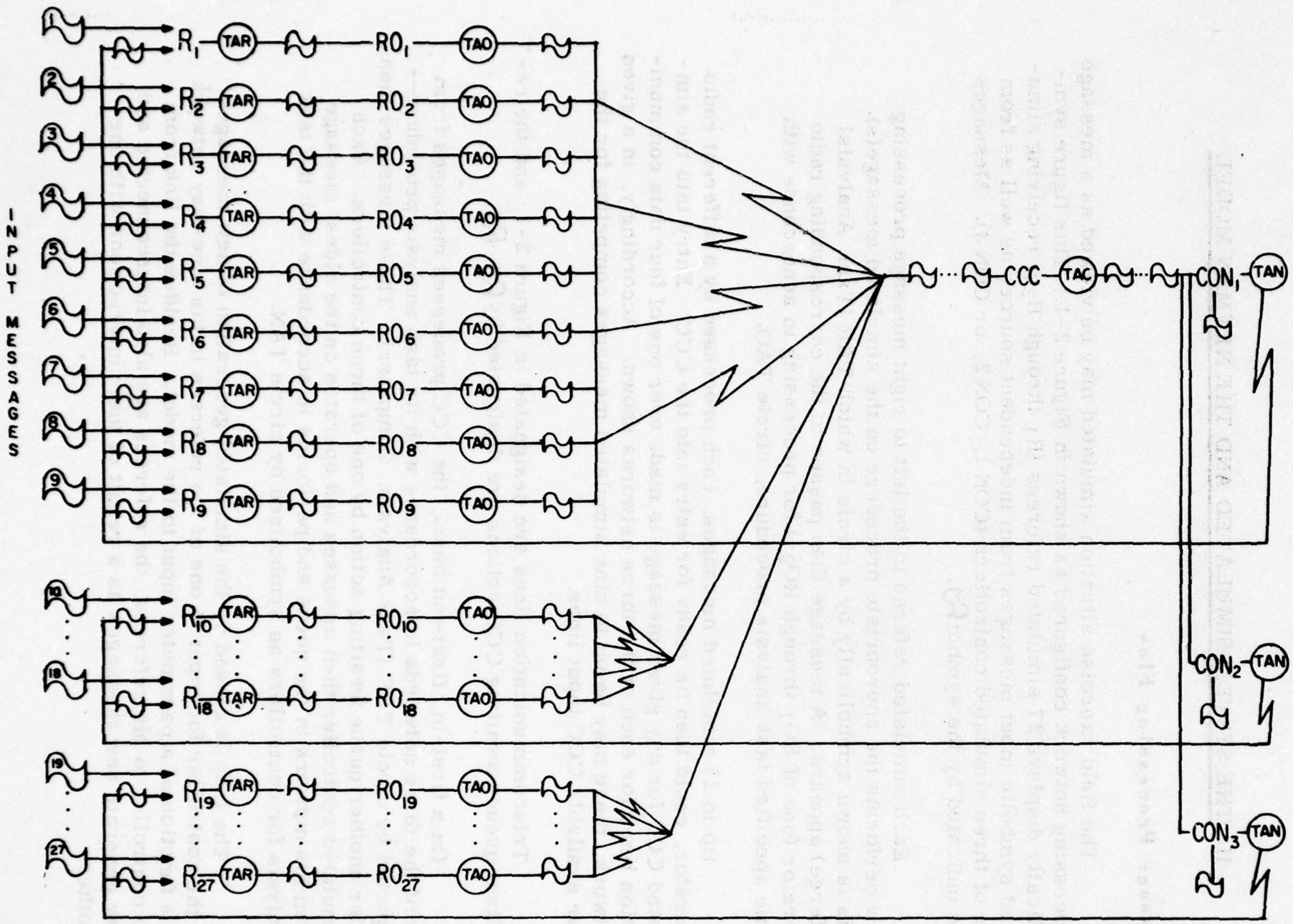
Each simulated referee in the left to right message processing flow performs the appropriate procedure on the simulated message(s). This is shown symbolically by a circle in which TAR (Task Analysis) Referee) appears. A message then passes to the corresponding radio operator (one of RO_1 through RO_{27}) for processing in accordance with some specified task analysis procedure, circle TAO.

Up to 27 simulated messages, each processed by a different radio operator, could then be ready for entry into the CCC. Entry into the simulated CCC for any given message is made over one of four data communication lines for each of the three networks shown. Accordingly, in a given network, there may be up to nine simulated messages competing for the four available CCC input lines.

Telecommunication lines are designated in Figure 2-1, and the resultant queues awaiting CCC actions are designated by ∿···∿.

On a first-in, first-out basis, the CCC processes messages from all of the three networds in accordance with its task analysis procedure--depicted by circle TAC (Task Analysis, Computer). These messages then enter another queue awaiting action by one of three controllers. Each simulated controller then assesses and operates on the oldest message from his network in the queue and performs in accordance with the task analysis for controllers as symbolized by circle TAN.

The loop is closed by the simulated generation of new messages by the controller for input to one of the referees in his nine-way network as a function of a parameter input to the model. Besides the link from the controller to his referees, the referees are also interconnected and may generate new messages as a result of their interactions with one another.



TAR = TASK ANALYSIS, REFEREE; TAO = TASK ANALYSIS, RADIO OPERATOR; TAC = TASK ANALYSIS, COMPUTER
TAN = TASK ANALYSIS, CONTROLLER

FIGURE 2-1. SCHEMATIC OF MESSAGE PROCESSING FLOW

The descriptions of the task element-by-task element process comprising the TAR, TAO, TAC, and TAN are contained in the Appendix.

The simulation continues until the number of messages processed by the controllers, LDONE, exceeds the input desired value, ICHAIN.

The basic range of capabilities of the model is presented in the list of principal model subscripts shown in Table 2-1. Table 2-1 indicates that:

- each message introduced into the system is given a sequence number, CMSG, which is retained as the message is processed and transfered between operators
- up to K = 8 task analyses (procedure list data) may be developed and stored as input for reference. Any task analysis may be assigned to any of the JMAX = 4 levels (R, RO, CON, CCC)
- each task analysis may consist of up to NTE = 10 task elements
- personnel limits are up to 27 = NETREF referees, up to 27 = IRO radio operators, and up to 3 = ICON controllers. Up to 9 referees per controller are provided for.
- a mission may be of up to IH = 12 hours duration
- there are up to NET = 3 networks
- the number of message types described is up to 7 = MAXIT
- a computer run consists of NSHIFT iterations of each mission
- computer and radio communication, as shown in Figure 2-1, is included; two-way communication simulation is partially possible

Table 2-1

Principal Model Subscripts

Subscript Name	*Application*	*Range of Values*	*Maximum Value*
CMSG	Message number	1-2000	-
I	Task element	1-10	-
K	Task analysis number	1-8	-
IREF	Referee number	1-27	MEN(1)
IRO	Radio operator	1-27	MEN(2)
ICON	Controller	1-3	MEN(4)
IH	Hour Number	1-8	IHMAX
NET	Network number	1-3	MAXNET
NEC	Effectiveness component	1-4	-
	1 - Thoroughness		
	2 - Completeness		
	3 - Responsiveness		
	4 - Accuracy		
IP	Priority number	1-5	-
II	Data items comprising message	1-10	-
J	Level	1-4	JMAX
	1 - Referee		
	2 - Radio operator		
	3 - CCC		
	4 - Controller		
M	Number men/machines	1-59	MEN(1) + MEN(2) + 1 + MEN(4)
IE	Error type	1-4	IEMAX

Procedure for Simulation

The NETMAN model simulates the message routing and processing procedure by implementing the following sequence of operations and procedures:

1. At the start of the simulation, the characteristics representing a number of messages sufficient to satisfy all requirements for the mission are calculated, sorted into order of time of arrival, and stored. Each message is tagged with a
   - message number
   - time of arrival
   - priority
   - type
   - length-referee/radio operator (no. of characters)
   - length-controller
   - origin
2. The messages with earliest arrival times are assigned to the referees. These are processed (simulated) by the Rs, and then the ROs in accordance with the task analyses assigned in input data IATA (IT, J)[see Appendix].
3. The resultant messages are then to be processed by the CCC. Their times of arrival at the CCC are determined by adding a stochastically determined delay as a function of the mean delay due to the lines to the CCC being busy (TRDEL).
4. The messages are then accepted by the appropriate controller. This rate of acceptance is a function of the controller's capability to accept inputs and the characteristics (length) of the messages involved.
5. The controller originates new messages with a probability equal to ORIG (1,IH) as given in input data.

This sequence is repeated for each batch of 27 messages to be processed until all messages have been processed. This completes a single exercise iteration. The entire process is repeated NSHIFT times representing the number of mission iterations which make up a NETMAN computer run.

Overview of the Simulation Model

In order to implement the processing sequence, as described, the NETMAN model was designed as a series of subroutines, each performing a unique function. Figure 2-2 presents a macro flow chart of the entire model. Figure 2-2 shows the relationship between the procedure sequences of the model and the subroutines. A complete list of all subroutines, together with a brief comment on the function of each, is given in Table 2-2. Note that some subroutines call other subroutines. For example, MESGEN calls MTYPE, POIS, and all other subroutines in the Msg Generation column of Table 2-2. The main flow of computation is determined by the principal program, MAIN, which controls the sequencing between the major subroutine blocks shown in Figure 2-2. More detailed descriptions of each subroutine are presented in the Appendix.

Following the read in of input data, the data are automatically recorded in the print file.

Separate data sets were specified in designing the model to allow the mission analyst (model user) to make a variety of simulation runs by selection of appropriate data input for variation.

On-Line Experimenter Control

If experimenter control is specified [ORO(7) = 1], then the user of NETMAN will have certain capability to modify and control the simulation model input data from an interactive display and/or typewriter terminal. In response to queries from the computer, the experimenter can select input data categories one at a time and then designate specific numeric values for many input parameters prior to a simulation run. Input data are identified, and the procedure for experimenter operation is specified in the Appendix.

Message Generation and Representation

Independent message queues are generated for each referee, IQONE (MSGT, IREF, NET), where MSGT or the total number of messages to a given referee during the simulation may not exceed 200. These messages are generated as a function of IGP(IH), and IGR(IH), the input mean and standard deviation of the *number* of stimulus messages arriving at each referee's station. Each stimulus message produces one or more network messages as a stochastic function of the input value of RMPS(IT). Message characteristics (length, type, arrival time, etc.) are generated for each message before the beginning of each iteration of the simulation.

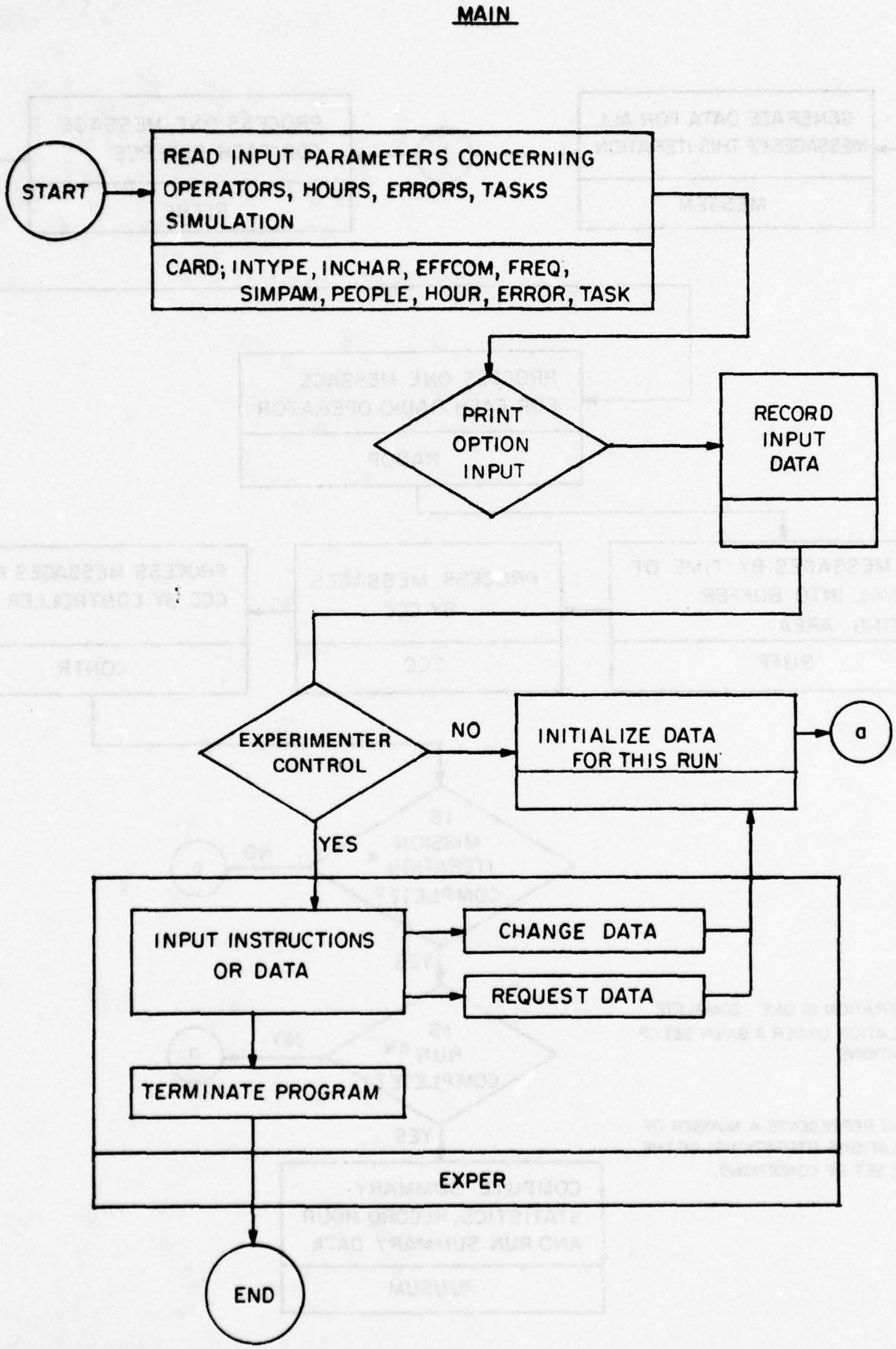
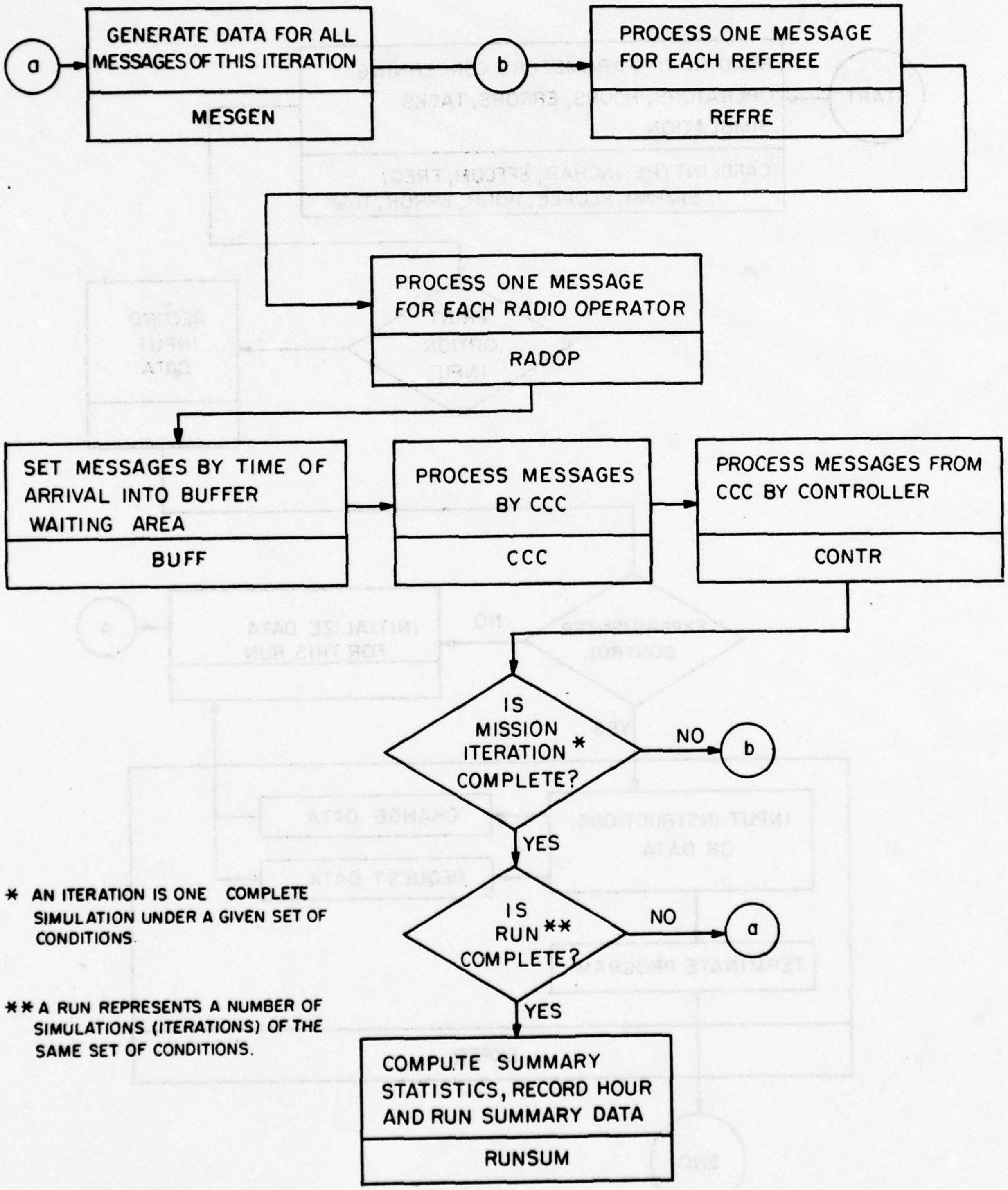


FIGURE 2-2. MACRO FLOWCHART OF NETMAN MODEL



* AN ITERATION IS ONE COMPLETE SIMULATION UNDER A GIVEN SET OF CONDITIONS.

** A RUN REPRESENTS A NUMBER OF SIMULATIONS (ITERATIONS) OF THE SAME SET OF CONDITIONS.

Table 2-2
List of NETMAN Subroutines

Subroutine	*Comment*	INPUT	OUTPUT	MSG. GENERATION	REFEREE SIMULATION	RADIO OPERATOR SIMULATION	CCC SIMULATION	CONTROLLER SIMULATION
SIMPAM	Read simulation parameters	x	x					
PEOPLE	Read operator parameters	x	x					
HOUR	Read hour parameters	x	x					
ERROR	Read error data	x	x					
TASK	Read task data	x	x					
EXPER	Communicate with experimenter	x	x					
MESGEN	Generate all messages			x				
RESET	Set up message initial conditions							
MTYPE	Determine message type			x				
POIS	Determine no. of messages produced by stimulus message			x				
MPRIOR	Determine priority of message			x				
ORIG	Determine message origin			x				
DIGIT	Determine message length for RO			x				
CONMSG	Determine message length for controller			x				
MTARIV	Determine message arrival time			x				
SORT	Sort messages by time of arrival			x				
REFRE	Process referees				x			
STRESS	Compute operator stress				x	x		x
ASPIRE	Compute operator aspiration				x	x		x
FATIGU	Compute operator fatigue				x	x		x
PROC	Simulate message processing				x	x	x	x
RADOP	Process radio operators	x				x		
BUFF	Store messages into buffer area						x	
CONTR	Simulate controller							x
RUNSUM	Compute run summary statistics		x					
INIT	Initialization of variables at start of run							
CCC	Process computer messages						x	
RANDU	Calculate uniform random number (0 - 1)			x	x	x	x	x
RANDN	Calculate distribution of random number			x	x	x	x	x
INTYPE	Read message type data	x	x					
INCHAR	Read message length	x	x					
EFFCOM	Read effectiveness component data	x	x					
FREQ	Read transmission delay data	x	x					

Each message, as it is generated, is assigned a unique number, CMSG, and this number is used to assess the message characteristics, MSGCHR (CMSG, 9) as the message passes from one level to another through the system.

Messages are represented in the model by a series of the seven descriptors:

1. cumulative message number--a unique number assigned to each message in order starting with 1. For each new message: CMSG = CMSG + 1.

2. message priority--an integer (1 to 5) determined by generating a pseudo random number equally probable in the range 0 to 1 (RY) and comparing its value against the five values of FREP(IP, IH)--cumulative proportion of the five types of message priorities given in input. The value of priority assigned is the smallest value of the five priorities, IP, for which $RY \leq FREP(IP, IH)$. The priority value does not affect the simulation.

3. a code indicating one of seven message types assigned similarly to priorities. Here, the type is assigned to be the smallest value for which a new $RY \leq FRET(IT, IH)$, where FRET(IT, IH) provided as input, indicates the cumulative proportion of messages by the seven types of messages, IT.

4. the length of the message for the referee/radio operator--a function of the average number of characters in that type of message, INC(IT), and the standard deviation around that average INS(IT), both input. To accomplish this, a random deviate, RD (mean 0, sigma 1), is calculated by the RANDN routine and used in the equation:

$$ILEN = INC(IT) + RD \cdot INS(IT)$$

5. the length of the message to the controller is determined through the equation:

$$ILEN = CHRCON(IT) + RD \cdot CHSCON(IT)$$

where CHRCON(IT) is the mean length and CHSCON(IT) is the standard deviation.

6. the time of arrival of the message as determined by a stochastic process, where all times during the arrival hour are equiprobable.

7. for each hour, ORIG(IOR, IH), the message origin generated to represent the source at each level of processing:

IOR = 1 for controller
IOR = 2 for other referee
IOR = 3 for current referee

In the field, it is not uncommon that a message received by a referee will in fact generate more than one network message, each of which must be processed by the operational personnel on duty. Incorporation of this feature yields improved realism and allows the system analyst to determine the effect of the ratio (number of generated to input messages) on system performance efficiency.

To accomplish this, the input data, RMPS(IT) specifies the average number of messages entered into the system as a result of input stimulus messages of each type. The program accepts these inputs and calculates for each input stimulus message a value from a Poisson distribution to represent the actual number of messages to be processed as a result of the single input stimulus of type IT: RP[RMPS(IT)]. The message generation subroutine is then adjusted to generate that integer number of messages for processing. Each resulting message is assigned the same time of arrival, as calculated by MESGEN, although the other message characteristics (priority, type, length) are calculated independently. Each stimulus message will always generate at least one network message.

During the MESGEN subroutine, a total of up to 5400 messages may be generated. These messages are then sorted in order by time of arrival for each referee, and the model then is ready to initiate message processing for an iteration.

Message Processing

The processing of a single message by each referee and radio operator is similar in that each processing involves the determination of:

	subroutine
operator stress	STRESS
operator aspiration and performance	ASPIRE
operator fatigue	FATIGU
execution time and success/failure	PROC

Stress

The stress function is based on the concept that operator anxiety is a function inversely related to the amount of idle time he has in processing his message workload. The same functional relationship is applied to any operator--referee, radio operator, or controller--but not, of course, to the CCC. Stress is operationally defined for operator M as STR(J), which assumes a value of unity for operators who feel no anxiety sufficient to affect performance. This condition applies to all operators who are idle one-third of the time or more. The stress increases linearly with additional workload until it reaches a maximum value called the stress threshold, STRM(J), whenever the operator has on the average only three minutes per hour of idle time. These situations are shown as a function of per cent time worked, PTW, together with the formulas, in Figure 2-3.

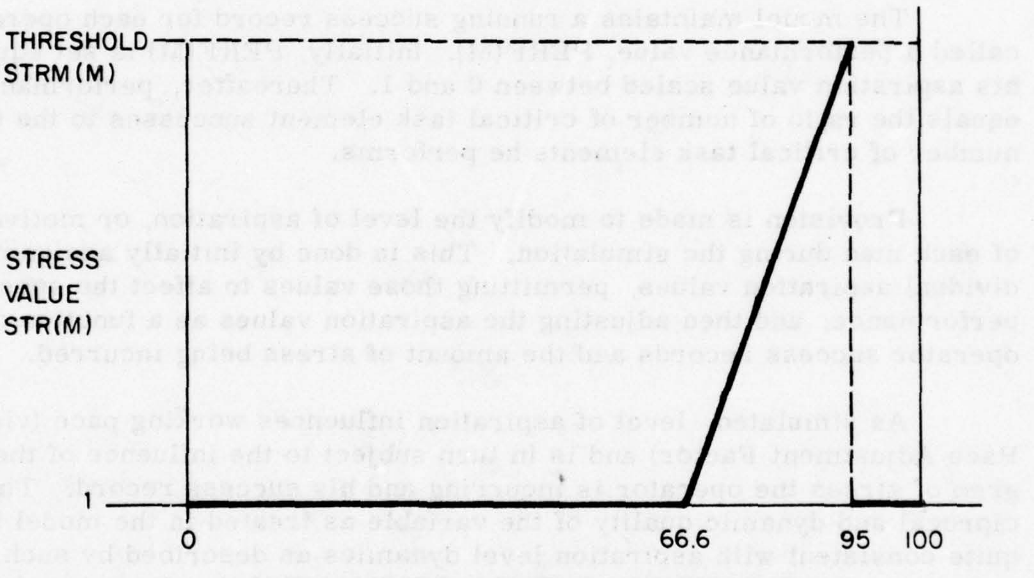
PTW, in the case of the controller, is calculated on the basis of mean message arrival rate during the hour, mean time to process a message, and a random deviate.

Using this stress calculation, a normalized stress factor, SF, is calculated for use in performance time determination:

$$SF = \frac{STR(J) - 1}{STRM(J) - 1}$$

This stress calculation is initiated only after the first half hour of simulation. During the first half hour, the no stress case is assumed. In practice, a stress threshold of 2.3 has been found to represent the "average" case. Stress thresholds from 2.1 to 2.7 may be selected.

MINUTES PER HOUR IDLE	PERCENT TIME WORKED	STRESS VALUE
0	100	1
3	95	THRESHOLD
20	67	1
60	0	1



$$
STR(J) = \begin{cases} 1 & PTW > 95 \\ 1 & PTW < 66.6 \\ 3.39 - 2.39\ STRM(J) - \left(\dfrac{1 - STRM(J)}{0.28} \right) PTW & 66.6 < PTW < 95 \end{cases}
$$

CONDITION

FIGURE 2-3. NETMAN STRESS FUNCTION

Aspiration

Values for the aspiration of each operator level are calculated stochastically after the initialization process for each run based upon the single operator input parameter, ASP(J). Values for J = 3, the CCC, are obviously not used.

Aspiration level for each operator represents the task success record that the operator would hope to attain, where success record is defined as the ratio of the number of task element successes to number of attempts. Thus, an operator with an aspiration value of 1.00 would aspire to succeed in every one of his task attempts, while an operator with an aspiration value of 0.50 would have lower motivation and would be viewed as considering a rate of one successful attempt in two as acceptable. Levels of aspiration from 0.90 to 0.99 have been found to be appropriate, where 1.0 represents striving for absolute perfection.

