A GPSS-2 SIMULATION APPLIED TO A COMMUNICATIONS TRAINING PROGRAM

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SUMMARY

Many newly commissioned officers in the United States Air Force are assigned duties as communications center managers without extensive training in that capacity. This thesis presents a communications training program to fill that need. The foundation for this course is a model of a typical USAF communications center. This model is then implemented on the UNIVAC 1108 digital computer by use of the programming language GPSS-2. The model studies the interactions of both men and machines in the environment, a novel approach to the subject. Data for model development were acquired from the Little Rock AFB communications center, a center typical of USAF tributary stations.

Using the simulation model as a base, a communications training course is developed. This course consists of a series of lectures, student inputs, computer runs, analyses, and critiques in the surroundings of a "game-simulation." The thesis is concluded by a series of recommendations for use in implementing and expanding the model and computer program at the USAF training center.

CHAPTER I

INTRODUCTION

It has often been said that training is the largest task in the peace-time military service. The truth of the statement can hardly be questioned when one considers the constant flow of people into and out of the services. The incoming personnel are seldom, if ever as capable as the outgoing at the time of replacement. Skills must be developed and enlarged if the mission capability of the unit is to be retained.

Many newly commissioned officers of the United States Air Force are assigned to the Communications Technical School at Keesler AFB, Mississippi. Following their communications training, they are then frequently placed in managerial positions all over the world. Too often the newly assigned manager finds himself in the field, saddled with the responsibilities of resource allocation, scheduling, and national security, yet he has no practical experience in the management of Communications Centers (COMMCEN). Unless a means of offsetting this lack of experience can be presented during the training of these officers, the military posture of our nation could suffer.

An example of near-disastrous results due to lack of training stands out prominently in the author's mind. Several years ago he was serving in a Communications Center managed by a relatively inexperienced officer. Due to a combination of rather unfortunate circumstances, the available manpower for the COMMCEN was suddenly reduced. The Officer in Charge (OIC) felt the situation required the somewhat extreme solution of twelve-hour duty tours for the workers in the COMMCEN. The decision to extend duty hours was largely intuitive, and because no one was familiar enough with analytical techniques to even determine the message flow through the facility (let alone the scheduling of men required for processing the flow), the twelve-hour duty tours were continued for three months. The result was a general lowering of morale and an increase in error rate for that period.

The arrival of an experienced analyst who studied the problem and suggested an alternate schedule resulted in a return to eight-hour shifts under a booster arrangement and a speed of message handling superior to that previously achieved under the twelve-hour shift conditions. This was achieved without a degradation of service due to increased error rate. Instead, the number of errors was reduced to the levels that existed before the severe schedule. The talent of the analyst lay in his ability to analyze message handling in COMMCEN operations, something the OIC, a recent graduate of a communications course, was unable to do.

In communications operations, training becomes a day-to-day problem for management. Skill development means very much when equated with communications capability. The untrained or inexperienced communications officer offers management great potential, but he must currently be considered as an expensive individual. In broad terms, the untrained or inexperienced man cannot work unsupervised (an added expense and a great blow considering the continued shortage of skilled supervisory personnel), and he cannot be relied upon to do his work in the desired time and with the quality expected by the unit. The man may have ability, but in his present state of