The model maintains a running success record for each operator, called a performance value, PERF(M). Initially, PERF(M) is set equal to his aspiration value scaled between 0 and 1. Thereafter, performance equals the ratio of number of critical task element successes to the total number of critical task elements he performs.

Provision is made to modify the level of aspiration, or motivation, of each man during the simulation. This is done by initially assigning individual aspiration values, permitting those values to affect the speed of performance, and then adjusting the aspiration values as a function of operator success records and the amount of stress being incurred.

As simulated, level of aspiration influences working pace (via a Pace Adjustment Factor) and is in turn subject to the influence of the degree of stress the operator is incurring and his success record. The reciprocal and dynamic quality of the variable as treated in the model is quite consistent with aspiration level dynamics as described by such writers as Lewin (1942) and Kelley and Thibaut (1954). Considered are: (a) the operator's goal discrepancy--the difference between the aspired success record and the actual record, and (b) the difference between current stress on the operator and the operator's stress threshold. Comparison of the goal discrepancy with the stress differential provides the basis for the reciprocal influences involving level of aspiration. Four discrete circumstances can exist.

Case 0	Zero or near zero goal discrepancy
Case 1	Positive goal discrepancy (i. e., aspiration in excess of actual performance recorded and subliminal stress)
Case 2	Negative goal discrepancy and subliminal stress
Case 3	Positive goal discrepancy and stress equal to or greater than threshold
Case 4	Negative goal discrepancy and stress equal to or greater than threshold

Case 1 presents a circumstance which will be recognized as predisposing positive motivational value--the operator is not performing as well as he would like to, yet he is only mildly stressed, if at all. The psychological expectation is that he would strive to perform better, and the model effects this by generating a Pace Adjustment Factor, (PAFA), less than unity, which will later have the effect of simulating his working faster. Figure 2-4 shows this effect.

Case 2 further illustrates the dynamic aspect of level of aspiration, both as occurring in life and as simulated in the model. Presented is a negative goal discrepancy, which means that performance exceeds operator aspiration, and stress is still of only modest magnitude. Psychological theory (e. g., Deutsch, 1954) indicates that under these conditions, the operator would "raise his sights" and aspire to do more, since he demonstrated to himself that he has easily attained the initial level. In this regard, Krech and Crutchfield (1948) wrote:

> ...a successful individual typically sets his next goal somewhat, but not too much, above his last achievement. In this way he steadily raises his level of aspiration. Although in the long run he is guided by his ideal goal, ..., nevertheless his real goal...is kept realistically close to his present position.

This process is simulated in the model according to a Monte Carlo procedure, in which aspiration is increased and the Pace Adjustment Factor is set equal to 1.

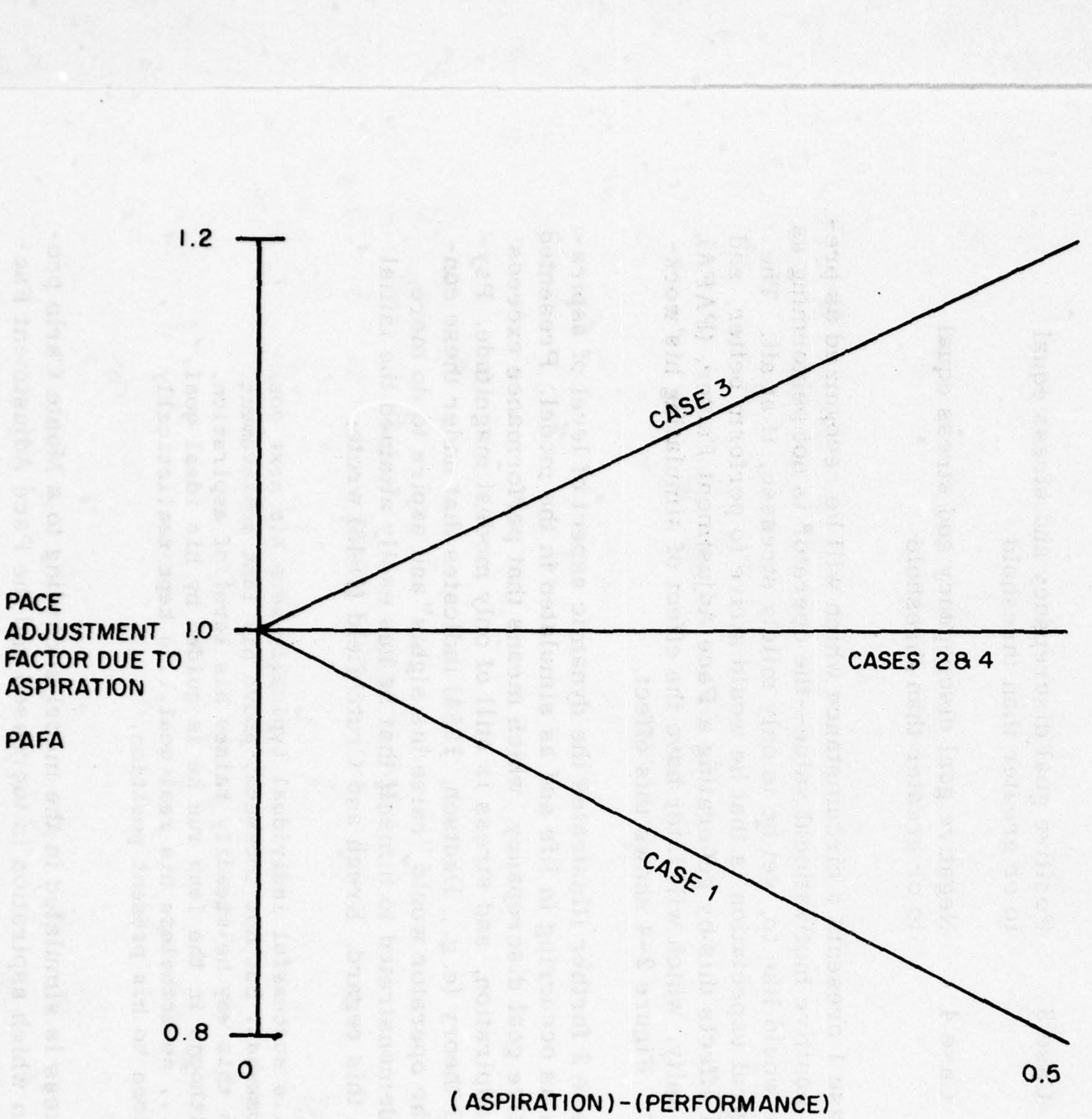


FIGURE 2-4. PACE ADJUSTMENT FACTOR AS A FUNCTION OF ASPIRATION AND PERFORMANCE

Case 3 presents a circumstance of resignation. The operator is not performing as well as he would like, but is incurring stress equal to his threshold. Because of the stress, he has no choice but to accept his current performance level. The model effects this by reducing the aspiration value so that it equals the performance record. The simulated operator has ceased his upward striving and avoids the severe stress by accepting his current performance. However, associated with the cessation of upward striving, with the "edge" off the individual's motivation, one might expect to observe the beginnings of a partly voluntary and partly involuntary deterioration in performance. This effect is simulated in the model by generating PAFA > 1, which will later have the effect of slowing down the rate at which the operator performs his tasks (see Figure 2-4).

In Case 4, current stress is altered. Specifically, Case 4 presents the circumstances of performance exceeding operator aspiration, but stress being substantial. That is, the operator is incurring severe stress, despite the fact that he has attained the level of performance he set for himself. It seems reasonable that, as he reviews his success record, he stops "sweating it" quite so desperately for he has demonstrated that he can attain his aspiration level. In the model, this is simulated by reducing the operator's current stress to a value 18 per cent below the stress threshold.

Fatigue

Provision is made in the model to simulate fatigue stress via the FATIGUE subroutine. The implementation of this variable in the model is based upon a study of fatigue in air traffic controllers (Grandjean, Wotzka, Schaad, & Gilgen, 1970), in which a number of measures were taken over a 10 hour work period. In this study, 68 air traffic controllers were tested on critical fusion frequency, a tapping test, and a grid tapping test. These tests were administered nine times within 24 hours over a three week period. The results are shown in Figure 2-5. The tapping data (equally weighting the two tapping tests) were converted to a percentage of baseline plot and are shown as the heavy line in Figure 2-6. As can be seen, the trend is a very slow dropoff up to six hours after starting work, followed by a more abrupt dropoff. Although the available data only extend through a 10 hour period, the extreme linearity of the data allow some degree of confidence in extrapolation through 12 hours.

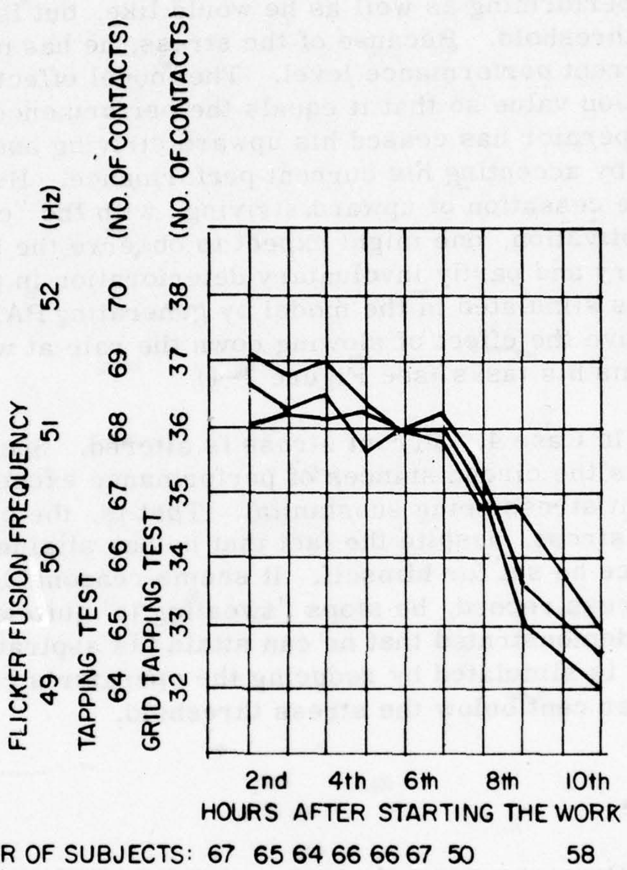


FIGURE 2-5. MEAN VALUES OF CRITICAL FUSION FREQUENCY, OF A TAPPING AND OF A GRID TAPPING TEST IN RELATION TO HOURS AFTER STARTING WORK (FROM GRANDJEAN ET AL., 1970)

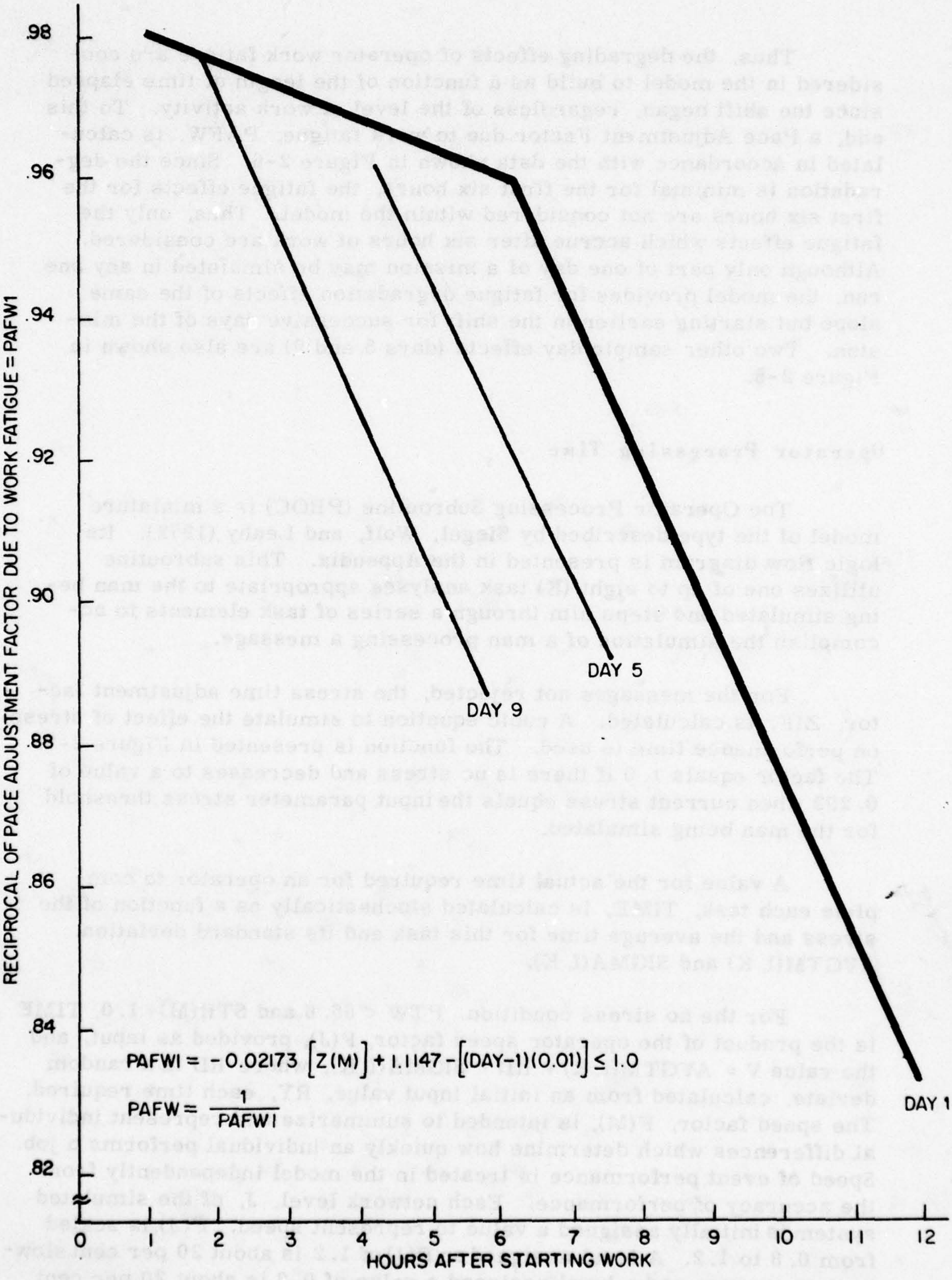


FIGURE 2-6. WORK FATIGUE FUNCTION

Thus, the degrading effects of operator work fatigue are considered in the model to build as a function of the length of time elapsed since the shift began, regardless of the level of work activity. To this end, a Pace Adjustment Factor due to work fatigue, PAFW, is calculated in accordance with the data shown in Figure 2-6. Since the degradation is minimal for the first six hours, the fatigue effects for the first six hours are not considered within the model. Thus, only the fatigue effects which accrue after six hours of work are considered. Although only part of one day of a mission may be simulated in any one run, the model provides for fatigue degradation effects of the same slope but starting earlier in the shift for successive days of the mission. Two other sample day effects (days 5 and 9) are also shown in Figure 2-6.

Operator Processing Time

The Operator Processing Subroutine (PROC) is a miniature model of the type described by Siegel, Wolf, and Leahy (1972). Its logic flow diagram is presented in the Appendix. This subroutine utilizes one of up to eight (K) task analyses appropriate to the man being simulated and steps him through a series of task elements to accomplish the simulation of a man processing a message.

For the messages not rejected, the stress time adjustment factor, ZIF, is calculated. A cubic equation to simulate the effect of stress on performance time is used. The function is presented in Figure 2-7. The factor equals 1.0 if there is no stress and decreases to a value of 0.292 when current stress equals the input parameter stress threshold for the man being simulated.

A value for the actual time required for an operator to complete each task, TIME, is calculated stochastically as a function of the stress and the average time for this task and its standard deviation, AVGTM(I, K) and SIGMA(I, K).

For the no stress condition, $PTW < 66.6$ and $STR(M) = 1.0$, TIME is the product of the operator speed factor, F(J), provided as input, and the value $V = AVGTM(I, K) + RD \cdot SIGMA(I, K)$, where RD is a random deviate, calculated from an initial input value, RY, each time required. The speed factor, F(M), is intended to summarize and represent individual differences which determine how quickly an individual performs a job. Speed of event performance is treated in the model independently from the accuracy of performance. Each network level, J, of the simulated system is initially assigned a value to represent speed. F(J) is scaled from 0.8 to 1.2. A level assigned an F(J) of 1.2 is about 20 per cent slower than average and a level assigned a value of 0.8 is about 20 per cent faster than average.

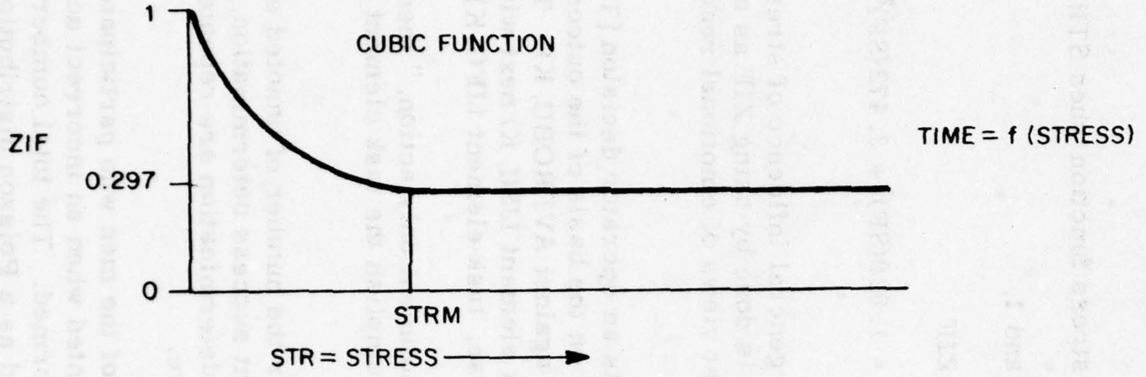


FIGURE 2-7. TIME ADJUSTMENT FACTOR DUE TO STRESS

For the case in which stress equals the threshold $95 < PTW < 100$,

$$TIME = \frac{F(J) \cdot V}{0.292}$$

based on the evaluation of the cubic stress function when $STR(M) = STRM(M)$.

When stress falls between 0 and 1,

$$TIME = F(J) \cdot V \cdot ZIF$$

where the cubic stress function $ZIF = 1.829(SF)^3 + 3.472(SF)^2 - 2.351(SF) + 1$, shown in Figure 2-7.

Thus, in the simulation, the general influence of stress is to increase the operator's working pace. (This is done by using ZIF as a multiplicative factor.) This is consistent with most views of emotional reactions as gearing the individual for overt activity.

If the task element represents an operator decision [TYPE(I, K) = 3], the next task element I is calculated on the basis of the outcome of comparing a pseudo random number RY against AVPROB(I, K). The two-way decision has the effect of taking task element IJS(I, K) next with probability equal to AVPROB(I, K). Otherwise, task element IJF(I, K) is selected.

If the task element is an "equipment only action," then the elapsed time that the equipment takes to accomplish the task element is calculated without any effect of stress.

The following calculations for the number of unnoted errors, task element execution time, task element success determination, bookkeeping for time, and next task element determination are repeated for each task element in the selected sequence.

Errors may be made by any of the men who participate in the mission simulated. Errors are counted when an incorrect act is not noticed or corrected when it is performed. The total number of these unnoted errors, TNUE, is calculated as a Poisson distribution function with mean equal to the product of the error rate per character, the length of the message, and the operator accuracy (precision) for the task element representing the transform operation, as follows:

$$\mathrm{TNUE} = \sum_{\mathrm{IT}} \mathrm{RP}[\mathrm{ER}(\mathrm{IE}, \mathrm{IT}) \frac{\mathrm{ILEN}}{100}]\, \mathrm{PREC}(\mathrm{J})$$

where:

TNUE = total number of undetected errors
RP = Poisson distributed variable
ER = error rate
ILEN = no. of characters in the message
PREC(J) = operator precision

All other task elements will either generate one unnoted error or no errors, depending on the undetected error probability (task analysis input) and the operator precision (operator parameter).

There are two Pace Adjustment Factors which generate an influence on performance time. The effect of fatigue is accomplished using PAFW, as shown in Figure 2-6. The factor for aspiration, PAFA, has no effect in aspiration cases 0, 2, and 4; its effect in cases 1 and 3 is presented in Figure 2-4. The simulated performance time for the task element is then the product of V with the other factors F(J), PAFW, and PAFA.

In cases for which the average execution time represents a per-character time (i. e., if the task element is one for which JTYPE (I, K) = 2), then the total time of the task element as determined is multiplied by the number of characters in the message.

As each task element is completed, a determination is made as to whether one of the basic time segments of message processing has been completed. Up to 20 time segments* may be accumulated and then summarized in the RUNSUM subroutine. The segment being ended is indicated in the input data in END(I, K).

Task Element Success Probability

Next, the success or failure of the task element is determined as a function of the input task element average probability of success, AVPROB(I, K), the current stress value, the stress threshold, and precision.

---

* A segment is any point in a task analysis relative to which the user wishes to collect data.

First, the average success probability input value is operated on by the current value of operator precision (an input parameter), as shown in Figure 2-8. This figure shows how the AVPROB(I, K) value is adjusted from one shown on the Y axis (as input to the model) to a new value as shown on the X axis as a function of the value of PREC(J). Sample PREC(J) values are shown. Note that no change takes place if PREC(J) equals 1. A degradation of success probability results for values of PREC(J) greater than 1. 0. The opposite effect is achieved for lower PREC(J) values, and all task elements will succeed with certainty if PREC(J) equals or is less than 0. 8. Note that in the model operator precision and speed are completely independent input parameters.

The result of this adjustment is used in success determination, as shown in Figure 2-9. If stress is relatively small (i. e., less than one-half of the threshold value), or if the current aspiration is less than the adjusted AVPROB(I, K) value, then that probability value is used as the fraction against which a pseudo random number (RY) is compared to determine success or failure. Success is the result if the RY selected is the lesser. Thus, in this nominal case, success will occur with probability equal to the average input value.

If stress is higher than one-half of but does not exceed the threshold, and if current aspiration exceeds AVPROB(I, K), then a linearly increasing function is used to determine the function against which RY is compared. This function, shown in Figure 2-9, is principally dependent on stress.

If stress exceeds the threshold, then the aspiration value is used as the fraction against which RY is compared, so that the success rate in the long run will equal the aspiration.

In each case, the success/failure indicator, SIF, is set to S or F as appropriate, and the processing continues.

The current operator time of day Z(M) and the total time worked TW(IH, M) are then adjusted as a result of the time worked on this task element.

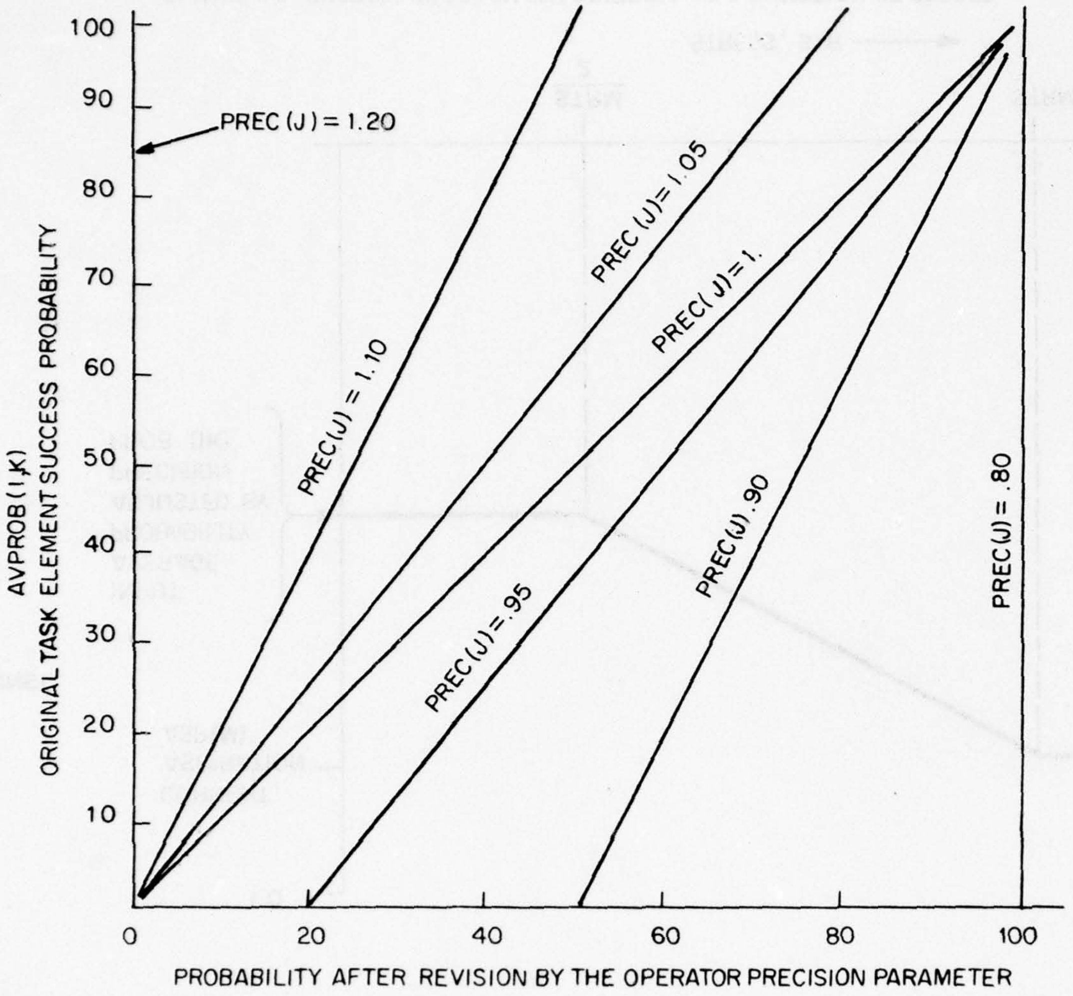


FIGURE 2-8. EFFECT OF OPERATOR PRECISION PARAMETER ON TASK ELEMENT SUCCESS PROBABILITY

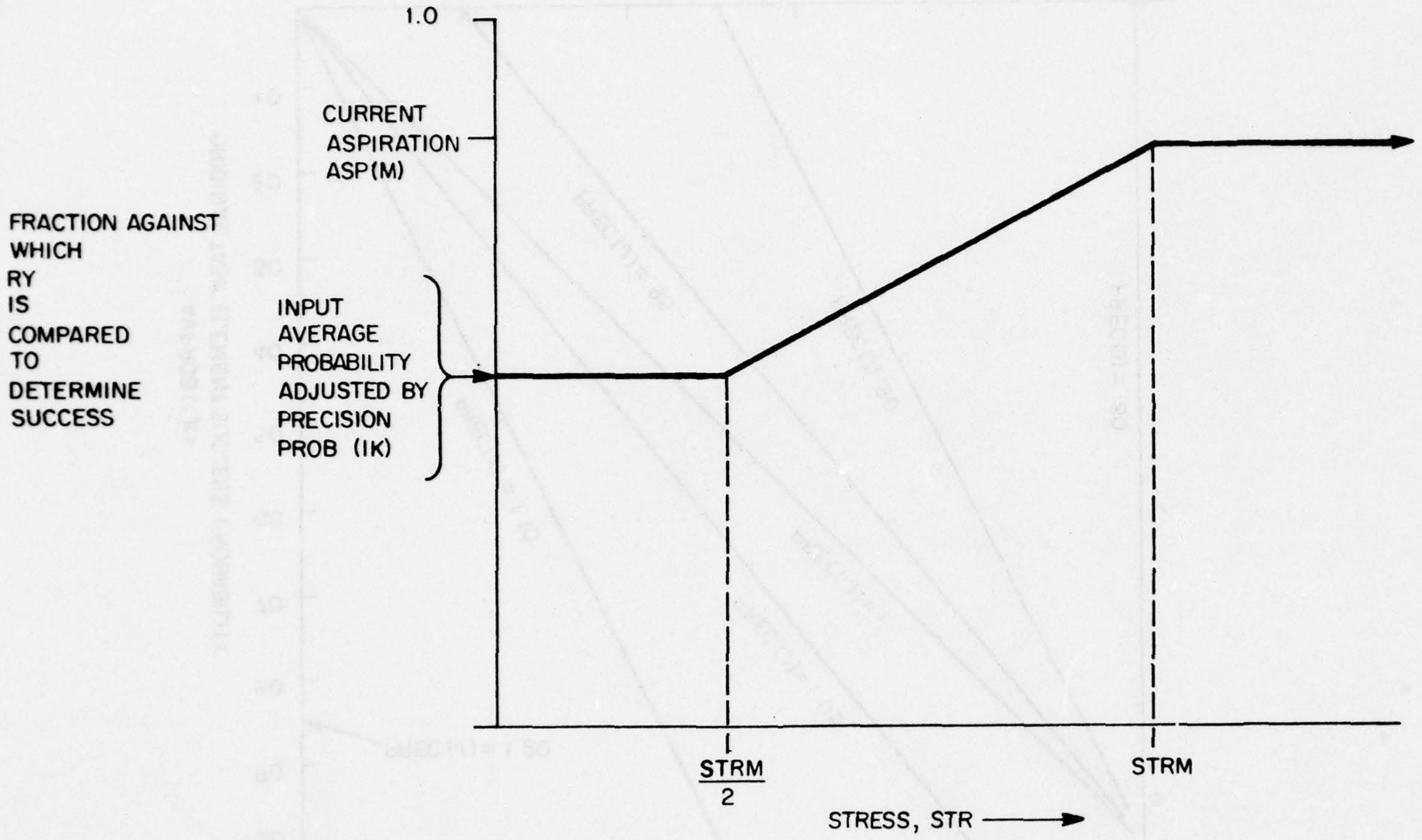


FIGURE 2-9. SUCCESS PROBABILITY CRITERIA AS A FUNCTION OF STRESS

Next, determinations are made of the next task element to be performed, and a count is kept of the number of successful and unsuccessful task elements for use in calculating performance. If the completion of this task element ran over into the next hour, the message processing results for the current hour are separated and appropriate message and task data are retained for the next hour.

Task element results are then recorded if ORO(5) has a value of 1.

This entire procedure, controlled by the PROC subroutine, is repeated for all task elements in the task analyses list selected. In accordance with IJS(I, K) and IJF(I, K) values and success or failure outcomes of task elements, this sequence can be linear (i. e., straight sequential) or can include skips and loops.

Information Loss

Following completion of operator task element processing, control returns to the main routine where a variable called the information loss (INFOLS) is calculated. Information loss is directly proportional to the total number of characters in the message. Information loss is also a function of the probabilities of errors going unnoticed in the CCC data base. Such errors of significant importance (probability = PUS) are weighted ten times more heavily than those of little importance (probability = PUL). When the INFOLS is less than one, it is set at zero and reported accordingly:

$$INFOLS = (10\ PUS + PUL) \times ILEN$$

where:

PUS = probability of a significant error
PUL = probability of an insignificant error
ILEN = message length

Effectiveness Measures

Baker (1970) defined four system performance measures--thoroughness, completeness, responsiveness, and accuracy. For the model, each of these was framed in terms of an output calculation and were combined into a single efficiency function and averaged over the run as a summary of performance.

Each component as well as the total effectiveness is scaled in the range from zero to one.

The first effectiveness component, EC(1), representing thoroughness, is the ratio of the number of messages completed during the hour by a controller divided by the number of messages arriving during the hour. The second component, completeness, EC(2), is defined as the mean of performance, PERF(J), values summarized over all men (performance represents the percentage of successful task elements).

The third component, responsiveness, is determined as:

$$EC(3) = \frac{\text{average message processing time from referee start to controller end}}{\text{average total elapsed message time (including idle periods)}}$$

Accuracy is determined from the relationship:

$$EC(4) = 1 - \frac{\text{Total information loss}}{\text{Number of messages completed}}$$

where total information loss is the sum of INFOLS values over all messages for the hour. Responsiveness will then approach perfection as information loss approaches zero. All components are upper limited at 1.0 and lower limited at 0.0.

Though two of the four factors are changed, the global effectiveness measure is calculated as in the model described by Siegel, Wolf, Leahy, and Bearde (1973):

$$EFS = \left[\frac{CC12)^2 + (CC13)^2 + (CC14)^2 + (CC23)^2 + (CC24)^2 + (CC34)^2}{6}\right] \bullet$$

$$[W(1)EC(1) + W(2)EC(2) + W(3)EC(3) + W(4)EC(4)]$$

$$+ \left[\frac{6 - (CC12)^2 + (CC13)^2 + (CC14)^2 + (CC23)^2 + (CC24)^2 + (CC34)^2}{6}\right] \bullet$$

$$[EC(1)^{W(1)}][EC(Z)^{W(2)}][EC(3)^{W(3)}][EC(4)^{W(4)}]$$

where:

EFF = effectiveness
CC12 = correlation between thoroughness and completeness
CC13 = correlation between thoroughness and responsiveness
CC14 = correlation between thoroughness and accuracy
CC23 = correlation between completeness and responsiveness
CC24 = correlation between completeness and accuracy
CC34 = correlation between responsiveness and accuracy
W(IC)= weight for each component
EC(1)= thoroughness
EC(2)= completeness
EC(3)= responsiveness
EC(4)= accuracy

Computer and Controller Delay

Within the processing, delay times for the computer and the controllers are calculated in accordance with an equation developed by Karlin (1969). These delay times are calculated as:

```
Q    =  G/(UM - G)
CALL POIS (Q, RY, KK)
```

where:

UM = 1/(average time to process a message)
G = (total messages per hour)/3600

The value Q is used as the mean of a poisson distribution with a random number generation routine to stochastically determine KK, the number of messages residing in queue when the current message arrives. The maximum allowed number of messages is upper limited at the number which would be performed on one-half hour. Once KKK is determined, this value is used in connection with the mean time per message to determine stochastically the delay time required before the current message is processed.

The time to process a message as used in the calculation of UM is determined from the task analysis with the assumption that task elements which are failed will be repeated until successful:

```
TPMC(K) = TPMC(K) + AVGTM(I, K)/AVPROB(I, K)
```

Results Recording

In addition to the tabulated listing of model inputs, there are three principal forms of output generated by the NETMAN model. These are:

- the detail results from simulation of individual messages by individual operators. This output presents extreme detail and its availability is optional under control of ORO(5)
- the end-of-hour report, showing results of performance by operator type for each hour across all iterations
- the run summary report, showing summaries across hours

Sample output listings for each of these three categories are shown in Figures 2-10, 2-11, and 2-12, respectively.

```
DETAIL RUN JULY 2                                                                       DAY NO.  5, PAGE   9

   DETAIL OUTPUT FROM SIMULATION OF COMPUT NUMBER  1 NETWORK NUMBER 1, MESSAGE NUMBER   1 ITERATION NUMBER  2
   TIME OF ARRIVAL-  2301.9 SECS, START TIME-  2301.9 SECS, STRESS  1.00, PERFORMANCE 1.000
   MESSAGE PRIORITY  2, TYPE  3, LENGTH  20 CHARACTERS, TASK ANALYSIS NO.  3, FATIGUE   1.0 ASPIRATION  1.00

    TASK    EXECUTION  CUMULATIVE  OUTCOME      TASK    CRITICALITY  SEGMENT  ERROR
   ELEMENT    TIME        TIME    S=SUCCESS  ELEMENT                 ENDED
   NUMBER    (SECS)                 F=FAIL     TYPE
                                   I=IGNORE
      1         1.52     2303.38      S          4                     10                    0   .00
      2          .14     2303.51      S          4                     11                    0   .00
      3         3.01     2306.52      F          4            C        12                    0   .00
      3         3.00     2309.52      F          4            C        12                    0   .00
      3         3.00     2312.53      S          4            C        12                    0   .00
      4          .11     2312.64      S          4            C        13                    0   .00
      5          .74     2313.38      S          0                     14                    0   .00
1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

DETAIL RUN JULY 2                                                                       DAY NO.  5, PAGE  10

   DETAIL OUTPUT FROM SIMULATION OF CONTRL NUMBER  2 NETWORK NUMBER 1, MESSAGE NUMBER   9 ITERATION NUMBER  2
   TIME OF ARRIVAL-  1142.9 SECS, START TIME-  1142.9 SECS, STRESS  1.00, PERFORMANCE  .950
   MESSAGE PRIORITY  4, TYPE  1, LENGTH 110 CHARACTERS, TASK ANALYSIS NO.  4, FATIGUE   1.0 ASPIRATION  1.00

    TASK    EXECUTION  CUMULATIVE  OUTCOME      TASK    CRITICALITY  SEGMENT  ERROR
   ELEMENT    TIME        TIME    S=SUCCESS  ELEMENT                 ENDED
   NUMBER    (SECS)                 F=FAIL     TYPE
                                   I=IGNORE
      1          .21     1143.14      F          0            C        15                    0   .00
      1          .17     1143.31      S          0            C        15                    0   .00
      2         1.99     1145.29      S          0                     16                    0   .00
      3        85.95     1231.25      S          0                     17                    0   .00
      4         3.20     1234.44      S          0                     18                    0   .00
      5        12.24     1246.68      S          0            C        19                    0   .00
      6         3.29     1249.97      S          0                     20                    0   .00
1XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Figure 2-10. Sample detail results.

```
---- DETAIL RUN JULY 2 ---------------------------------------------------------------- DAY  5    PAGE NO. 36

---RESULTS FOR HOUR    1 --------------------------------------------------------------------------
                   NUMBER       TOTAL       MEAN TIME PER    PROP.     FINAL           FINAL         MEAN
       LEVEL         OF        MESSAGES     OPERATOR PER     TIME     ASPIRATION    PERFORMANCE    STRESS
----------------- OPERATORS   COMPLETED    MESSAGE (SECS)    BUSY -----------------------------------------
     REFEREE           2           8.              58.        .03        .95             .90          1.0
     RADIO OPERATOR    2           8.             104.        .06        .95             .82          1.0
 ----COMPUTER -------- 1 --------- 8. ------------- 8. ------ .01 ------ 1.00 ---------- 1.00 -------- 1.0 ----
     CONTROLLER        1           8.             194.        .22        .95             .87          1.0


---- DETAIL RUN JULY 2 ---------------------------------------------------------------- DAY  5    PAGE NO. 37

---MEANS ACROSS HOURS -----------------------------------------------------------------------------
                   NUMBER       TOTAL       MEAN TIME PER    PROP.     FINAL           FINAL         MEAN
       LEVEL         OF        MESSAGES     OPERATOR PER     TIME     ASPIRATION    PERFORMANCE    STRESS
----------------- OPERATORS   COMPLETED    MESSAGE (SECS)    BUSY -----------------------------------------
     REFEREE           2           8.              58.        .03        .95             .90          1.0
     RADIO OPERATOR    2           8.             104.        .06        .95             .82          1.0
 ----COMPUTER -------- 1 --------- 8. ------------- 8. ------ .01 ------ 1.00 ---------- 1.00 -------- 1.0 ----
     CONTROLLER        1           8.             194.        .22        .95             .87          1.0

---- TOTAL -------------------------- 32. ------- 364.0  GRANDMEANS ------------------------------------ 1.00
```

Figure 2-11. Sample end of hour report.

```
1   DETAIL RUN JULY 2                                                                              PAGE NO. 39
    SUMMARY OUTPUT FOR  2 ITERATION RUN
------------------------------------------------------------------------------------------------
        MESSAGES    MEAN TIME PER                          EFFECTIVENESS                          TOTAL
        COMPLETED   MESSAGE (SECS)   THOROUGHNESS  COMPLETENESS  RESPONSIVENESS  ACCURACY
------------------------------------------------------------------------------------------------
            8         451.76             .73          .90            .90          .69           .80
------------------------------------------------------------------------------------------------
   MESSAGE TYPE        1       2       3       4       5       6       7
                                                                                       TOTAL
------------------------------------------------------------------------------------------------
   NUMBER PROCESSED   12      12       8       0       0       0       0
                                                                                         32
------------------------------------------------------------------------------------------------
    Divide by 4 to yield messages completed
------------------------------------------------------------------------------------------------
 MEAN TIME IN SECONDS PER SEGMENT AND(PROPORTION)
---------------------------MESSAGE TYPE---------------------------------------------------------
                 1             2             3             4             5             6             7
-- SEGMENT--------------------------------------------------------------------------------------
   NUMBER
     2          6.3          13.9           9.8            .0            .0            .0            .0
---------(    .016    )(    .031    )(    .020    )(    .000    )(    .000    )(    .000    )(    .000    )
     3         22.9          33.3          26.5            .0            .0            .0            .0
         (    .054    )(    .073    )(    .054    )(    .000    )(    .000    )(    .000    )(    .000    )
-----4-------733.9----------94.0---------497.9-------------.0------------.0------------.0------------.0
         (   1.000    )(    .208    )(   1.000    )(    .000    )(    .000    )(    .000    )(    .000    )
     5         49.6          61.5          66.6            .0            .0            .0            .0
---------(    .117    )(    .135    )(    .136    )(    .000    )(    .000    )(    .000    )(    .000    )
     6        162.3         144.1         166.3            .0            .0            .0            .0
         (    .384    )(    .317    )(    .339    )(    .000    )(    .000    )(    .000    )(    .000    )
-----7-------199.9---------175.6---------190.8-------------.0------------.0------------.0------------.0
         (    .472    )(    .387    )(    .389    )(    .000    )(    .000    )(    .000    )(    .000    )
     8        235.7         162.5         223.2            .0            .0            .0            .0
---------(    .557    )(    .358    )(    .455    )(    .000    )(    .000    )(    .000    )(    .000    )
     9        254.5         234.6         266.6            .0            .0            .0            .0
         (    .601    )(    .516    )(    .543    )(    .000    )(    .000    )(    .000    )(    .000    )
-----10------255.4---------235.6---------267.9-------------.0------------.0------------.0------------.0
         (    .604    )(    .518    )(    .546    )(    .000    )(    .000    )(    .000    )(    .000    )
     11       255.6         235.8         268.0            .0            .0            .0            .0
---------(    .604    )(    .519    )(    .546    )(    .000    )(    .000    )(    .000    )(    .000    )
     12       259.7         241.8         275.5            .0            .0            .0            .0
         (    .614    )(    .532    )(    .562    )(    .000    )(    .000    )(    .000    )(    .000    )
-----13------259.7---------241.9---------275.6-------------.0------------.0------------.0------------.0
         (    .614    )(    .532    )(    .562    )(    .000    )(    .000    )(    .000    )(    .000    )
     14       260.3         242.7         277.0            .0            .0            .0            .0
---------(    .615    )(    .534    )(    .565    )(    .000    )(    .000    )(    .000    )(    .000    )
     15       260.6         242.8         277.2            .0            .0            .0            .0
         (    .616    )(    .534    )(    .565    )(    .000    )(    .000    )(    .000    )(    .000    )
-----16------262.3---------244.3---------278.8-------------.0------------.0------------.0------------.0
         (    .620    )(    .538    )(    .568    )(    .000    )(    .000    )(    .000    )(    .000    )
     17       401.6         430.1         468.9            .0            .0            .0            .0
---------(    .949    )(    .946    )(    .956    )(    .000    )(    .000    )(    .000    )(    .000    )
     18       406.7         440.0         474.1            .0            .0            .0            .0
         (    .961    )(    .968    )(    .966    )(    .000    )(    .000    )(    .000    )(    .000    )
-----19------419.1---------450.8---------485.3-------------.0------------.0------------.0------------.0
         (    .991    )(    .992    )(    .989    )(    .000    )(    .000    )(    .000    )(    .000    )
     20       423.2         454.4         490.7            .0            .0            .0            .0
```

Figure 2-12. Sample run summary report.

III. SENSITIVITY

Having developed the model in the form described in Chapter II, a set of computer runs was completed to assess the rationality and sensitivity of the NETMAN model to input variation. While such tests provide no information relative to the predictive validity of the model, the results of such tests allow initial evaluation of the model from the point of view of the logicalness of its output.

Four input variables were manipulated in these sensitivity tests: operator speed, operator precision, message frequency, and message length. These were selected because of their saliency in system performance. The model input data used in the sensitivity evaluation are shown in Figure 3-1.

The variations introduced into the Figure 3-1 data to test the sensitivity of NETMAN are shown in Table 3-1

Table 3-1

Summary of Sensitivity Test Runs Completed

RUN Number	*Parameter(s) Changed*
1	See basic input
2	All operators precision= 1.1
3	All operators precision= 0.9
4	All operators speed= 0.7
5	All operators speed= 0.9
6	All operators speed= 1.1
7	Referee/radio operator's message length 22 characters
8	Referee/radio operator's message length 11 characters

```
NUMBER OF ITERATIONS        5
NUMBER OF HOURS        1
NUMBER OF MESSAGE TYPES        7
NUMBER OF LEVELS IN NETWORK        4
NUMBER OF NETWORKS        1
INITIAL RANDOM NUMBER        .77
NUMBERS OF DAYS WORKED        5
NUMBER OF REFEREES IN NET 1        2
NUMBER OF REFEREES IN NET 2        0
NUMBER OF REFEREES IN NET 3

OUTPUT RECORDING OPTIONS(1=YES)
   1          1
   2          1
   3
   4          1
   5
   6          1
   7          1
   8          3
   9          1

TASK ANALYSIS ALLOCATION
LEVEL  MESSAGE TYPE TASK ANALYSIS
   1          1          1
   1          2          1
   1          3          1
   1          4          1
   1          5          1
   1          6          1
   1          7          1
   1          8          1
   2          1          2
   2          2          2
   2          3          2
   2          4          2
   2          5          2
   2          6          2
   2          7          2
   2          8          2
   3          1          3
   3          2          3
   3          3          3
   3          4          3
   3          5          3
   3          6          3
   3          7          3
   3          8          3
   4          1          4
   4          2          4
   4          3          4
   4          4          4
   4          5          4
   4          6          4
   4          7          4
   4          8          4
                          OPERATOR PARAMETERS
     NETWORK LEVEL         SPEED   PRECISION STRESS   ASPIRATION
                                             THRESHOLD

REFEREES            1      1.00      1.00      2.30      .95
RADIO OPERATORS     2      1.00      1.00      2.30      .95
COMPUTER            3      1.00      1.00      2.30      .95
CONTROLLERS         4      1.00      1.00      2.30      .95
MESSAGE TYPE DATA
NUMBER  NAME   MEAN MESSAGES GENERATED
  1     INFORM            1.20
  2     ASK               1.20
  3     ASK               1.20
  4     ASK               1.20
  5     ASK               1.20
  6     ASK               1.20
  7     ASK               1.20

        HOUR PARAMETERS
         CUMULATIVE MESSAGE PROPORTION BY TYPE          CUM. MSG PROP. BY PRIORITY     INPUT MESSAGES
   HOUR   1    2    3    4    5    6    7    8          1    2    3    4    5          MEAN    SIGMA

     1  .20  [illegible]  .60  .83  [illegible]  [illegible]  .00          .20  .40  .60  .80  1.00          80


MESSAGE ORIGINATING POINT DATA  (CUMULATIVE BY SOURCE)
                              HOUR
                 1      2      3      4      5      6      7      8      9      10     11     12
CONTROLLER     .300   .300   .300   .300   .300   .300   .300   .300   .300   .300   .300   .300
REFEREE        .600   .600   .600   .600   .600   .600   .600   .600   .600   .600   .600   .600
OUTSIDE       1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
```

Figure 3-1. Input data used for NETMAN sensitivity tests.

```
THE PROBABILITY OF A LOW SIGNIFICANCE ERROR IS          .070
THE PROBABILITY OF A HIGH SIGNIFICANCE ERROR IS         .030

  ERROR FREQUENCY

                  MESSAGE TYPE                        REFEREE  RADIO OPERATOR
   TYPE    1     2     3     4     5     6     7
    1     1.20  2.10  3.10  4.20  3.40  2.30  1.20      1.200     2.300
    2     1.20  2.10  3.10  4.20  3.40  2.30  1.20      1.200     2.300
    3     1.20  2.10  3.10  4.20  3.40  2.30  1.20      1.200     2.300
    4     1.20  2.10  3.10  4.20  3.40  2.30  1.20      1.200     2.300
3

NUMBER OF DIGITS FOR REFEREE/RADIO OPERATOR MESS
 TYPE MEAN   STANDARD DEVIATION
  1     17.00        1.70
  2     17.00        1.70
  3     17.00        1.70
  4     17.00        1.70
  5     17.00        1.70
  6     17.00        1.70
  7     17.00        1.70

NUMBER OF DIGITS FOR CONTROLLER MESSAGES
 TYPE MEAN   STANDARD DEVIATION
  1    160.00       30.00
  2    150.00       30.00
  3    150.00       30.00
  4    150.00       30.00
  5    100.00       30.00
  6    150.00       30.00
  7    160.00       30.00
1

   TASK ANALYTIC DATA

                                                                                      UNDETECTED-ERR
TASK    ELEMENT    TYPE   CRITICAL   SEGMENT  NEXT-FAIL NEXT-SUCC MEAN-TIME    SIGMA  PROBABILITY TYPE    PR

 1
           1         0                 2         1          2     10.300      3.000     .950             .05
           2         2        C        3         3          4      1.200       .400     .750       T     .05
           3         0                 4         3          4     20.000      7.000     .800             .00
           4         0                 5         4          0     25.000      1.500     .990             .00
 2
           1         0                 6         1          2     11.000      3.300     .990             .10
           2         2        C        7         2          3      1.200       .300     .750             .00
           3         6                 8         3          4     35.100     10.500     .900             .00
           4         0        C        9         4          0     10.700      3.500     .750             .00
 3
           1         4                10         1          2      1.000       .300     .990             .00
           2         4                11         2          3       .230       .070     .950             .00
           3         4        C       12         3          4      3.005       .002     .700             .00
           4         4        C       13         4          5       .100       .030     .900             .00
           5         0                14         5          0       .500       .200     .800             .00
 4
           1         0        C       15         1          2       .200       .070     .900             .10
           2         0                16         2          3      1.200       .400     .750             .00
           3         0                17         3          4      1.000       .300     .900             .00
           4         0                18         4          5      3.400      1.100     .600             .00
           5         0        C       19         5          6     15.000      5.000     .900             .00
           6         0                20         6          0      4.000      1.500     .900             .00
TASK ANALYSIS DURATIONS
   1      85.29
   2      91.35
   3       6.25
   4     247.05
EFFECTIVENESS COMPONENTS

 CORRELATIONS BETWEEN COMPONENTS
  CC12=  .500
  CC13=  .500
  CC14=  .500
  CC23=  .500
  CC24=  .500
  CC34=  .500

 WEIGHTS OF EACH COMPONENT
  W(1)=  .250
  W(2)=  .250
  W(3)=  .250
  W(4)=  .250

 TRANSMISSION DELAY DATA
 HOUR   DELAY    SIGMA
  1    10.000     3.200
```

Figure 3-1 (cont.)

Results

On the general level, the sensitivity tests indicated reasonable model output and acceptable directional response to input variation. The results seem intuitively reasonable and appropriate for message processing evaluation relative to field exercises.

Speed

Figure 3-2 summarizes the message processing time results when operator speed was varied from 0. 7 (fast) to 1. 1 (slow). The anticipated directional trend is clearly evident. Processing time refers to time actually spent working on messages and does not include message time in queue. The average processing time was derived by dividing the total amount of time worked by the number of messages processed. With the very fast crew [F(J) = 0. 7] mean working time was 272 seconds per message. When simulated crew speed was degraded to the F(J) = 1. 1 level, an increase of 77 per cent (average time per message = 481 seconds) of working time was indicated for each message.

Figure 3-3 shows the mean total message handling time (i. e., including both working and queuing time) for each of four operator speeds. The effect of operator speed on total message handling time was larger than the effect on processing time, and again the anticipated trend was evidenced. The fastest simulated team required 630 seconds to handle a message as opposed to 3793 seconds for the slowest simulated team. This represents an increase in handling time of 502 per cent and an increase in queuing time of 825 per cent:

Speed	Handling		Working		Queuing
. 7	630	-	272	=	358
1. 1	2008	-	367	=	3312

$$\frac{3312-358}{358} = 8.25 \times 100 = 825\%$$

Accordingly, within the simulation, slower operators produced a realistic chain effect of longer message waiting in a queue before processing. The effect of slower workers in a chained type system was indicated to be greater than would be predicted by their slowness alone. This effect seems quite reasonable and is most evident in a high workload situation such as the current test runs.

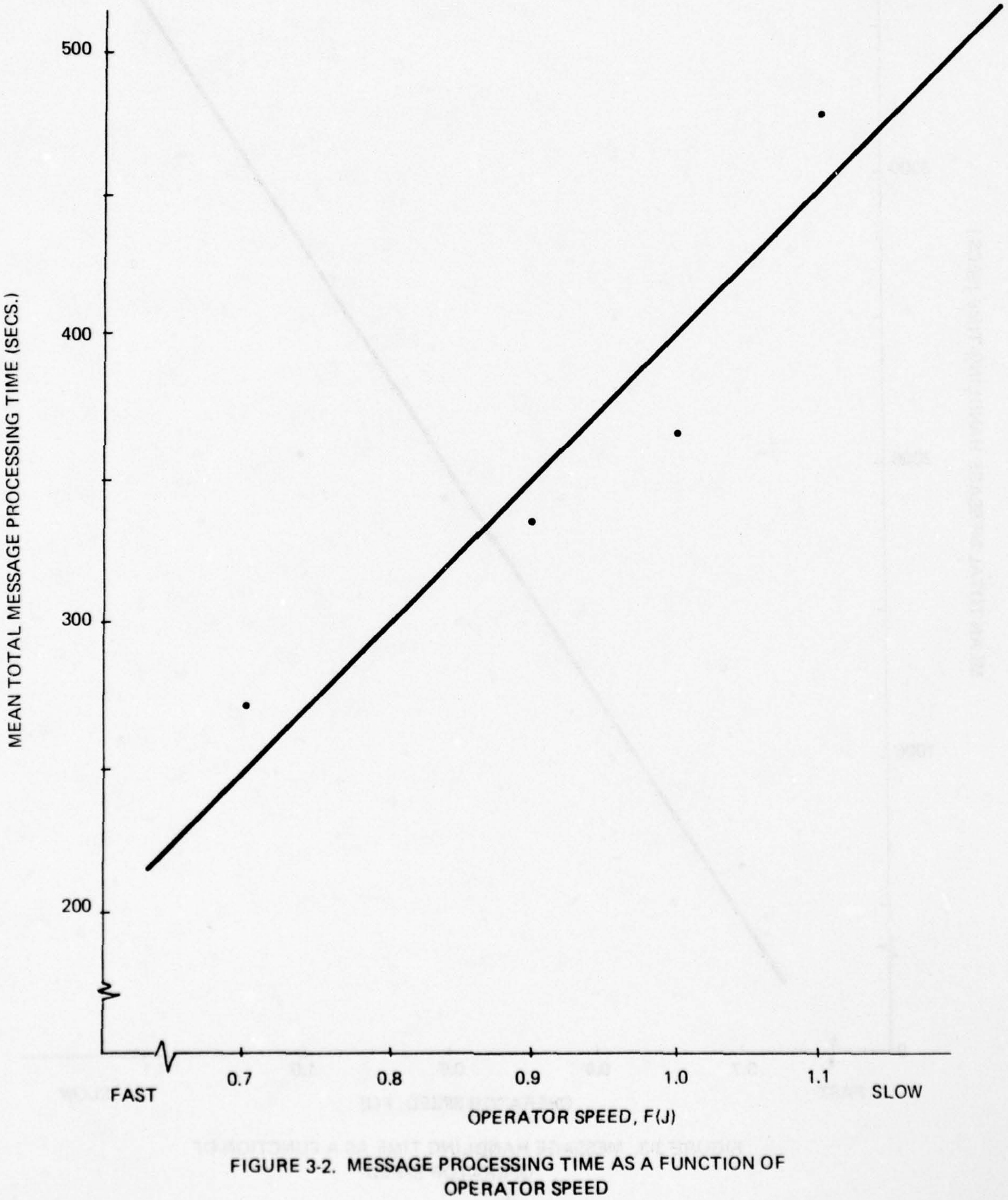


FIGURE 3-2. MESSAGE PROCESSING TIME AS A FUNCTION OF OPERATOR SPEED

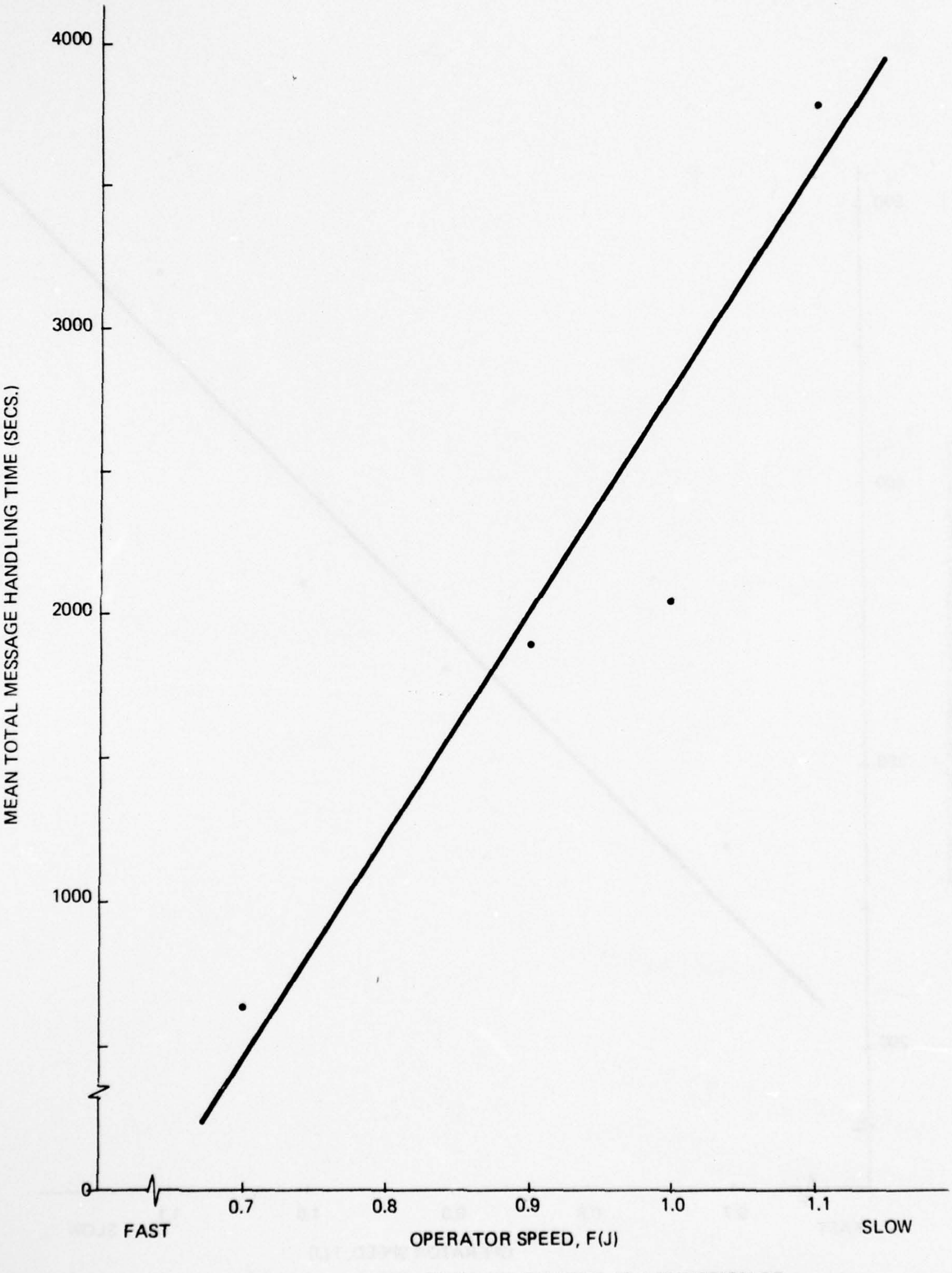


FIGURE 3-3. MESSAGE HANDLING TIME AS A FUNCTION OF OPERATOR SPEED

The effects of operator speed on the overall system effectiveness measure, as indicated by the sensitivity tests, are presented in Figure 3-4. The fastest simulated [F(J) = 0.7] team was indicated to have the best overall effectiveness (.84). This result is in agreement with the message time data described above. The simulated extremely slow team's overall effectiveness was indicated to be marginal (.66). Accordingly, the sensitivity test results indicate the effectiveness measure to be sensitive to the operator speed variable.

The overall effectiveness index is based on a weighted composite of the four effectiveness components: thoroughness, responsiveness, completeness, and accuracy. Of the four, the thoroughness and the responsiveness components are most directly related to operator speed, while the completeness and the accuracy components are more directly related to errors. Thoroughness is essentially a measure of the number of messages processed compared to the number which should have been completed. The responsiveness component is based on the ratio of message processing (actual work) time to total throughput time.

The obtained results relative to the effects of operator speed on the thoroughness component are presented in Figure 3-5. While the anticipated directional trend is indicated in Figure 3-5, the maximum obtained thoroughness value was only .56. This is due to the very heavy heavy simulated message load in the present simulations. In the case of the slow operator working speed [F(J) = 1.1], thoroughness dropped to .22.

The obtained relationship between operator speed and the responsiveness component is shown in Figure 3-6. Again, the anticipated directional trend was indicated. The fastest simulated team's responsiveness index was .94, while for the slowest team the index fell to .81.

Precision

Precision was the other major operator parameter varied in the present set of sensitivity tests. Precision is the humanistic variable in the model which reflects errors. A more precise operator team will commit fewer errors. Since errors impose a requirement for task repetition or for canceling part of work already completed, errors are time consuming. Additionally, errors which are not detected will eventuate an incorrect or incomplete message--degrading system performance. Precision can be varied independently within the model and was so varied for the sensitivity tests.

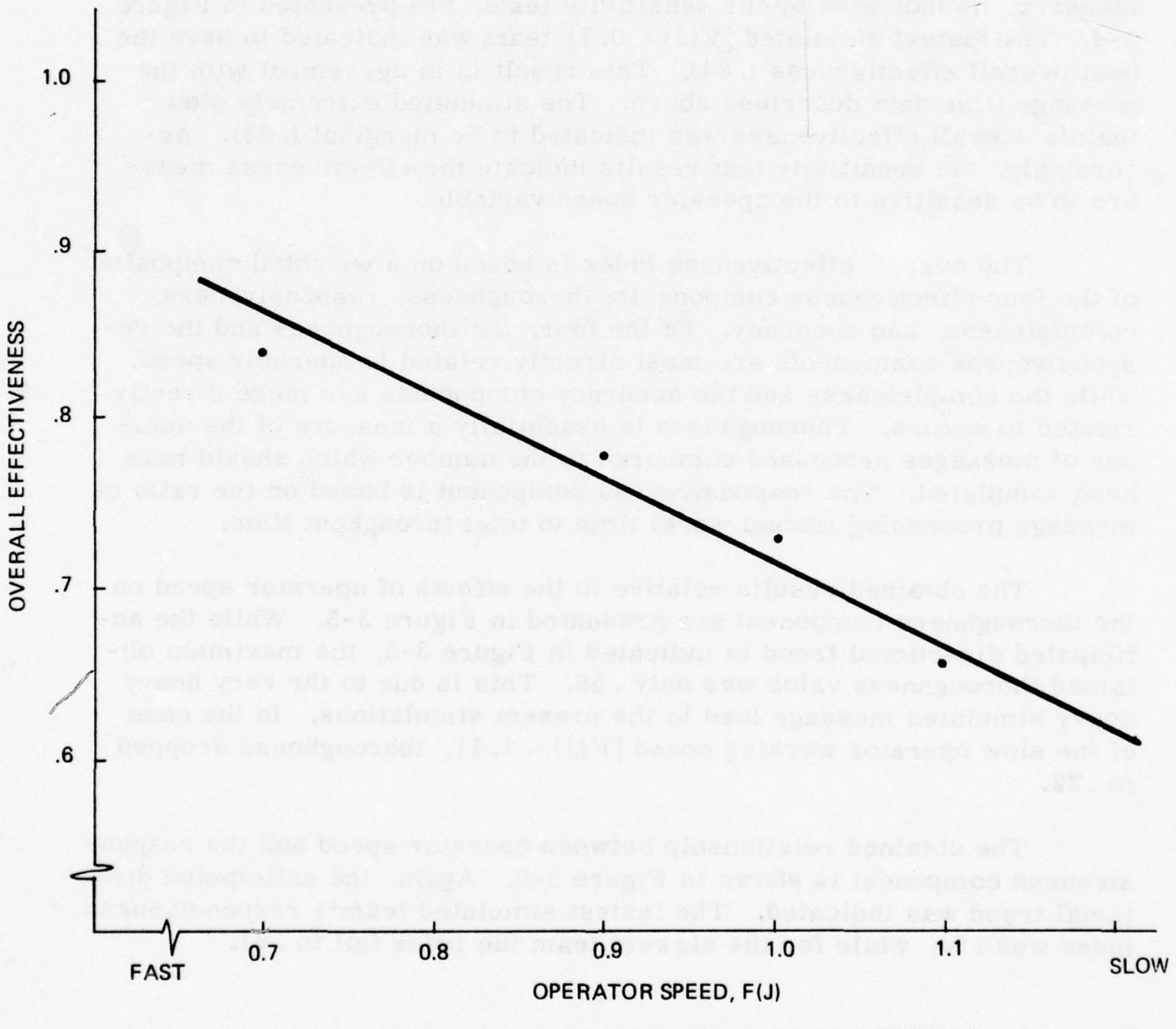


FIGURE 3-4. SYSTEM OVERALL EFFECTIVENESS AS A FUNCTION OF OPERATOR SPEED

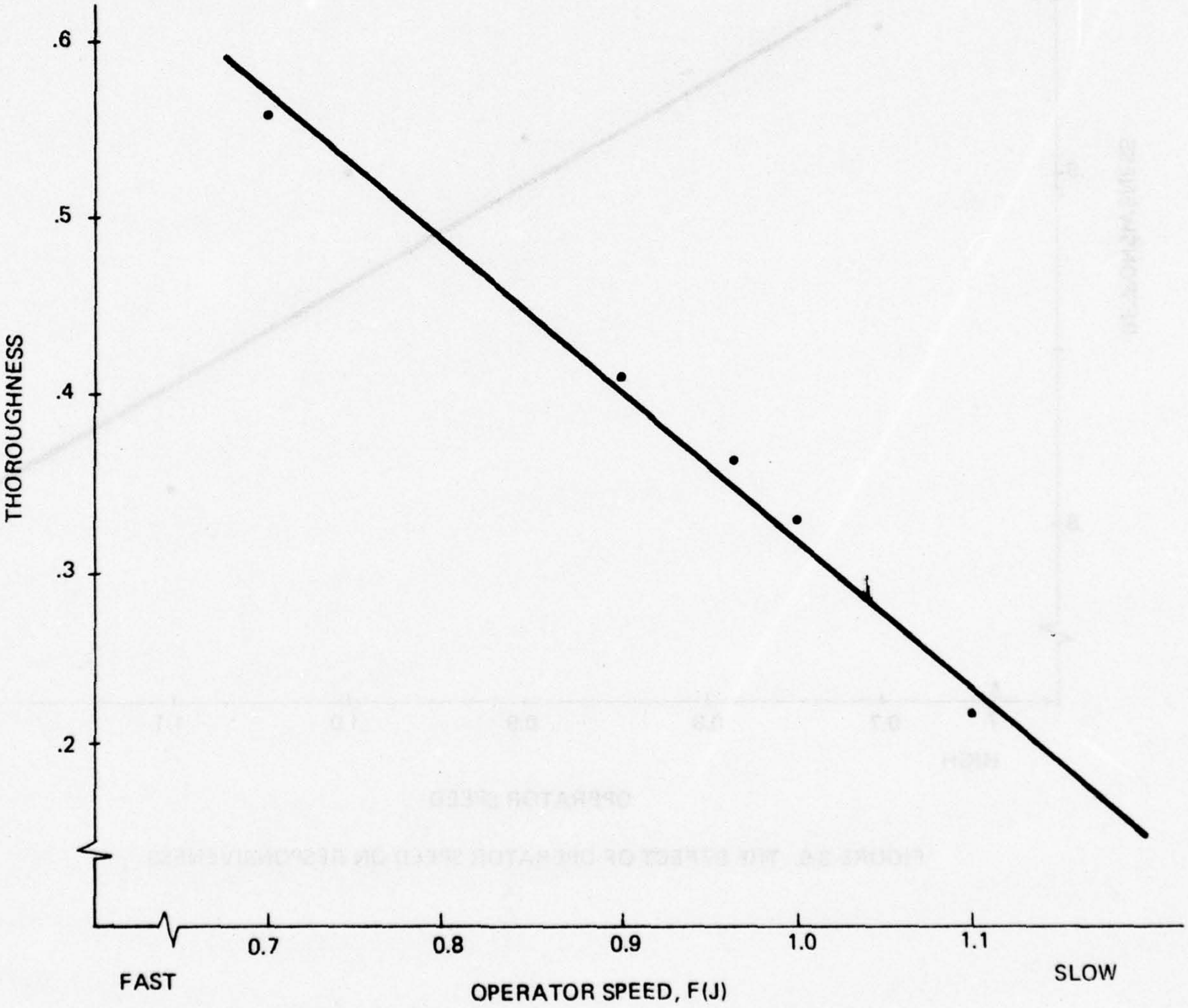


FIGURE 3-5. THE EFFECT OF OPERATOR SPEED ON THOROUGHNESS

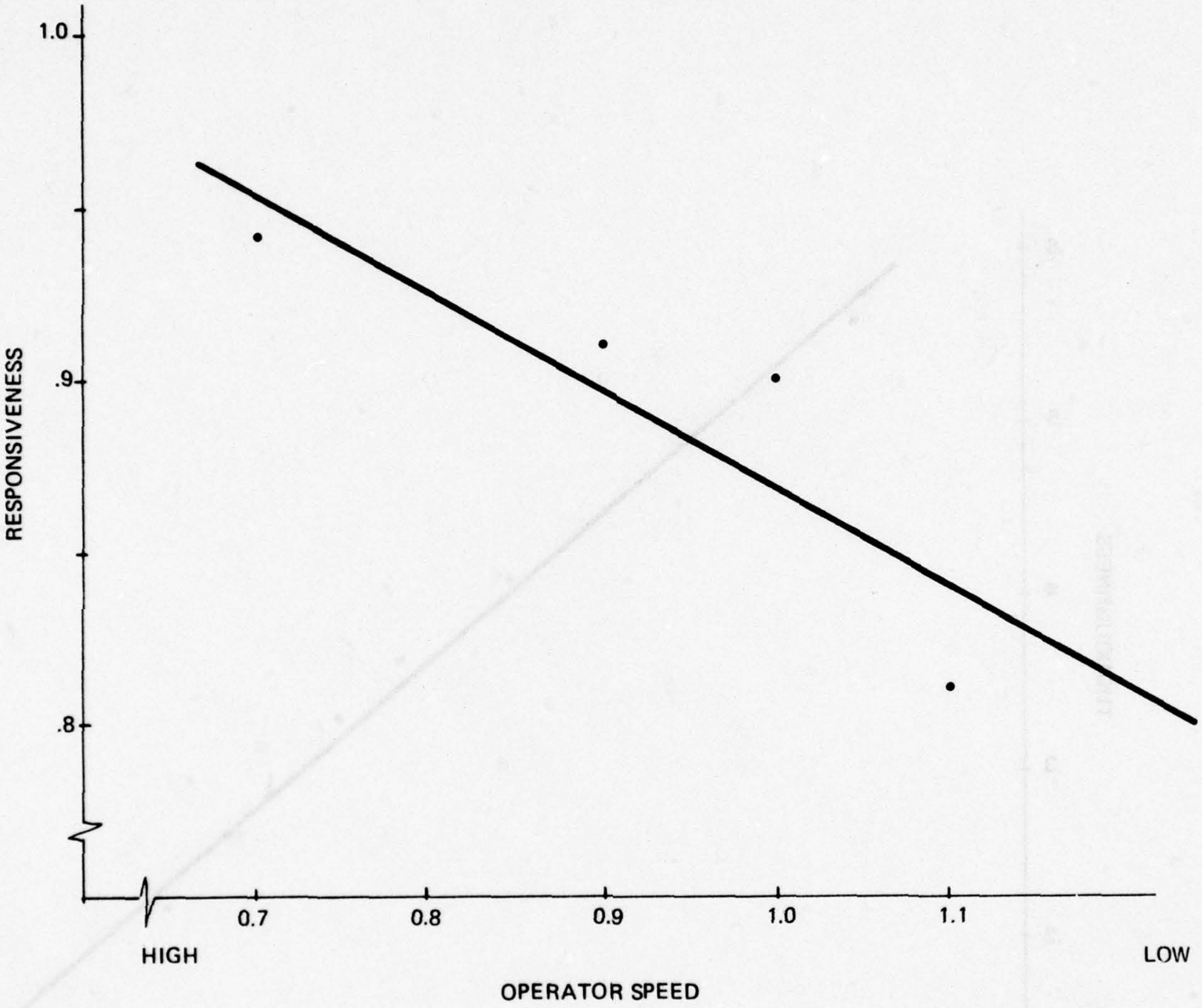


FIGURE 3-6. THE EFFECT OF OPERATOR SPEED ON RESPONSIVENESS

Figure 3-7 presents the effects of precision variation on processing time. Processing time which, as indicated earlier, represents actual working time, was 326 seconds for the highly precise network team and increased at a positively accelerated rate to 627 seconds for the most error prone simulated team. This represents an increase (i. e., decrement) from baseline [P(j) = 1.0) of 71 per cent, while the results for the more precise team represent a savings of 11 per cent over the baseline team.

Total message handling time, as shown in Figure 3-8, also showed a positively accelerated increase as precision was degraded. The results for the more accurate team [P(J) = 0.9] indicated a 44 per cent margin over the baseline team, while the results for the lowest precision simulated team (P_j = 1.1) indicated a 136 per cent deficit (i. e., increase in handling time). A comparison of the performance of the most precise team with that of the least precise simulated team indicated that the least precise team spent 92 per cent more working time on each message and 321 per cent more time in message handling. As was indicated in the case of operator speed, increases in working time were accompanied by a much larger increase in queue waiting time (814 per cent in the current case). Again, the bottleneck situation, in which the network speed is determined by the poorest (or most error prone in this case) chain within the network was indicated.

The effect of precision variation on overall effectiveness is shown in Figure 3-9. Again, the desired directional trend was indicated by the model's output. Comparison of the data of Figure 3-9 with the parallel plot for speed (Figure 3-4) indicates that with everything else held constant, a precision of 0.9 produced an overall effectiveness of value .81, while a speed factor of 0.9 produced an effectiveness of .78. Similarly, the 1.1 precision value produced an overall effectiveness of .58, while a speed of 1.1 produced an effectiveness of .66. Accordingly, the overall effectiveness value seems more sensitive to precision variation than to simulated operator speed variation. Such a tendency seems entirely reasonable since some degree of slowness can usually be tolerated to a greater extent than the same degree of inaccuracy.

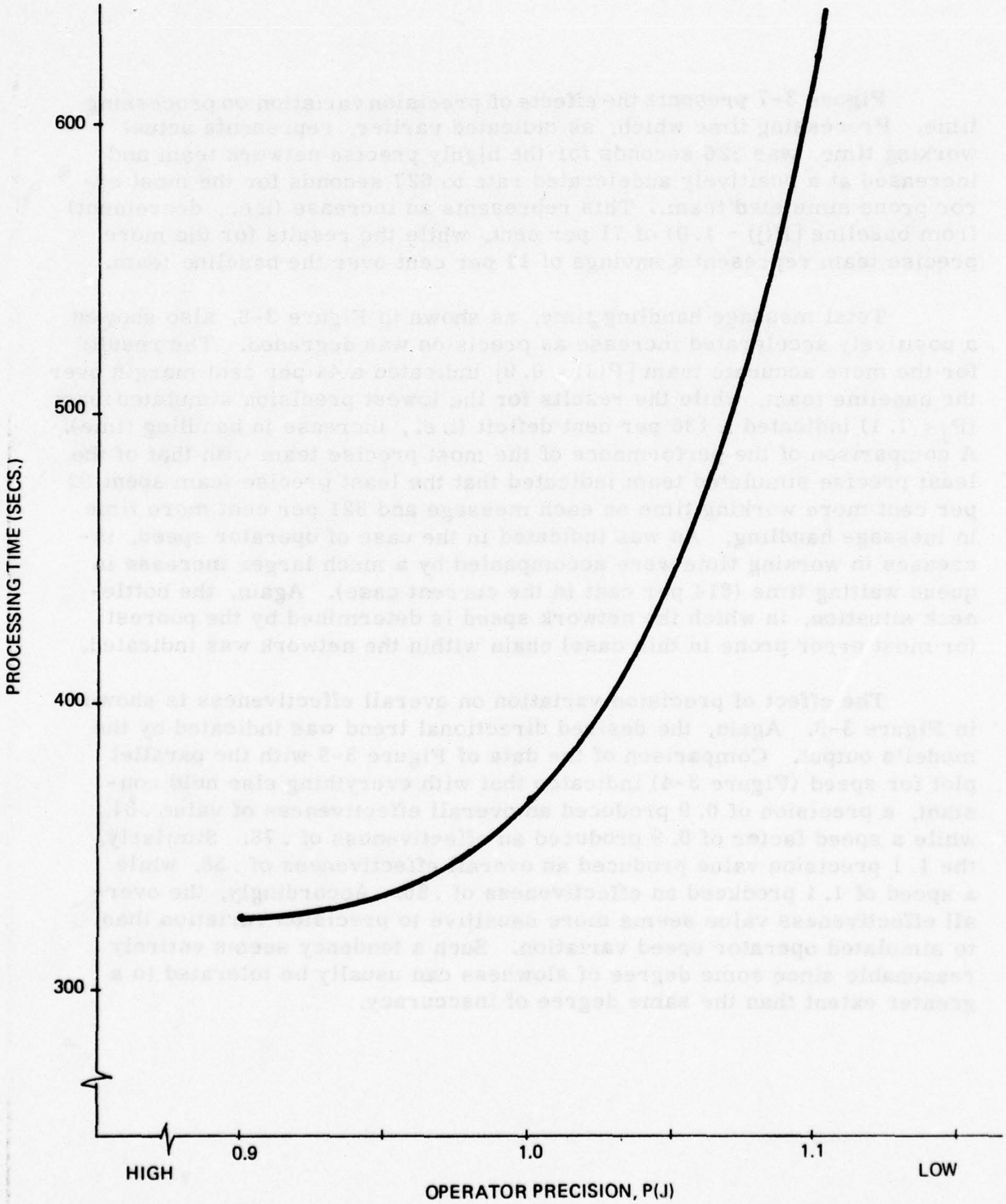


FIGURE 3-7. EFFECT OF OPERATOR PRECISION ON MESSAGE PROCESSING TIME

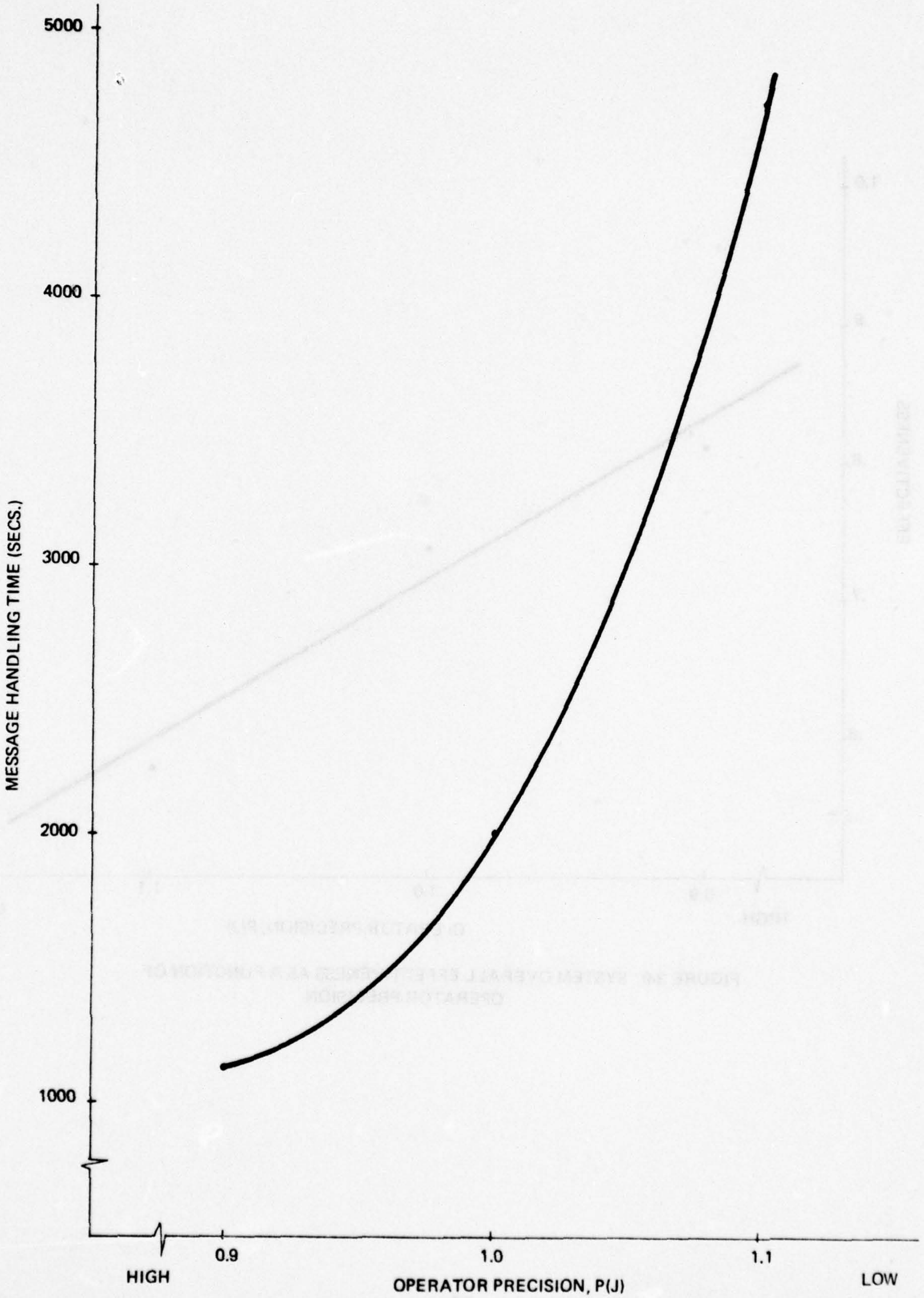


FIGURE 3-8. MESSAGE HANDLING TIME AS A FUNCTION OF OPERATOR PRECISION

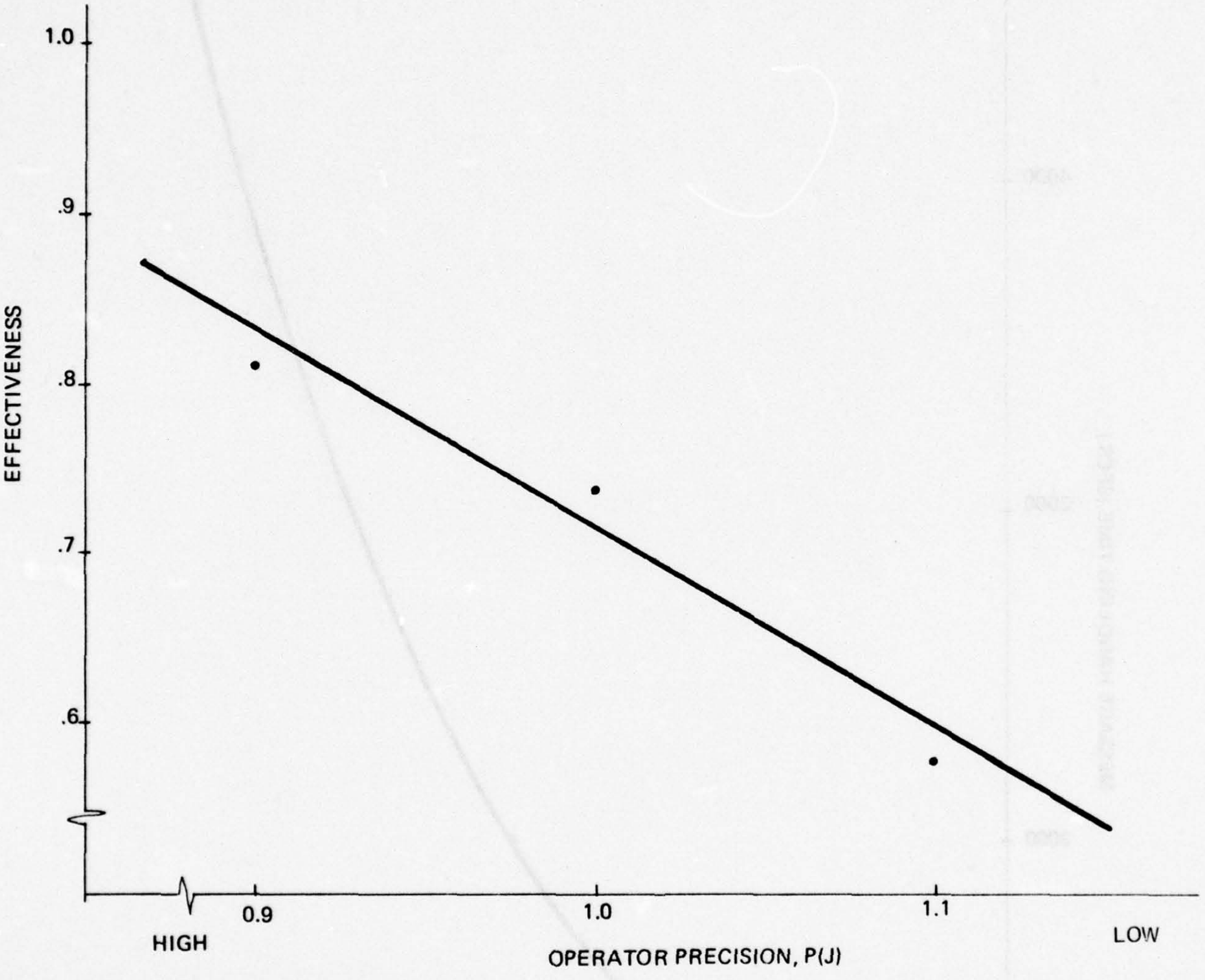


FIGURE 3-9. SYSTEM OVERALL EFFECTIVENESS AS A FUNCTION OF OPERATOR PRECISION

Figure 3-10 shows the obtained completeness index as a function of operator precision. Here, as in the time curves, a curvilinear decrement was indicated as a function of decreasing precision. A range of .29 effectiveness points was indicated between the lowest and the highest error producing groups.

Simulated operator speed is directly related to the thoroughness component. However, because precision effects time by requiring touch ups and task repetition, we would also expect precision to have an effect on thoroughness. Figure 3-11 presents this relationship and indicates that the anticipated directional relationship was yielded by the sensitivity tests.

Responsiveness, as shown in Figure 3-12, was also strikingly affected in the anticipated direction. A drop of .27 effectiveness points was indicated as simulated operator precision was varied between 0. 9 and 1. 1. The rate of responsiveness drop was greater compared with the .09 and 1. 0 teams.

Accordingly, within the stochastic simulation model, precision seems to be a primary factor affecting the calculated system effectiveness. The test results suggest that for systems such as that simulated, the result of allowing error prone teams to operate the system is to grossly degrade network performance. The sensitivity test results suggest the importance of maintaining at least minimum performance standards for system personnel and the model seems quite sensitive to these effects.

Message Length

Message length for the referee/radio operator messages was simulated in the sensitivity tests at 11, 17, and 22 characters. The 22 character messages required somewhat longer processing time than the 17 character baseline (441 versus 367 seconds) messages. However, the other comparisons produced little or mixed effect which can be attributed to random variation. The difference between handling a message of 11 characters and one of 22 characters only amounts to a few seconds. Accordingly, in view of the limited message length range simulated, little effect of message length may have been anticipated. At any rate, within the range of the tests performed, the model seems more sensitive to operator oriented variables than to message length.

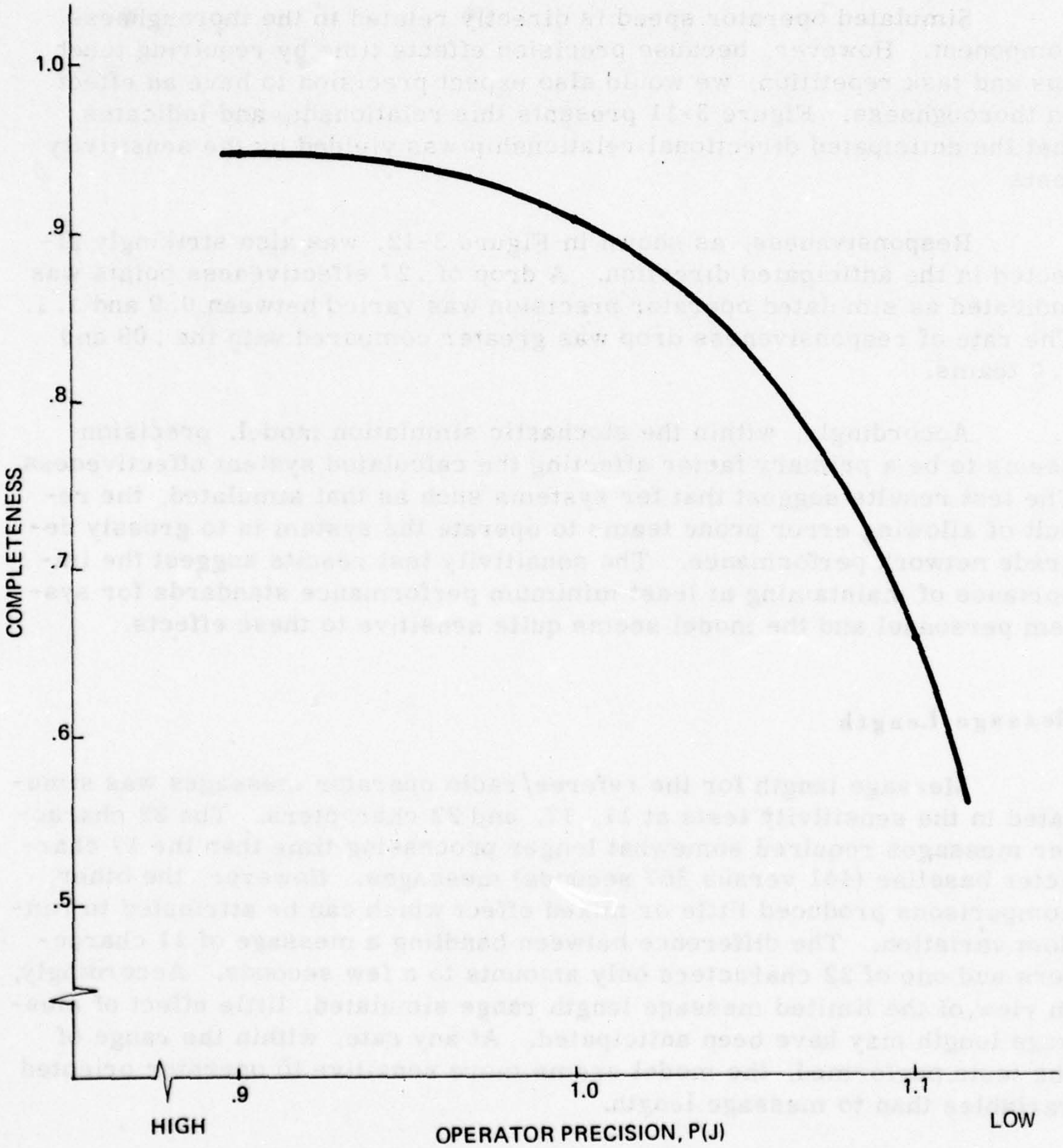


FIGURE 3-10. EFFECT OF OPERATOR PRECISION ON COMPLETENESS

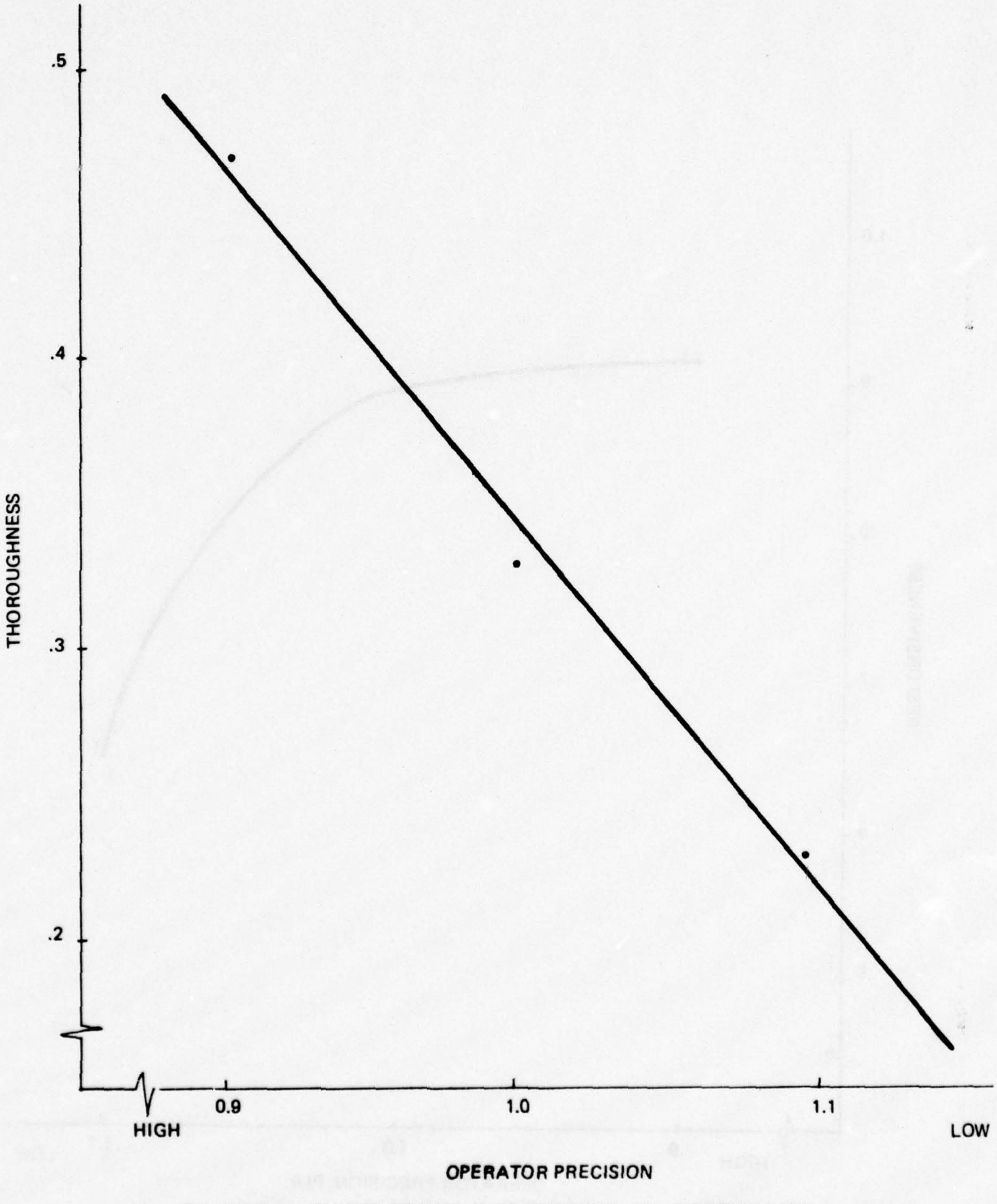


FIGURE 3-11. EFFECT OF OPERATOR PRECISION ON THOROUGHNESS

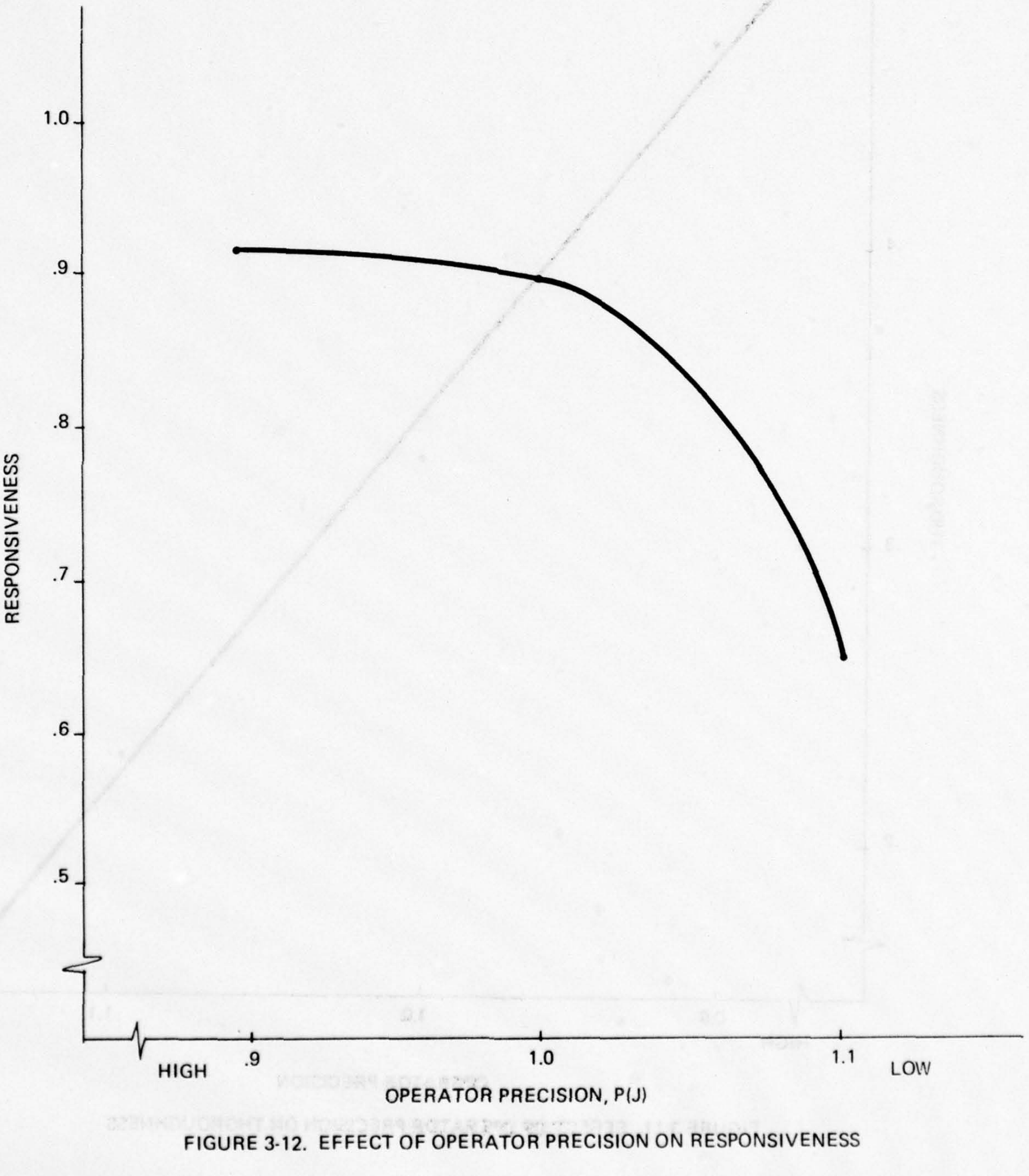


FIGURE 3-12. EFFECT OF OPERATOR PRECISION ON RESPONSIVENESS

IV. SUMMARY AND DISCUSSION

The NETMAN model was designed to allow simulation of message processing in a system composed of up to three networks. Each network may be composed of up to nine referees, up to nine radio operators, and one controller. One computer is assumed to accommodate the three networks. As such, the model allows simulation and test of the effects on system effectiveness of varying such aspects as: number of referees, number of networks, task procedures, message arrival rate, message length, and operator skill.

The results of the simulation are interpretable in terms of a number of formal effectiveness measures (accuracy, thoroughness, responsiveness, completeness) and an overall effectiveness index. Additionally, the results are interpretable in terms of such model results as work time, stress imposed, message processing time, errors, number of messages processed, and fatigue.

NETMAN, in a sense, represents a second generation development since many of its subroutines are based on and drawn from subroutines included in stochastic models previously developed by the Army Research Institute for the Behavioral and Social Sciences. As such, some confidence can be placed in the results of the simulation. However, a need for independent validation of the present model exists.

The results of the sensitivity tests suggest that the data obtained from NETMAN are directionally logical and that the output is sensitive to input variation. To this extent, a workable model can be said to have been achieved.

From the point of view of operator performance analysis, the model is believed to be highly flexible. The analyst may vary operator characteristics and, through task analytic input, the characteristics of the work performed by each operator. Accordingly, a wide variety of "experiments" may be performed by the analyst to determine optimum conditions.

If agreement of the results from such a model with parallel field exercises can be shown, then considerable savings can be introduced by substituting model simulated "exercises" for field exercises. It should be possible for the model to yield results in a few hours which would require weeks of time and teams of personnel in the actual exercise situation. Moreover, due to the interactive (remote terminal) feature, the completion of such stochastic simulations is highly convenient.

The structuring built into the computer program should allow addition of new subroutines, if warranted, without undue difficulty. Similarly, modifications within any individual subroutine are believed practical. Both the user and the model's developers should collaborate in the design and implementation of such modifications.

We do not contend that the NETMAN model can directly solve operational problems. Similarly, operational exercises may or may not provide solution avenues relative to true operational problems. But, the simulation should normally provide clean and clear indications. Such indications may be confounded in operational exercises. The stochastic model can, presumably, capture the core of a problem and set it in a form in which it can be understood.

Finally, we note that NETMAN like any stochastic model may tell the user what will happen to a system "on the average." However, the officer in the field will be little overjoyed to know something about averages. He wants to know whether current information has entered and been consolidated by the system network. The average will be of little use to him tactically, although it may be very satisfying statistically. And, the person who is wounded because of an information flow bottleneck will find little comfort in knowing that he is incapacitated because of a situation which is really three standard deviations from the mean.

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APPENDIX

USER'S MANUAL FOR THE NETMAN MODEL

User's Manual

The simulation model, NETMAN, is controlled primarily by card input but the capability for changing parameters in the real time mode is provided. Table 1 shows the required card input sequence. This sequencing must be adhered to. The "card types" from 1 to 18 refer to the order and format requirements for each type of input data.

Card Types 1, 2, and 3

Table 2 shows the card column requirements for card types 1 to 3. These data (as well as card type 4) are read in and processed in subroutine SIMPAM.

The first data card is used for simulation identification purposes. The (up to 72 character long) prose descriptor identification information will be printed at the top of each page of printout. A unique title is recommended for each simulation to prevent confusing similar simulation runs. A blank card may be used if no identification information is desired.

The major simulation parameters are identified on card type 2. The number of simulation iterations,NSHIFT, is the first entry. A value of at least 30 is recommended. In the case of simulations with many low probability events, 100 or more iterations will be required in order to produce stable output.

The number of hours over which statistics will be generated is indicated by the variable IHMAX. This value is entered into columns 4-6 on card type 2. The maximum value for IHMAX is 12 as shown in Table 3. The limits shown in Table 3 are set by the current storage allocation in the computer program.

The maximum number of message types; MAXIT, is limited by current dimensioning to 7. Message type is used to specify the task procedure to be used, the message length, and relative frequency.

Table 1

Sequence of Input Data

Card Type	*Description of input card contents/function*
1	Mission title
2	Simulation parameters
3	Printout recording options
4	Task analysis allocation
5	Operator characteristics
6	Message types
7	Hour parameters
8	Mesage originator
9	Error significance probability
10	Error rate
11	Message length - ratio operator, mean
12	Message length - radio operator, standard deviation
13	Message length - controller, mean
14	Message length - controller, standard deviation
15	Task elements
16	Task analytic data
17	Effectiveness computational data
18	Transmission delay data

Table 2

Input--Mission Identification and Simulation Parameters

Mission Title (card type 1)		Card Columns	Format
IDENT	A simulation identifier up to 72 characters long is printed at the top of each page of printout.	1-72	12A6
Simulation Parameters (card type 2)			
NSHIFT	The number of repetitions of the simulation to be performed.	1-3	I3
IHMAX	The maximum number of hours per iteration	4-6	I3
MAXIT	The maximum number of message types	7-9	I3
JMAX	The maximum levels within the network	10-12	I3
MAXNET	The number of networks	13-15	I3
RY	The initial value for the random number generator. It must be odd.	16-24	F9.0
IDAY	The number of days worked without a day off	25-27	I3
NETREF(1)	The number of referees in network #1	28-30	I3
NETREF(2)	The number of referees in network #2	31-33	I3
NETREF(3)	The number of referees in network #3	34-36	I3
Printout Recording Options (card type 3)			
ORO(1)	Recording option #1 - not used	1	A1
ORO(2)	Recording option #2 - not used	2	A1
ORO(3)	Recording option #3 - Detailed data for debug	3	A1
ORO(4)	Recording option #4 - not used	4	A1
ORO(5)	Recording option #5 - If set equal to 1 detailed task performance data are recorded	5	A1
ORO(6)	Recording option #6 - not used	6	A1
ORO(7)	Recording option #7 - If set equal to 1 the input data may be changed in real time mode	7	A1
ORO(8)	Recording option #8 - If set equal to 3, summary tables upon which means are based are printed before the run summary. Also the message characteristics are printed when ORO(5) equals 1.	8	A1
ORO(9)	Recording option #9 - not used	9	A1

Table 3

Maximum Value for Variables

Variable	*Function*	*Upper Limit*
IHMAX	Maximum number of hours	12
JMAX	Number of network levels	4
MAXI	Maximum number of task elements in each task analysis	10
MAXIT	Maximum number of message types	7
MAXK	Maximum number of task analyses	8
MAXNET	Maximum number of networks	3
MAXSEG	Maximum number of time segments on which counts can be maintained	20
NETREF(NET)	Number of referee/radio operator teams per controller	9

The number of levels within the network is identified by the variable JMAX. The value of JMAX must be 4 where level 1 is the referee level, level 2 is the radio operator level, level 3 is the computer level, and level 4 is the controller level.

The number of networks, MAXNET, controls the number of referee/radio operator/controller strings which are processing messages simultaneously through a common computer. Up to three networks may be simulated.

The stochastic processes used within the model are controlled by a pseudo-random number generator. This random number generator must be initialized with an odd number from which it produces its own values for subsequent random numbers.

Human operator fatigue is simulated within the model as a function of hour and as a function of the number of days worked without a day off. The variable IDAY identifies the number of continuous days which have been worked.

The number of referee/radio operator teams per controller may be varied from 1 to a maximum of 9. Different numbers of referee/radio operator teams may be specified for each controller as long as each individual controller has no more than nine teams in his network.

The output recording options control the level of detail of the tabulations. At present, only options 5 and 7 are used. Option 5, provides a maximum level of detail with full recording of task element processing including performance time, success or failure, and the operator factors: stress, fatigue, level of aspiration which are active during the performance of that task element.

Option 7 turns program control over to a time sharing terminal after the basic card input data are entered.

Card Type 4

Table 4 presents the input format for task analysis allocation. Task analyses are assigned according to network level and message type. The same or different task procedures may be assigned to each network level-message type combination up to the maximum of eight task procedures.

Table 4
(Card Type 4)
Input - Task Analysis Allocation

IATA(1,1) - Task procedure used by network level 1 for processing message type 1	1-2	I2
IATA(1,2) - Network level 1 message type 2	3-4	I2
IATA(1,3) - Network level 1 message type 3	5-6	I2
IATA(1,4) - Network level 1 message type 4	7-8	I2
IATA(1,5) - Network level 1 message type 5	9-10	I2
IATA(1,6) - Network level 1 message type 6	11-12	I2
IATA(1,7) - Network level 1 message type 7	13-14	I2
IATA(1,8) - Network level 1 message type 8	15-16	I2
IATA(2,1) - Network level 2 message type 1	17-18	I2
IATA(2,2) - Network level 2 message type 2	19-20	I2
IATA(2,3) - Network level 2 message type 3	21-22	I2
IATA(2,4) - Network level 2 message type 4	23-24	I2
IATA(2,5) - Network level 2 message type 5	25-26	I2
IATA(2,6) - Network level 2 message type 6	27-28	I2
IATA(2,7) - Network level 2 message type 7	29-30	I2
IATA(2,8) - Network level 2 message type 8	31-32	I2
IATA(3,1) - Network level 3 message type 1	33-34	I2
IATA(3,2) - Network level 3 message type 2	35-36	I2
IATA(3,3) - Network level 3 message type 3	37-38	I2
IATA(3,4) - Network level 3 message type 4	39-40	I2
IATA(3,5) - Network level 3 message type 5	41-42	I2
IATA(3,6) - Network level 3 message type 6	43-44	I2
IATA(3,7) - Network level 3 message type 7	45-46	I2
IATA(3,8) - Network level 3 message type 8	47-48	I2
IATA(4,1) - Network level 4 message type 1	49-50	I2
IATA(4,2) - Network level 4 message type 2	50-52	I2
IATA(4,3) - Network level 4 message type 3	53-54	I2
IATA(4,4) - Network level 4 message type 4	55-56	I2
IATA(4,5) - Network level 4 message type 5	57-58	I2
IATA(4,6) - Network level 4 message type 6	59-60	I2
IATA(4,7) - Network level 4 message type 7	61-62	I2
IATA(4,8) - Network level 4 message type 8	63-64	I2

Card Type 5

Table 5 shows the input format for the operator characteristics. Four cards of card type 5 are read in: (one for each network level) referee (J= 1), radio operator (J= 2), computer (J=3), and controller (J= 4). The characteristics are speed, precision, stress threshold and level of aspiration.

Table 5

Input - Operator Characteristics

Card Type 5		*Card Column*	*Format*
J	Network level. Note: a card is required for level 3 (the computer) despite the fact that these factors are not used	1-2	I2
F(J)	Operator speed	3-12	F10.2
PREC(J)	Operator precision	13-22	F10.2
STRM(J)	Operator stress threshold	23-32	F10.2
ASP(J)	Operator level of aspiration	33-42	F10.2

Operator speed, F(J), is scaled from .9 to 1.1. An operator assigned a .9 speed is approximately 10 percent faster than a 1.0 or average operator, and a 1.1 operator is about 10 percent slower than an average operator.

Operator precision, PREC(J), is scaled similarly to speed. An operator with a precision of .9 would be expected to commit fewer errors than an average (1.0) operator. Similarly, an operator with a precision of 1.1 would be expected to commit more errors than an average operator.

Operator stress is a facilitating force produced by working almost continuously with no breaks. As a stress increases, performance will improve up to some maximum. When stress reaches the stress threshold, the facilitary effect disappears to simulate the case in which operator is working as fast as he can. Stress threshold from 2.1 to 2.7 may be selected. A stress threshold of 2.3 has been found to be generally satisfactory.

Level of aspiration represents the degree of success or error free performance which a person generally tries to maintain. Levels of aspiration of from .90 to .99 have been found to be appropriate where 1.0 represents striving for absolute perfection. Level of aspiration is modified during a simulation depending on the actual success/fail ratio and level of stress.

Card type 5 data is read in by subroutine PEOPLE.

Card Type 6

Subroutine INTYPE reads in message type data on card type 6. One card type 6 is read in for each message type as specified by MAXIT. A six character name, NMTYP(IT), is entered and this is followed by the mean number of messages generated by a stimulus message, RMPS(IT). It is assumed that each incoming message to the referee will generate at least one and, sometimes more than one message. The actual number of messages generated is determined stochastically for each incoming message.

Table 6

Input - Message Types

Card Type 6		*Card Columns*	*Format*
IT	Message type	1-2	I2
NMTYP(IT)	Name of message type	3-8	A6
RMPS(IT)	Mean number of messages generated by the referee for each stimulus message	9-18	F10.2

Card Type 7

The hour parameters (card type 7) are read in subroutine HOUR. The number of type 7 cards read is determined by IHMAX.

IGP(IH) is the mean number of messages (from whatever source) received by each referee (see Table 7). This number is used in conjunction with IGR (the standard deviation of IGP) to stochastically* determine the actual number of messages received by the referee. Note that after this number is determined, RMPS is used to determine how many messages actually enter the system.

After messages are generated, the variable FRET is used to determine the message type. FRET is the proportion of all messages which are of the particular type. For example in hour IH the values in FRET(1,IH) to FRET(7,IH) might be .1, .2, .3, .4, .5, .6, 1.0. Notice that the proportions must be cumulative. The actual proportion frequency of type 2 would be .1 or 10 per cent. The highest numbered messages type used must always have a value of 1.0.

**Note: In all calls for random number from a normal distribution extreme values greater than 2.5 sigma are not allowed. In the case of a uniform distribution, the allowed range is from .001 to .999.*

Table 7

Input - Hour Parameters

Card Type 7		Card Column	Format
IH	Hour number	1-2	I2
IGP(IH)	*Mean number of messages incoming to each* referee	3-4	I2
IGR(IH)	Standard deviation of IGP(H)	5-6	I2
IUR(IH)	Not used	7-8	I2
FRET(1,IH)	Cumulative proportional frequency - Message type 1	10-14	1X,F5.5
FRET(2,IH)	Message type 2	15-19	F5.5
FRET(3,IH)	Message type 3	20-24	F5.5
FRET(4,IH)	Message type 4	25-29	F5.5
FRET(5,IH)	Message type 5	30-34	F5.5
FRET(6,IH)	Message type 6	35-39	F5.5
FRET(7,IH)	Message type 7	40-44	F5.5
FREP(1,IH)	Cumulative proportional frequency - Message priority 1	59-54	5X,F5.5
FREP(2,IH)	Message priority 2	55-59	F5.5
FREP(3,IH)	Message priority 3	60-64	F5.5
FREP(4,IH)	Message priority 4	65-69	F5.5
FREP(5,IH)	Message priority 5	70-74	F5.5

Card Type 8

Table 8 shows the input format for the card type 8 message originator data. Three sources of message organization are considered: controller, another referee, and current referee. The probabilities across message originators are also cumulative. For example, the values in ORIG(1,1), ORIG(2,1), and ORIG(3,1) might be .1, .4, and 1.0. This would mean that the controller originates 10 per cent of the messages in hour 1, colateral referees generate 30 per cent, and the referee generates them himself from his own sources 60 per cent of the time. Naturally, if less than 12 hours are being simulated, data for hours not used may be left blank. Three type 8 cards must be read in and the order must be controller data (IOR= 1), other referee data (IOR= 2), and present referee (IOR= 3).

Table 8

Input - Message Originator

Card Type 8 *(3 cards, IOR= 1 to 3)*		*Card Columns*	*Format*
ORIG(IOR,1)	The cumulative probability that message originator IOR (1= controller, 2= another referee, 3= present referee) originated the current message in hour 1	1-4	F5.3
ORIG(IOR,2)	Same in hour 2	6-10	F5.3
ORIG(IOR,3)	Same in hour 3	11-15	F5.3
ORIG(IOR,4)	Same in hour 4	16-20	F5.3
ORIG(IOR,5)	Same in hour 5	21-25	F5.3
ORIG(IOR,6)	Same in hour 6	26-30	F5.3
ORIG(IOR,7)	Same in hour 7	31-35	F5.3
ORIG(IOR,8)	Same in hour 8	36-40	F5.3
ORIG(IOR,9)	Same in hour 9	41-45	F5.3
ORIG(IOR,10)	Same in hour 10	46-50	F5.3
ORIG(IOR,11)	Same in hour 11	51-55	F5.3
ORIG(IOR,12)	Same in hour 12	56-60	F5.3

Card Types 9 and 10

Various sources and aspects of error generation are considered. These error aspects are entered in subroutine ERROR and read in on card types 9 and 10 as shown in Table 9.

Two variables read in concerning error are PUL and PUS. PUL and PUS are the probabilities of errors being undetected (and therefore uncorrected) and entering the computer. PUL is the probability of an insignificant error while PUS is the probability of a significant error. PUL and PUS are used in the computation of information loss, INFOLS, and in the computation of the accuracy overall effectiveness component.

Errors are divided into four categories as shown in Table 9. One card type 10 must be entered for each of the four error types although the order of error types is not important since the appropriate type, IE, is identified on the card itself.

Different error rates, ER(IE, IT), may be identified for each error type/message type combination. These are error rates per 100 characters in the message. Error occurrence in the model is a function of not only the average error rate, ER, but also the precision, PREC(J), of the network level performing the work.

Finally, the probability that a given error was caused by the referee is indicated by ERPG(IE) and the probability that an error is caused by the radio operator is indicated by ERPI(IE).

Table 9

Input - Error Data

Error significance probability - Card type 9

		Card Columns	Format
PUL	The probability of entering a non important undetected error into computer for each message	1-10	F10.3
PUS	The probability of entering a significant undetected error into the computer for each message	11-20	F10.3

Error rate - Card type 10 (4 cards, IE= 1 to 4)

IE	Type of error, 1= commission, 2= abbreviation, typographical or spacing, 3= omission, 4= other	1	I1
ER(IE,1)	Error rate per 100 characters of message type 1	2-9	F8.8
ER(IE,2)	Same for message type 2	10-17	F8.8
ER(IE,3)	Same for message type 3	18-25	F8.8
ER(IE,4)	Same for message type 4	26-33	F8.8
ER(IE,5)	Same for message type 5	34-41	F8.8
ER(IE,6)	Same for message type 6	42-49	F8.8
ER(IE,7)	Same for message type 7	50-57	F8.8
ERPG(IE)	Probability of an error due to referee error	58-62	F5.2
ERPI(IE)	Probability of an error due to radio operator error	63-67	F5.2

The message that the referee prepares and the radio operator transmits is different than the message received by the controller. The highly coded message prepared by the referee ranges from 12 to 22 characters in length while the message received by the controller is longer and has been largely decoded into prose.

Card Types 11, 12, 13, and 14

Table 10 shows the card type 11, 12, 13, and 14 formats required for entering the message length data. These data are entered in subroutine INCHAR.

The length of the message prepared by the referee is determined stochastically from a normal distribution with a mean of INC(IT) and a standard deviation of INS(IT). Since the message length is identified by message type, different message types can have different mean lengths.

The length of the message received by the controller is also generated stochastically from a normal distribution with a mean of CHRCON(IT) and a standard deviation of CHSCON(IT). The message length is one factor in the determination of the time to process a message.

Table 10

Input - Message Length

Message length-radio operator, mean. Card type 11.		*Card Columns*	*Format*
INC(1)	Mean message length (# of characters) of message type 1 to radio operator	1-9	F9.9
INC(2)	Same for message type 2	10-19	F10.10
INC(3)	Same for message type 3	20-29	F10.10
INC(4)	Same for message type 4	30-39	F10.10
INC(5)	Same for message type 5	40-49	F10.10
INC(6)	Same for message type 6	50-59	F10.10
INC(7)	Same for message type 7	60-69	F10.10

Note: INC is explicitely specified as REAL.

Message length - radio operator standard deviation. Card type 12.

INS(1)	Standard deviation of INC(1)	1-9	F9.9
INS(2)	Standard deviation of INC(2)	10-19	F10.10
INS(3)	Standard deviation of INC(3)	20-29	F10.10
INS(4)	Standard deviation of INC(4)	30-39	F10.10
INS(5)	Standard deviation of INC(5)	40-49	F10.10
INS(6)	Standard deviation of INC(6)	50-59	F10.10
INS(7)	Standard deviation of INC(7)	60-69	F10.10

Note: INS is explicitely specified as REAL.

Message length- Controller, mean. Card type 13.

CHRCON(1)	Mean message length (# of characters) of message type 1 to the controller	1-10	F10.2
CHRCON(2)	Same for message type 2	11-20	F10.2
CHRCON(3)	Same for message type 3	21-30	F10.2
CHRCON(4)	Same for message type 4	31-40	F10.2
CHRCON(5)	Same for message type 5	41-50	F10.2
CHRCON(6)	Same for message type 6	51-60	F10.2
CHRCON(7)	Same for message type 7	61-70	F10.2

Message length- Controller, standard deviation. Card type 14.

CHSCON(1)	Standard deviation of CHRCON(1)	1-10	F10.2
CHSCON(2)	Standard deviation of CHRCON(2)	11-20	F10.2
CHSCON(3)	Standard deviation of CHRCON(3)	21-30	F10.2
CHSCON(4)	Standard deviation of CHRCON(4)	31-40	F10.2
CHSCON(5)	Standard deviation of CHRCON(5)	41-50	F10.2
CHSCON(6)	Standard deviation of CHRCON(6)	51-60	F10.2
CHSCON(7)	Standard deviation of CHRCON(7)	61-70	F10.2

Exact, step by step, descriptions of the procedures used to process a message must be entered. Each procedure is termed a task analysis, K, and is composed of task elements, I. As shown in Table 3, a maximum of eight task analyses, MAXK, can be entered and a single task analysis can contain no more than 10 task elements, MAXI.

Card Types 15 and 16

The task analytic information is entered into subroutine TASK through card type 15 whose format is described in Table 11.

The first parameter to be entered is the total number of task elements across all task analyses, NTE. The value of NTE determines the number of card type 16's to be read in.

Each card type 16 identifies the task analysis, K, and task element, I, to which it refers. Accordingly, these cards need not be in serial order or even grouped by task. It is recommended however, that they be sequenced in order to reduce the probability of a set up error.

The variable JTYPE(I,K) identifies special types of task elements which must be processed differently from regular task elements. Types 2 and 5 identify task elements in which message length must be taken into consideration while types 3 and 4 merely bypass some of the normal task element processing. Special types of task elements can be added to the program if further effects are desired.

Task criticality determines whether or not simulated operator failure or success on the task will be considered in the computation of the operators performance level, PERF(M). The performance level is compared with the level of aspiration, ASP(M), to determine if an aspiration increment, PAFA, is warranted.

Message processing within the model is documented in terms of message segments. Message segments are defined by the user. However, a segment generally indicates critical points within the message handling process. Up to 20 segments, MAXSEG, may be accounted for where segment 1 is the time at which processing on the message by the referee begins. Other segment end points, 2,3,..., 20, are indicated in END(I,J).

Table 11

Input - Task Analysis

Task elements- Card type 15		Card Columns	Format
NTE	Number of task elements to be read in	1-2	I2
Task analysis data - Card type 16 (NTE cards read in)			
K	Task analysis number	1-2	I2
I	Task element number	3-5	I3
JTYPE(I,K)	Task element type. Type 2 is an element for which the number of referee/radio operator message characters will be multipled by the stochastically determined time to produce the time required to process the message. Type 3 is a decision element where operator factors of speed, precision, stress are not allowed to affect the duration or success of the element. Type 4 is an equipment element where operator factors are not considered and the task cannot be failed. Type 5 us the same as Type 2 except that controller message length is used. Type 6 is an element for which transmission to the computer is required.	7	1X,I1
CRIT(I,K)	Criticality of the task element. A "C" identifies a critical task	8	A1
END(I,K)	Message processing segment ended by this element if any.	9-10	I2
IJF(I,K)	The number (i.e. I) of the task element which will be performed subsequent to the current task if the current task is failed.	11-13	I3
IJS(I,K)	The number of the task element which will be performed subsequent to the current task if the current task is performed successfully. If left blank it signifies the completion of the task analysis.	14-16	I3
AVGTM(I,K)	The average performance time	17-26	F10.2
SIGMA(I,K)	Standard deviation of AVGTM(I,K)	27-36	F10.2
AVPROB(I,K)	Task element success probability	37-46	F10.2
UETYPE(I,K)	Undetected error type. T= transform	47	A1
UEP(I,K)	Undetected error probability (for non transform)	48-53	F6.2

The sequence in which task elements are performed is controlled by IJF(I,K) and IJS(I,K). If the task element I is failed than the element specified by IJF(I,K) will be performed next, while if the element is successful then IJS(I,K) will be performed next. The probability that the element will be successful is indicated by AVPROB(I,K) while the probability that the task will be failed is 1 minus AVPROB(I,K)

The average time to perform the task element is indicated by AVGTM(I,K) while the standard deviation is SIGMA(I,K). A number from a normal distribution is used to stochastically determine the particular duration at a given occurrence.

A particular error type accounted for, UETYPE(I,K) is the transform error. In this case, the number of characters in the message being prepared by the referee is used to stochastically produce errors in the message. The probability of these errors is indicated in UEP(I,K).

The overall mission effectiveness is computed as a weighted combination of four types of effectiveness: thoroughness, completeness, responsiveness and accuracy. Due to the fact that these factors are not independent, a number of relationship factors must be used in the computation of mission (overall) effectiveness.

Card Type 17

Table 12 shows the required card type 17 entries for computing mission effectiveness. All of these values are entered in the subroutine EFFCOM.

Correlations between each of the effectiveness components, CC12 through CC34 are entered first. The entries are followed by the relative weight or importance, W(NEC), of each component. In the absence of other information, correlations of .50 between components and equal weights of .25 for each component have been found to be applicable. However, situations in which a particular factor is paramount would warrant assigning a higher weight to that factor. The weights must sum to 1.0.

When the radio operator attempts to send a message to the computer, he must first find an open frequency. This point in the radio operator's task analysis is identified by a type 6 task element. When this type task element is involved, the transmission delay, DEL(IH), is used with the standard deviation, DELSD(IH), and a random number from a normal distribution. This time is added to the task element processing time. The format for entering the required transmission delay data is shown in Table 13 (card type 18).

Table 12

Input - Effectiveness Computational Data

Effectiveness components (Card type 17)		*Card Columns*	*Format*
CC12	Correlation between thoroughness and completeness	1-4	F4.4
CC13	Correlation between thoroughness and responsiveness	5-9	F5.5
CC14	Correlation between thoroughness and accuracy	10-14	F5.5
CC23	Correlation between completeness and responsiveness	15-19	F5.5
CC24	Correlation between completeness and accuracy	20-24	F5.5
CC34	Correlation between responsiveness and accuracy	25-29	F5.5
W(1)	Relative weight of thoroughness in computing overall effectiveness	30-34	F5.5
W(2)	Weight of completeness	35-39	F5.5
W(3)	Weight of responsiveness	40-44	F5.5
W(4)	Weight of acucracy	45-49	F5.5

The weights must sum to 1.0.

Table 13

Input - Transmission Delay Data

Transmission (Card type 18 IHMAX cards)		*Card Columns*	*Format*
DEL(IH)	Mean delay required for radio operator to locate an open frequency	1-10	F10.2
DELSD(IH)	Standard deviation of DEL(IH)	11-20	F10.2

Operations and Output

The program may be controlled through either a batch processing or a time sharing (real time) mode. The experimenter control or time sharing option must be indicated in the card input data.

The card input data are stored in the data file MANMOD*NETCARD1. A new set of card data is entered in the following card sequence:

```
@RUN......     (standard run)
@ASG, A    MANMOD*NETCARD1.
@DATA,IL   MANMOD*NETCARD1
   .
   .
   .
   card data as described in previous section
   .
   .
   .
@END
@FIN
```

Inserting a set of cards in this fashion automatically erases the previous data stored in NETCARD1.

A simple print of the card data file is obtained through the card sequence.

```
@RUN... (standard run card)
@ASG,A    MANMOD*NETCARD1.
@DATA,L
@END
@FIN
```

The NETMAN program is called up on the U1108 facility at Edgewood Arsenal byan appropriate RUN identification followed by the instructions:

```
@ASG,A    MANMOD*TRY.
@ADD     TRY.NETMAN1
```

This instruction contains the following:

```
@ASG,A    NETMAN.
@ASG,A    NETPRT1.
@ASG,A    NETCARD1.
@USE      7,NETCARD2
@USE      2,NETPRT2
@XQT      NETMAN.NETMAN
```

which prepares the program file (NETMAN), the output file (NETPRT1), and the input file (NETCARD1) and then executes the program.

When the program is in the experimenter control mode, a number of messages and data change categories will be presented to the time sharing terminals. These categories are self explanatory. When all desired simulations have been completed, the program is terminated by selecting a data category greater than 22 to be changed (only 22 categories are available to be changed) and then entering @END when the computer indicates it is ready for another instruction.

The output record from the simulation may be printed in a number of different ways. The fastest is to immediately enter the following instructions at the time sharing console:

(no RUN instruction is necessary unless the previous RUN was terminated)

```
@ASG,CP T
@BRKPT  PRINT$/T
@DATA,L  NETPRT1
@END
@BRKPT  PRINT$
@FREE  T
@SYM   T,,ARI318
@END
```

The results should begin printing on the printer almost immediately. "ARI318" identifies the printer in the ARI facility.

The output data may also be printed via cards using the following cards:

```
@RUN......
@ASG,A  MANMOD.NETPRT1
@DATA,L  MANMOD.NETPRT1
@END
@FIN
```

In the case that a printer is not immediately available, printouts may be directed to the Edgewood Arsenal for mailing to the user. The instructions to be used in this case are:

```
@RUN.......     (if required)
@SUSPEND
@DATA,L    MANMOD*NETPRT1
@END
@RESUME,P
@FIN
```

The P option following the instruction RESUME will cause an immediate printout (when a printer is available) at the U1108 facility at the Edgewood Arsenal.

The print file must be printed or copied to another file before the simulator program is called up again. Otherwise, the data will be irreversibly lost as new data are entered into the file. The data may be copied by the following sequence of instructions.

```
@RUN.......     (if necessary)
@ASG,CP    MANMOD*NEWFILE.,F2///1000
@ASG,A     MANMOD*NETPRT1
@COPY      MANMOD*NETPRT1.,MANMOD*NEWFILE.
@END
```

where any new file name may be used as long as it is not currently catalogued under the MANMOD project ID.

Interactive Mode

In the interactive mode, the simulation parameters may be changed through a direct time sharing computer link. The procedure required to call the program is described in the section on program control language. Once the program has been called in the interactive mode, the display shown below will appear at the remote console:

```
                 AN ON-LINE EXPERIMENTER CONTROL OF THE
                 ----------------NETMAN-----------------

                             PREPARED FOR

                      THE ARMY  RESEARCH INSTITUTE FOR
                 THE BEHAVIORAL AND SOCIAL SCIENCES

                                  BY

                   APPLIED PSYCHOLOGICAL SERVICES

   IN ORDER FOR THE PROGRAM TO RECEIVE YOUR INSTRUCTIONS IMMEDIATELY
   SET THE CRT IN THE CONVERSATIONAL MODE (I.E.  DEPRESS BUTTON CONV.)

   INSTRUCTIONS SHOULD BE INSERTED BETWEEN BRACKETS WHERE INDICATED.

   THE NEW LINE BUTTON SHOULD BE DEPRESSED AFTER ENTRY OF INSTRUCTIONS.
```

After receiving this display, the new line (or return button depending on the type of time sharing terminal) button should be depressed. A new display will appear:

```
   [     ]  WHICH DATA CATEGORY IS TO BE CHANGED?
            ENTER 99 IF YOU WISH TO SEE THE TABLE OF CATEGORIES.
```

The data category to be changed should be placed in the location indicated by brackets. This number must be right justified (i.e., no blanks between number and right bracket). An entry of 99 (followed by depressing the new line button) will cause a list of the categories which can be changed to appear. After viewing the list, depressing the new line button will return the program to the display shown above. The new line button must be pressed after each entry or point at which the computer stops and is waiting for a response. Note that numbers entered in a CRT type terminal should be entered exactly within the brackets whereas an entry on a paper printer type of terminal requires that the entry be transposed one column to the right of the indicated location. In both cases, it is not required that the entry be made on the line on which the brackets appear. The new entry may be made on any line, as long as the correct columns are used.

An example of a simulation change would be to enter 12 as the data category to be changed. The old simulation identifier will appear as shown below:

```
[SENSIT RUN 9 16 MSG WITH 17 CHAR    ]
INSERT NEW MISSION TITLE ABOVE
```

A new title should be entered between the brackets.

The data category display will appear again. If 9 is selected, the following display will appear:

```
[    ]=HOUR        [    ]=NUMBER OF MESSAGES.
INDICATE CHANGES ABOVE. CHANGES WILL BE REFLECTED BELOW

    MEAN NUMBER OF MESSAGES ARRIVING PER HOUR
        HOUR       NUMBER OF MESSAGES
          1             10
          2             10
          3              0
          4              0
          5              0
          6              0
          7              0
          8              0
          9              0
         10              0
         11              0
         12              0
```

By filling in the appropriate column(s). The mean number of messages arriving each hour can be changed. If any change is indicated, the display will repeat with the new value shown replacing the old value. When all desired changes have been entered, depressing the new line key without having made any entry will return the program to the data category selection display.

As a third example, if data category 4 is selected operator precision may be changed.

```
[      ]= OPERATOR NUMBER   [      ]= PRECISION
INDICATE CHANGES ABOVE. CHANGES WILL BE REFLECTED BELOW.
OPERATOR           PRECISION
   1                  1.00
   2                  1.00
   3                  1.00
   4                  1.00
```

If any precision value is changed, the table will be displayed and indicate the new value. When no change is indicated the data category selection will return. The following variables may be selected for change:

1. number of iterations
2. output options
3. operator type data
4. operator precision
5. operator aspiration
6. mean time for tasks
7. message error rate
8. probability of an error of low significance
9. incoming messages to referee
10. message priority occurrence rate
11. sigma for characters
12. mission title
13. task analysis indicators
14. operator speed
15. operator threshold
16. sigma for task time
17. probability of significant error
18. sigma referee messages
19. message type occurrence rate
20. mean number of characters per referee message

The technique for change in all cases is the same as that described above.

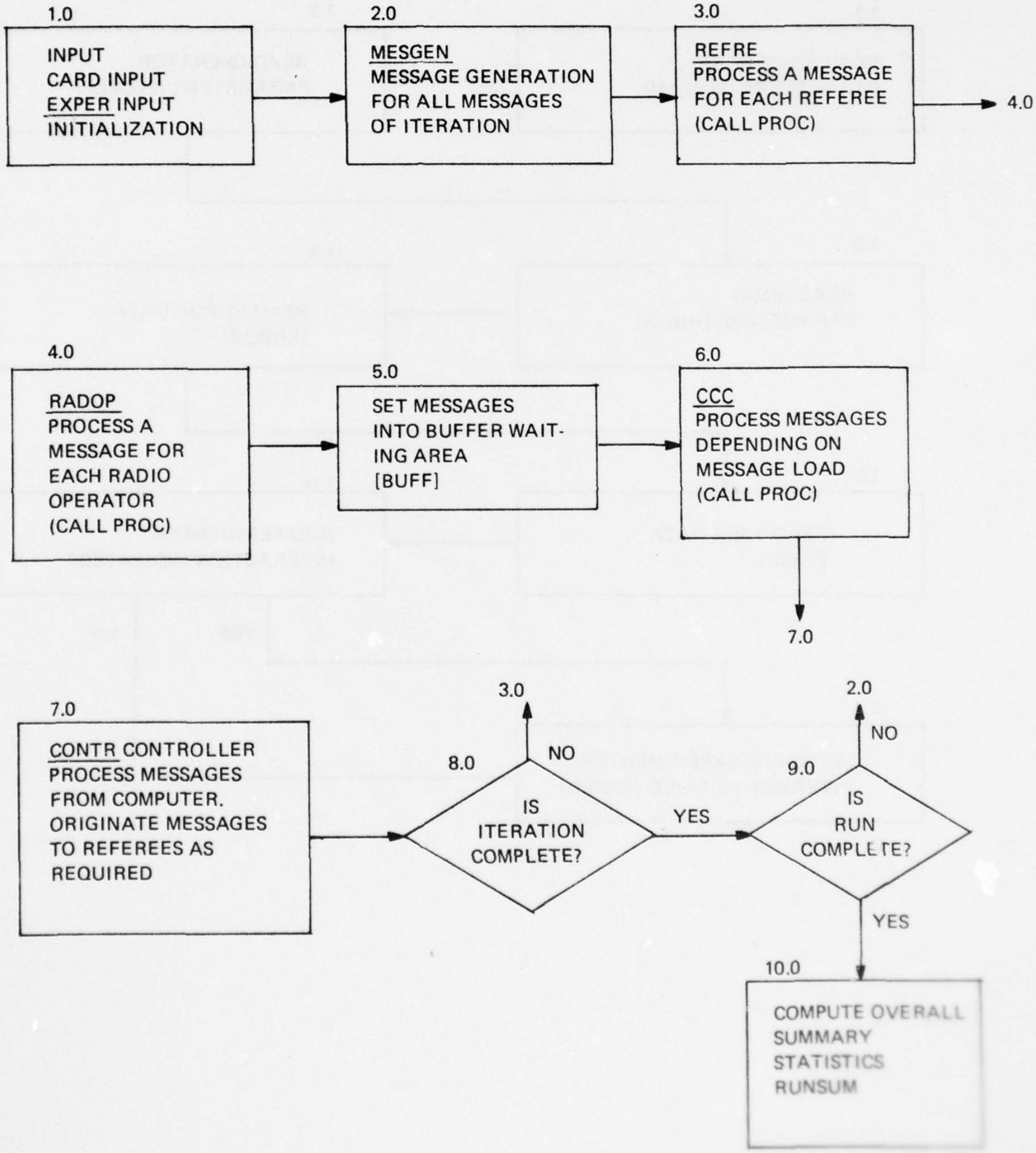
Making no entry in the data selection display signals the completion of data changing and the program goes automatically into simulation. Any changes made will be automatically recorded in the print file.

After the simulation is completed, the program will return (after showing summary data) to the data selection display. Entering the value 76 in the category to be changed will provide a normal termination of the program. This is the desired way to terminate the program since it causes the program to write an end of file mark in the print file. Without this end of file mark, file printing problems can be induced.

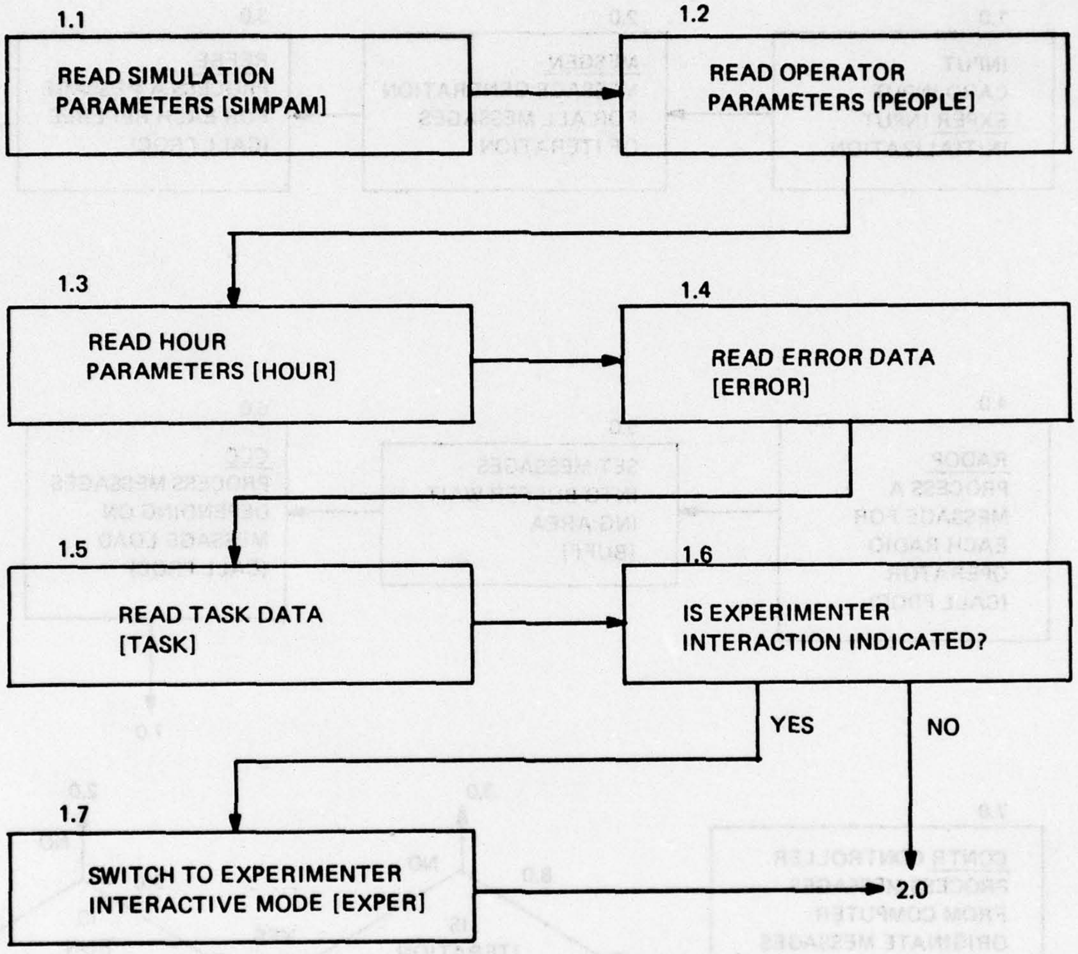
In the process of adapting the NETMAN model for interactive processing extended core was necessary. This system option was exercised through the addition of the statement "COMPILER(XM= 2)" in front of each subroutine.

MODEL FLOW

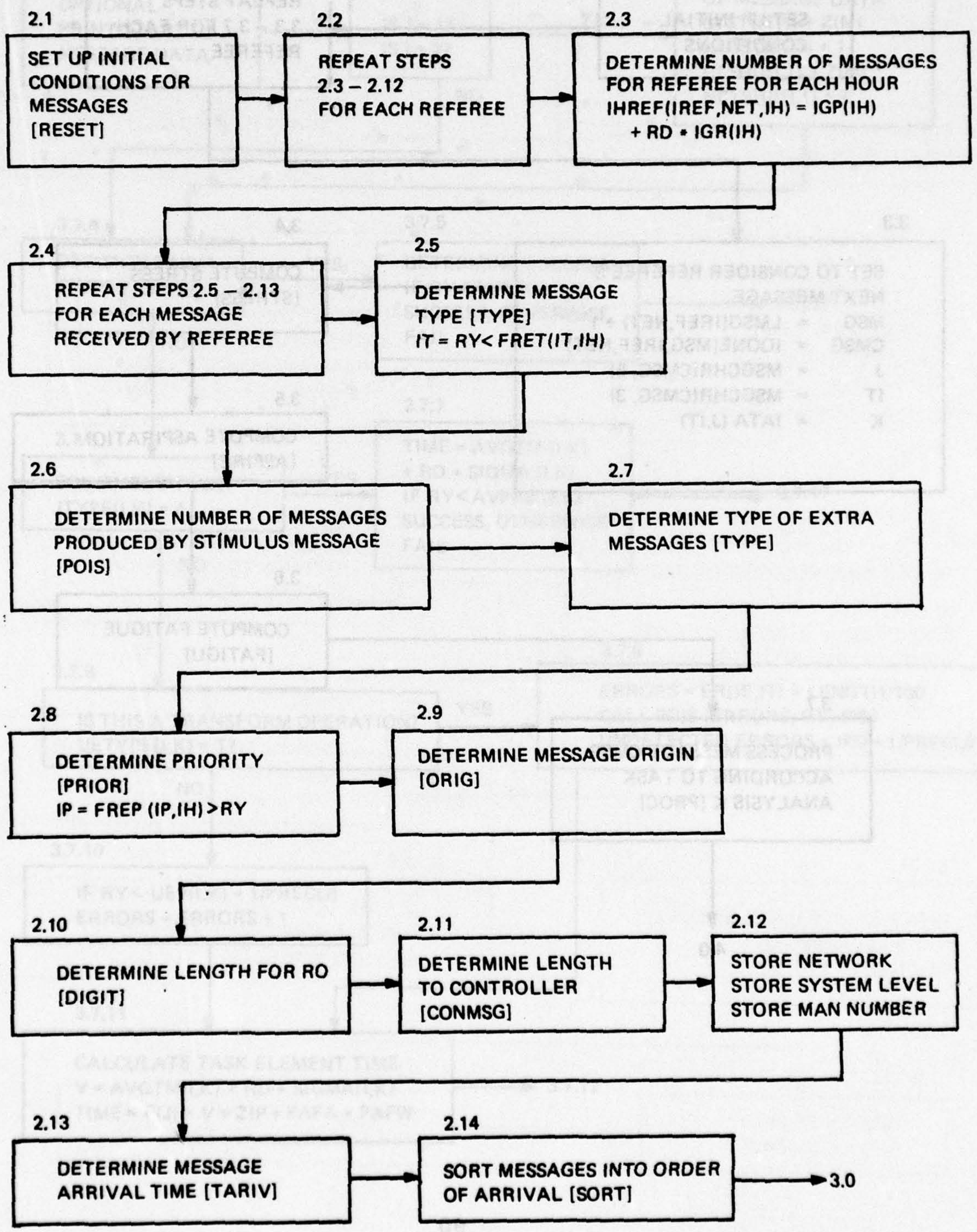
NETMAN MACRO FLOW



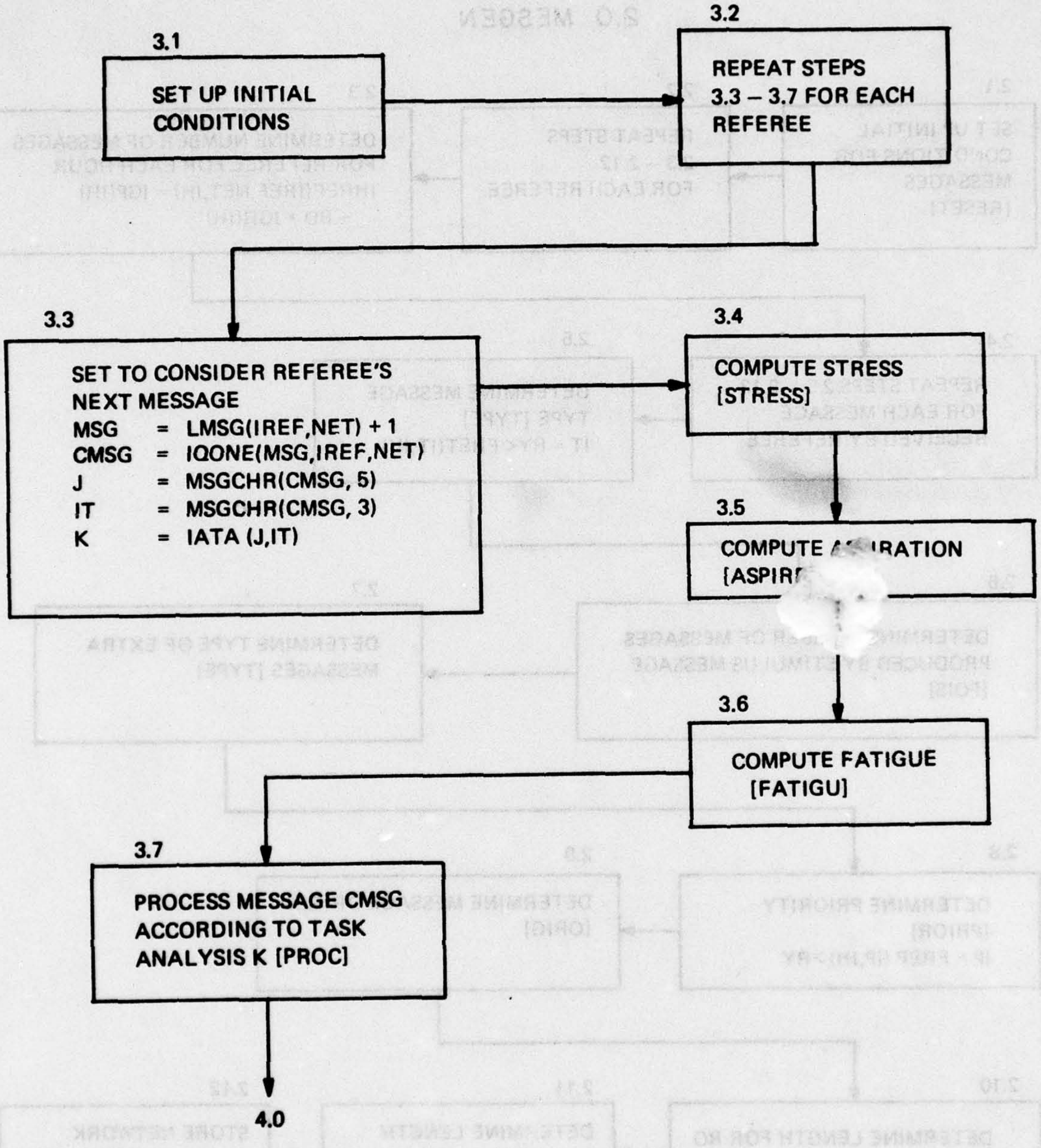
I.O INPUT ROUTINES



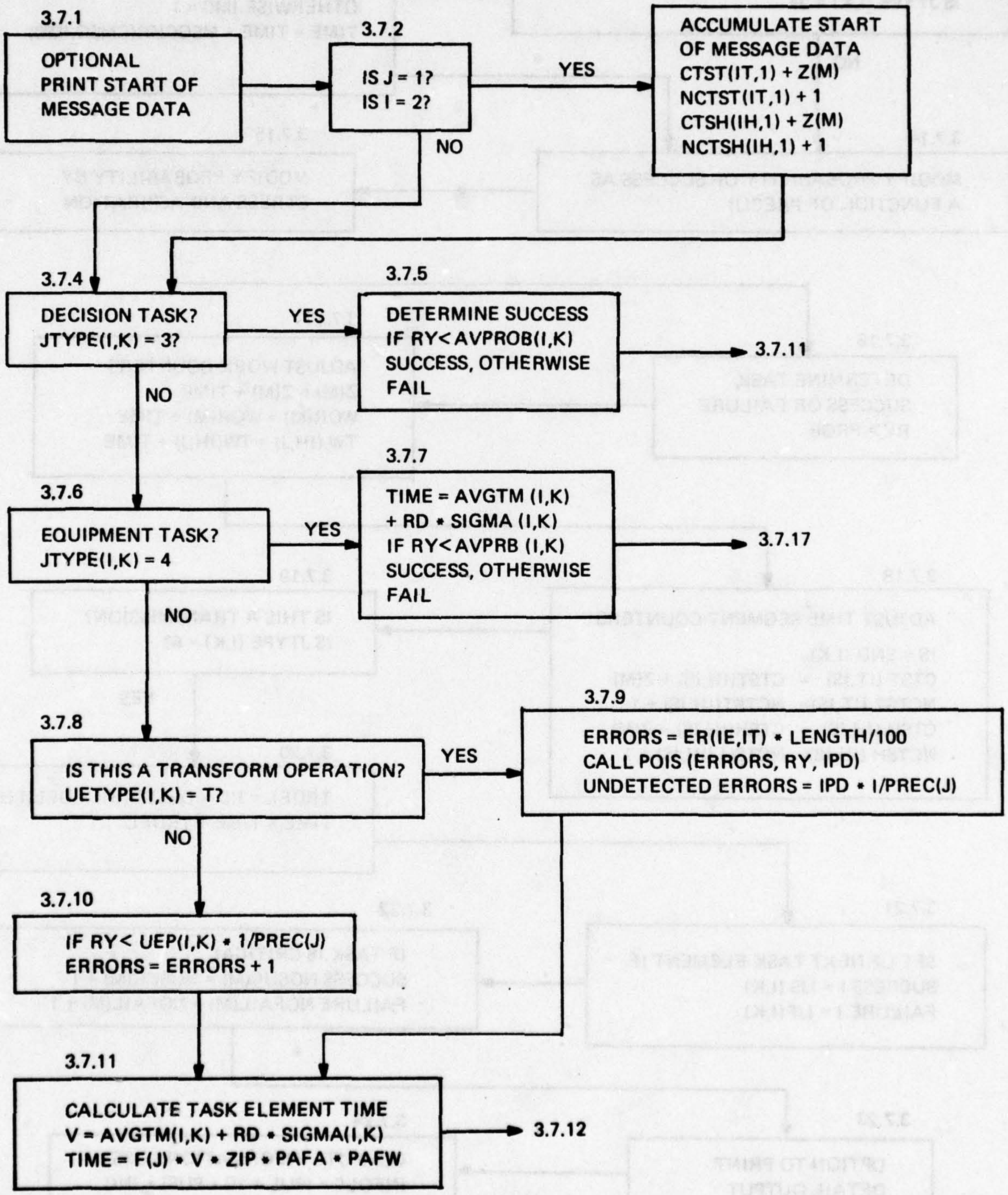
2.0 MESGEN

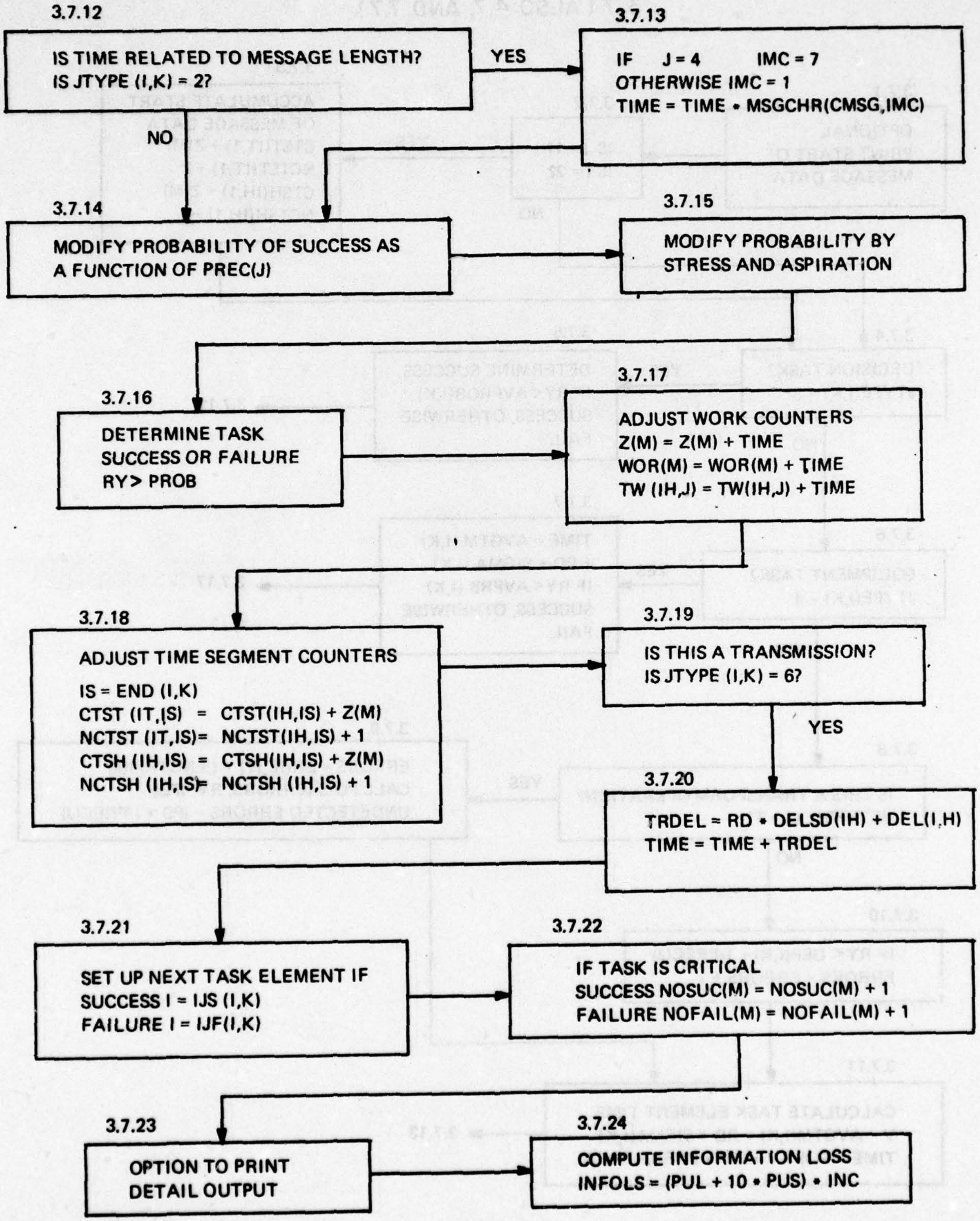

2.1
SET UP INITIAL CONDITIONS FOR MESSAGES [RESET]
2.2
REPEAT STEPS 2.3 – 2.12 FOR EACH REFEREE
2.3
DETERMINE NUMBER OF MESSAGES FOR REFEREE FOR EACH HOUR
IHREF(IREF,NET,IH) = IGP(IH) + RD * IGR(IH)
2.4
REPEAT STEPS 2.5 – 2.13 FOR EACH MESSAGE RECEIVED BY REFEREE
2.5
DETERMINE MESSAGE TYPE [TYPE]
IT = RY< FRET(IT,IH)
2.6
DETERMINE NUMBER OF MESSAGES PRODUCED BY STIMULUS MESSAGE [POIS]
2.7
DETERMINE TYPE OF EXTRA MESSAGES [TYPE]
2.8
DETERMINE PRIORITY [PRIOR]
IP = FREP (IP,IH) >RY
2.9
DETERMINE MESSAGE ORIGIN [ORIG]
2.10
DETERMINE LENGTH FOR RO [DIGIT]
2.11
DETERMINE LENGTH TO CONTROLLER [CONMSG]
2.12
STORE NETWORK
STORE SYSTEM LEVEL
STORE MAN NUMBER
2.13
DETERMINE MESSAGE ARRIVAL TIME [TARIV]
2.14
SORT MESSAGES INTO ORDER OF ARRIVAL [SORT]
3.0

3.0 REFRE

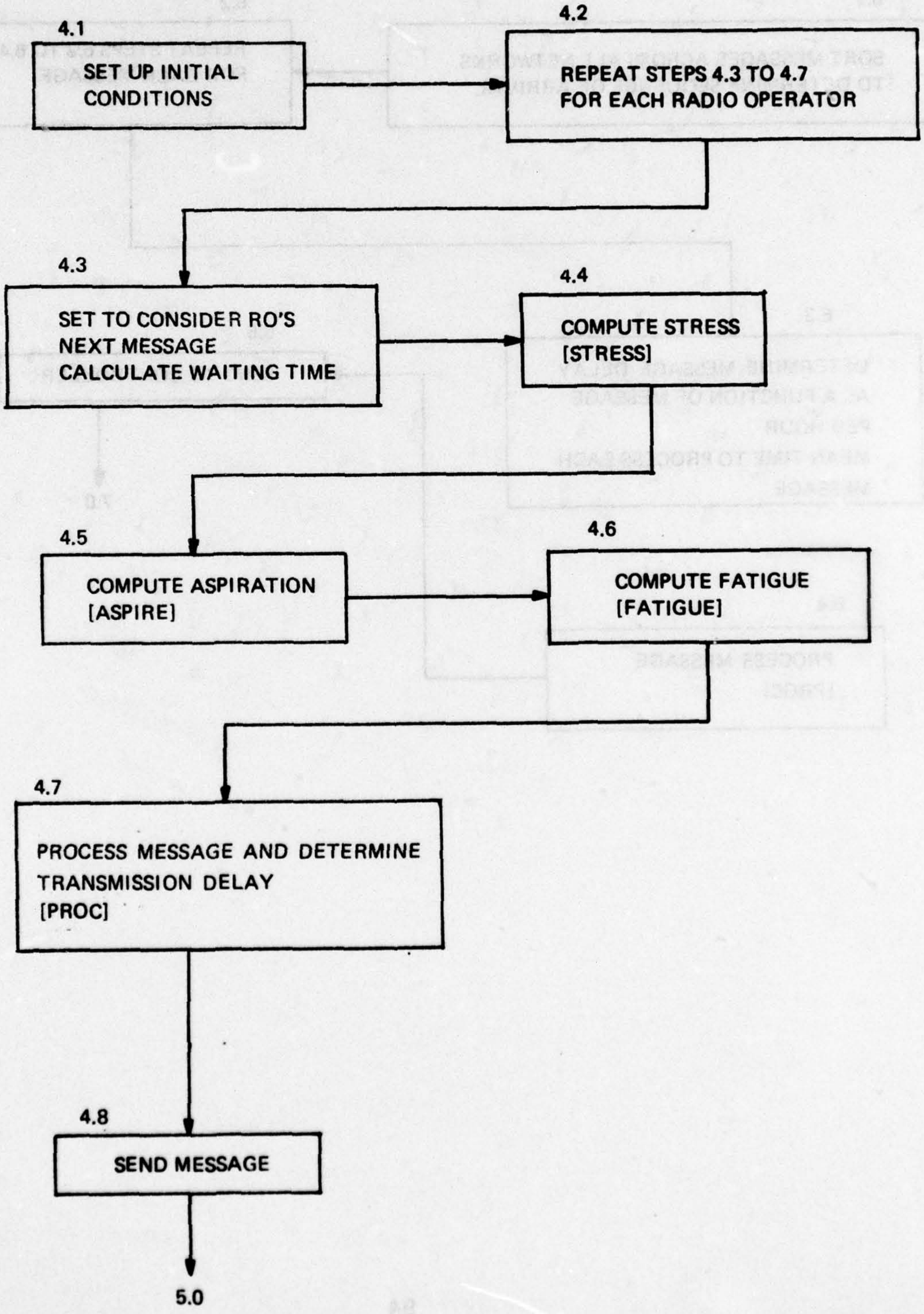

3.1
SET UP INITIAL CONDITIONS
3.2
REPEAT STEPS 3.3 – 3.7 FOR EACH REFEREE
3.3
SET TO CONSIDER REFEREE'S NEXT MESSAGE
MSG = LMSG(IREF,NET) + 1
CMSG = IQONE(MSG,IREF,NET)
J = MSGCHR(CMSG, 5)
IT = MSGCHR(CMSG, 3)
K = IATA (J,IT)
3.4
COMPUTE STRESS [STRESS]
3.5
COMPUTE A[illegible]RATION [ASPIR[illegible]
3.6
COMPUTE FATIGUE [FATIGU]
3.7
PROCESS MESSAGE CMSG ACCORDING TO TASK ANALYSIS K [PROC]
4.0

3.7 (ALSO 4.7, AND 7.7)

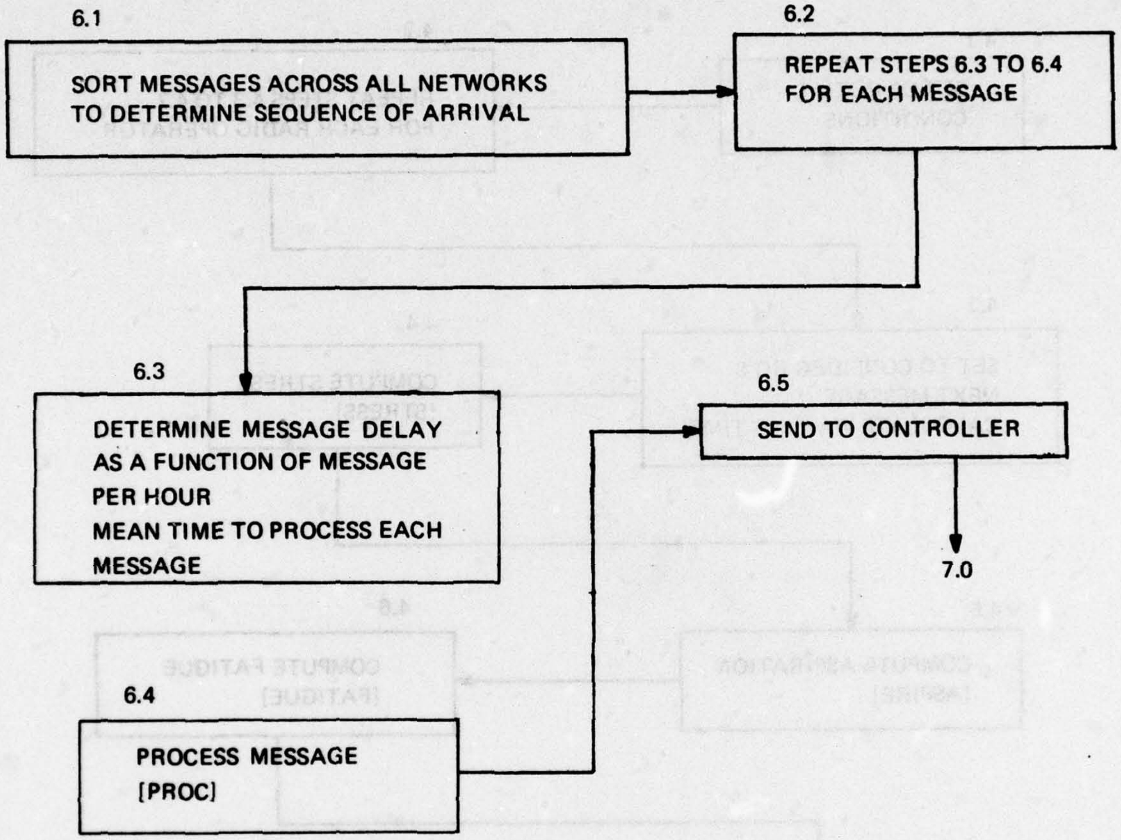



3.7.12
IS TIME RELATED TO MESSAGE LENGTH?
IS JTYPE (I,K) = 2?
YES
NO
3.7.13
IF J = 4 IMC = 7
OTHERWISE IMC = 1
TIME = TIME * MSGCHR(CMSG,IMC)
3.7.14
MODIFY PROBABILITY OF SUCCESS AS
A FUNCTION OF PREC(J)
3.7.15
MODIFY PROBABILITY BY
STRESS AND ASPIRATION
3.7.16
DETERMINE TASK
SUCCESS OR FAILURE
RY> PROB
3.7.17
ADJUST WORK COUNTERS
Z(M) = Z(M) + TIME
WOR(M) = WOR(M) + TIME
TW (IH,J) = TW(IH,J) + TIME
3.7.18
ADJUST TIME SEGMENT COUNTERS
IS = END (I,K)
CTST (IT,IS) = CTST(IH,IS) + Z(M)
NCTST (IT,IS)= NCTST(IH,IS) + 1
CTSH (IH,IS) = CTSH(IH,IS) + Z(M)
NCTSH (IH,IS)= NCTSH (IH,IS) + 1
3.7.19
IS THIS A TRANSMISSION?
IS JTYPE (I,K) = 6?
YES
3.7.20
TRDEL = RD * DELSD(IH) + DEL(I,H)
TIME = TIME + TRDEL
3.7.21
SET UP NEXT TASK ELEMENT IF
SUCCESS I = IJS (I,K)
FAILURE I = IJF(I,K)
3.7.22
IF TASK IS CRITICAL
SUCCESS NOSUC(M) = NOSUC(M) + 1
FAILURE NOFAIL(M) = NOFAIL(M) + 1
3.7.23
OPTION TO PRINT
DETAIL OUTPUT
3.7.24
COMPUTE INFORMATION LOSS
INFOLS = (PUL + 10 * PUS) * INC

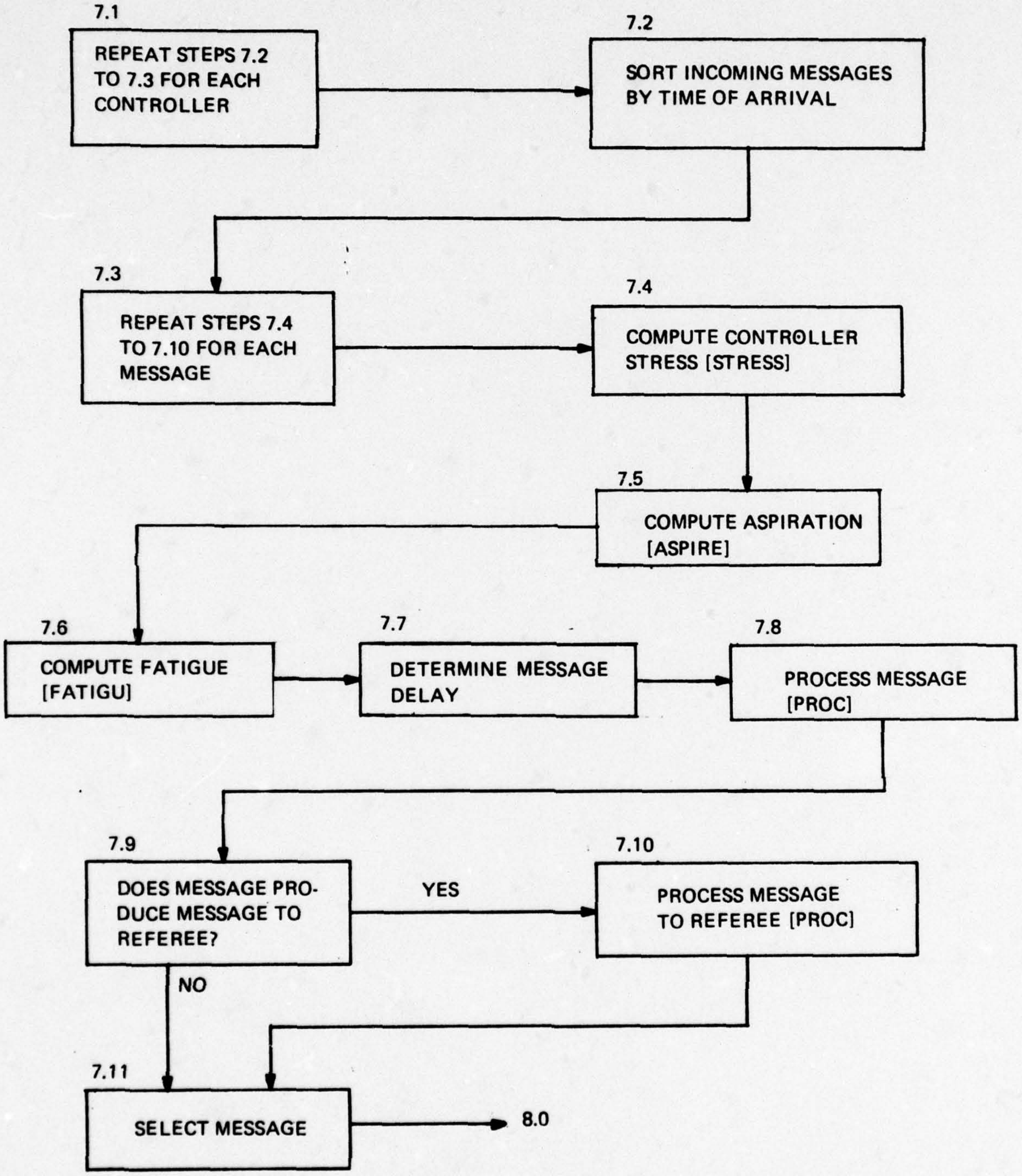
4.0 RADOP


4.1
SET UP INITIAL CONDITIONS
4.2
REPEAT STEPS 4.3 TO 4.7 FOR EACH RADIO OPERATOR
4.3
SET TO CONSIDER RO'S NEXT MESSAGE CALCULATE WAITING TIME
4.4
COMPUTE STRESS [STRESS]
4.5
COMPUTE ASPIRATION [ASPIRE]
4.6
COMPUTE FATIGUE [FATIGUE]
4.7
PROCESS MESSAGE AND DETERMINE TRANSMISSION DELAY [PROC]
4.8
SEND MESSAGE
5.0

6.0 CCC


6.1
SORT MESSAGES ACROSS ALL NETWORKS TO DETERMINE SEQUENCE OF ARRIVAL
6.2
REPEAT STEPS 6.3 TO 6.4 FOR EACH MESSAGE
6.3
DETERMINE MESSAGE DELAY AS A FUNCTION OF MESSAGE PER HOUR
MEAN TIME TO PROCESS EACH MESSAGE
6.4
PROCESS MESSAGE [PROC]
6.5
SEND TO CONTROLLER
7.0

7.0 CONTR


7.1
REPEAT STEPS 7.2 TO 7.3 FOR EACH CONTROLLER
7.2
SORT INCOMING MESSAGES BY TIME OF ARRIVAL
7.3
REPEAT STEPS 7.4 TO 7.10 FOR EACH MESSAGE
7.4
COMPUTE CONTROLLER STRESS [STRESS]
7.5
COMPUTE ASPIRATION [ASPIRE]
7.6
COMPUTE FATIGUE [FATIGU]
7.7
DETERMINE MESSAGE DELAY
7.8
PROCESS MESSAGE [PROC]
7.9
DOES MESSAGE PRODUCE MESSAGE TO REFEREE?
YES
7.10
PROCESS MESSAGE TO REFEREE [PROC]
NO
7.11
SELECT MESSAGE
8.0

GLOSSARY OF VARIABLES

-A-

A--Temporary variable used when arithmetic calculations are made with an integer variable.

AHT--Average handling time for a message.

AM--Mean number for poisson distribution.

ASP(M)--Mean final aspiration level for each man. An aspiration of 1.0 represents striving for perfection. An aspiration level of .9 has been found appropriate in many situations.

ASS(M)--Mean final aspiration level.

ATPM--Average time per message processing.

AVGTM(I,K)--Average task element performance time.

AVPROB(I,K)--Task element success probability. That is, the probability that the following task will be IJS and not IJF.

-B-

B--Temporary variable used when calculations must be made using an integer variable.

-C-

CCC--Subroutine used to select each message for computer processing.

CC12--The average correlation between the effectiveness of measures thoroughness and completeness.

CC13--The average correlation between the effectiveness measures thoroughness and responsiveness.

CC14--The average correlation between the effectiveness measures thoroughness and accuracy.

CC23--The average correlation between the effectiveness measures completeness and responsiveness.

CC24--The average correlation between the effectiveness measures completeness and accuracy.

CC34--The average correlation between the effectiveness measures responsiveness and accuracy.

CEC(IH,IOP)--Accumulative effectiveness measures for run summary.

CFA(IH,J)--Cumulative final aspiration level for run summary.

CFS(IH,J)--Cumulative final stress level for run summary.

CH(IS)--Cumulative segment completion times.

CHAR(37)--The array in which characters are stores. In the order, 1,2,3,4,5,6,7,8,9,0, blank, A,B,C,D,E,F,G,H,I,J,K,L, M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z.

CIDH(IH,J)--Cumulative time idle for run summary.

CMSG--Cumulative message number. A unique number (within iterations) assigned to each message when it is created. Explicitly specified as integer.

CMTG(IH,M)--Time spent on message processing per man per hour.

COMBLK--Procedure definition processor in which common (Variables in Dimensions) is stored.

COMMNS(5)--Overall effectiveness measures for run.

CONMSG--Subroutine in which the number of characters in the message received by the controller is determined.

CONTR--Subroutine used to select each message for controller processing.

CP(IP,IS)--Iteration mean performance time per priority per segment.

CRIT(I,K)--Criticality of the task element, C= critical.

CHRCON(IT)--Mean number of characters displayed to the controller for each message type.

CHSCON(IT)--Standard deviation of CHRCON(IT).

CT(IT,IS)--Iteration total time per segment per message type.

CTSH(IH,IS)--Cumulative segment time by hour.

CTSP(IP,IS)--Cumulative time segments by message priority data for run summary.

CTST(IT,IS)--Cumulative time segments by message type data for run summary.

CTWH(IH,J)--Cumulative performance level for run summary.

-D-

D--Dummy indexer used for glossary reference to matrix.

DEL(IH)--Mean transmission to computer delay.

DELSD(IH)--Standard deviation of transmission to computer time.

DIGIT(ID)--Subroutine in which the number of digits in the message prepared by the referee is determined.

-E-

EC(IH,IC)--The value of each effectiveness component.

EFF--Overall or composite effectiveness.

END(I,K)--Message processing segment, if any, ended by this task element.

ER(IE,IT)--Error rate per 100 characters for each type of error -IE- and each type of message, IT.

ERP(IE)--Proportions of errors which will cause computer error messages.

ERPG--Proportion of Referee errors which will cause computer error messages.

ERPI--Proportion of Radio Operator errors which will cause computer error messages.

-E-

ERSUMT(IT,IOP)--Error sums.

EXASP(M)--Aspiration level per man in run summary.

EXASPH(IH,M)--Aspiration level, run summary.

EXTPMH(IH,M)--Time per message, run summary.

-F-

F(J)--The speed factor of each man. An average man would be 1.0. A fast man would be .8 and a slow man would be 1.2.

FREP(IP,IH)--The cumulative proportional occurrence of message priority -IP- as IP goes from 1 to 5 during hour IH. The highest used priority within each hour must have a proportion of 1.0.

FREQ--Subroutine used to input transmission delay to the computer.

FRET(IT,IH)--The cumulative proportional occurrence of message IT as IT goes from 1 to ITMAX during hour IH. For example FRET (1-7, 1) might be .1, .23, .25, .48, .73, .84, 1.00. Used in random calculation of actual message types in any given simulation hour.

-G-

GMEANS--Grand means.

GTSMNS--Grand total means.

-H-

HROVER--Indicator for hour completion.

-I-

I--Task element number. Also temporary index.

IATA(J,IT)--Task analysis to be used for each operator type, J and for each message - IT.

ICF--Temporary counter for number of messages.

ICHAIN--Number of messages to be processed in each iteration.

ID--The number of digits in the message prepared by a referee. Argument in subroutine DIGIT.

IDAY--Day of mission simulation. Used in computation of fatigue.

IDENT(18)--A run description or header of 72 characters printed on the top of each page of printout.

IDONE--The current number of messages completed by controller.

IDL(IH,J)--The amount of idle time for each man in each hour.

IDUM--Dummy variable.

IE--Error type, 1= commission, 2= typographic (includes abbreviation and spacing), 3= omission, 4= other.

IEND--Option to terminate program (when= 1).

IEK--Time segment indicator point.

IFTET--Temporary storage for IFTE.

IGP(IH)--Number of messages arriving per hour IH.

IGR(IH)--Standard deviation of IGP(IH).

IH--Hour number.

IHH--Index for hour.

IHMAX--Temporary indexer.

IJF(I,K)--The number of the task element to be performed next if the current task element is failed.

IJS(I,K)--The number of the task element to be performed next if the current task element is performed successfully.

INC(IT)--Mean number of characters in the message provided by the referee. Explicitly specified as REAL.

INFHR(IH)--Information lost per hour.

INFOLS(CMSG)--Information loss in current message.

INS(IT)--Standard deviation of number of characters per message type, INC(IT). Explicitly specified as REAL.

INT(M)--Number of error returns remaining in hour interrupted message data.

INTOP--Option for card input of interruption and transmission delay.

INTS--Total number of interruptions to be run in a task element.

IOP--Option code.

IOR--Indexer for message originating point, 1= normal, 2= another referee, 3= controller.

IP--Message priority number where, 1= routine, 2= priority, 3= operational immediate, 4= flash, 5= presidential interrupt. Argument in subroutine MPRIOR.

IPAGE--Page number of printout.

IPD--Random number from a poisson distribution.

IPRI(CMSG)--Message priority.

IPT1--Pointer for random access file 1.

IPT2--Pointer for random access file 2.

IPT3--Pointer for random access file 3.

IPT4--Pointer for random access file 4.

IPT5--Pointer for random access file 5.

IPT6--Pointer for random access file 6.

IQONE(MSG,IREF,NET)--Queue of all coming messages.

IREF--Indexer for referee within network.

IRESH(IOP,IH)--Information lost (IOP= 6) number of error return (IOP= 5) tasks performed per hour (IOP= 7), IOP 1 to 4 accumulate errors per error type.

IREST(IOP,IT)--Information lost (IOP= 6), number or error return (IOP= 5), tasks performed (IOP= 7) per message type. IOP 1-4 accumulate number of errors per error type.

IS--Time segment for message processing.

ITEM--Temporary storage.

ITYMAX--Maximum number of interruption types per task element.

IUR(IH)--Not used.

-J-

J--Operator type, 1= referee, 2= radio operator, 3= computer, 4= controller.

JE--Index for type of message and other purposes.

JJ--Temporary index for operator type.

JTYPE(I,K)--Task element type for element I of task analysis K. Allowable types are, 2= task element in which the number of characters for this message type will be multiplied by the stochastically determined mean time to produce the time required to transform the messages, 3= a decision task element where operator factors such as speed - F(M), precision- PREC(M), and stress level - STR(M) are not allowed to affect the duration or success probability of the task element, 4= an equipment task element where operator factors are not considered and the task can not be failed, 5= not used, 6= a task in which a transmission to the computer occurs.

-K-

K--Task analysis number.

KK--Temporary index for message queue and others.

-L-

LDONE--Counter for messages completed.

LMSG(IREF,NET)--Last message processed by each referee in each network.

LTH--Number of characters in message to controller. Argument in COMSG.

-M-

M--Man machine. Each man involved in a simulation is assigned a unique number.

MANT--Temporary storage for MAN.

MCL(M)--Messages completed per man for run summary.

MCUM--Cumulative message number of current message.

MEN(D)--Number of men, D= 1, for referees, D= 2 for radio operators, D= 3 for computer, D= 4 for controllers.

MENS--Total number of men in system.

MESS(LA,J)--Messages for performance this hour, LA= 1 total for hour; LA= 2 messages remaining for hour. This category is decreased as messages are performed.

MGCP(IH,M)--Cumulative messages completed.

MQCPL(IH,M)--Messages completed per hour per man.

MSCPL(M)--Messages completed per man.

MSEL--Man initials selected to perform next task.

MSG--Message position within queue.

MPRIOR--Subroutine in which message priority is determined.

MTYPE--Subroutine in which message type is determined.

MSGCHR(CMSG,IMC)--Message characteristics array. IMC= 1 for message length in digits (RO), 2= priority, 3= type, 4= origin (1 for outside, 2 for controller, 3 for other referee), 5= level (J) where message currently is, 7= message length for controller, 8= NET, 6= man number (M), 9= IREF or IRO depending on J.

MSGNO--Number of messages being processed.

MSGS--Message number index.

MSGT--Temporary storage for CMSGNO.

MUCOMP(IH,J)--Cumulative messages completed per hour, queue for run summary.

-N-

NAME(M)--The name or title for each man (up to 6 characters).

NCP(IP)--Number of tasks performed on each priority.

NCT(IT)--Number of times task types are completed in current iterations.

NCTSH(IH)--Number of messages performed per hour for run summary.

NCTSP(IP)--Number of task performance by priority data for run summary.

NCTST(IT)--Number of times task types completed across all iterations.

NERT--Temporary storage for controller network.

NET--Indexer for controller network.

NETREF(NET)--Number of referees in each controller network.

NOFAIL(M)--Number of task element failures in an hour.

NOMSG--Cumulative priority weight of message in queue.

NOSUC(M)--Number of task element successes in an hour.

NSHF--Current iteration number.

NSHIFT--Total number of iterations to be performed.

NTE--Number of task elements, total across all task analyses. Used in data input.

NTMT(IT)--Number of tasks performed by type.

NUET--Temporary storage for TNUE.

N1--Temporary index.

N2--Temporary index.

N3--Temporary index.

N5--Temporary index.

-O-

ORIG(IOR,IH)--Cumulative probability for originating a message. IOR= 1 normal, 2= another referee, 3= controller.

ORIGIN--Subroutine in which the originating point for each message is determined.

ORO(D)--Output recording option.

-P-

PAFA--Pace adjustment factor for aspiration level.

PAFW--Pace adjustment factor for work fatigue.

PASP(J)--Permanent or initial aspiration level for each crewman. Used for resetting the aspiration level at the beginning of each iteration.

PERF(M)--The performance level of M. PERF(M)= NOSUC(M)/(NUSUC(M) + NOFAIL(M).

PRIOR(MSG,J)--Message priority.

PRIORT--Temporary storage for message priority.

PROB--Temporary, adjusted, task element success probability.

PROBI(I,K,ITYP)--Probability of occurrence of task element interruption.

PROBOP(NOP)--Probability (cumulative) that each information search option will be selected for performance.

PROP--Temporary variable used for numerous proportions.

PRP(IS)--Proportion of message handling time spent in each segment.

PUL--Probability of a low importance undetected error getting through to the central computer data store.

PUS--Probability of a significant error undetected error getting through to the computer data store.

-R-

RADOP--Subroutine used to select the next message for each radio operator.

RANDN(RY,RD,M,SD)--Subroutine which produces a pseudo random from a normal distribution with mean M and a standard deviation SD.

RANDU(RY,D)--Subroutine which produces a pseudo random number from a uniform distribution between 0 and 1. The second argument must always be 1.

REFRE--Subroutine used to select the next message for each referee.

RD--Pseudo randum number from a uniform distribution. Mean and sigma specified by input data.

RID--Temporary storage of REAL value of ID.

RLTH--Temporary REAL version of LTH.

RMPS(IT)--The mean number of messages produced for each referee received item by message type.

RY--Pseudo random number from a uniform distribution between 0 and 1.

-S-

SEGS(CMSG.ISEG)--Time at which each message segment is completed.

SF--Stress factors.

SHFTOV--Shift completed indicator.

SIF--Success or fail indicator, S= success, F= fail.

SIGMA(I,K)--Standard deviation of the mean task element performance time - AVGTM(I,K).

SRS(M)--Average final stress per man.

SRTA--System average response time to an inquiry.

SRTS--Standard deviation of the system response time to an inquiry.

ST--Starting time for message processing.

START(M)--Actual starting time for message which was interrupted by hour and processing.

STR(M)--Current crewman stress level.

STRM(M)--The stress threshold for each man.

-T-

TARIV(MSG,J)--Time of message arrival in queue.

TARVT--Temporary storage for TARIV.

TIE1(MSG,M)--Total number of undetected errors of type 1.

TIE2(MSG,M)--Total number of undetected errors of type 2.

TIE3(MSG,M)--Total number of undetected errors of type 3.

TIE4(MSG,M)--Total number of undetected errors of type 4.

TIME--Task element performance time.

TLEN--Intermediate value in the computation of message length.

TMIDL--Average idle time.

TMI(M)--Mean idle time.

TMT(MSG,J)--Total number of undetected errors in a message.

TPM--Time per message.

TPCM(M)--Time per message per man.

TRDEL--Transmission delay time.

TW(IH,M)--Amount of time (seconds) worked by each crewman during each hour

-U-

UEP(I,K)--The probability of the occurrence of an undetected error.

UETYPE(I,K)--Undetected error type, T= transfer.

-V-

V--Basic execution time function.

-W-

W(IC)--The relative weight of each effectiveness component in computing overall effectiveness.

WOR(M)--Mean time worked.

-X-

X--Temporary storage for ICHAIN.

-Y-

Y--Number used to initialize the random number generator.

-Z-

Z(M)--Current time (seconds) for each crewman.

ZA--Adjusted task element success probability when stress level exceeds the stress threshold.

ZIF--Stress function for execution time.

ZIH--IH minus 1 in seconds.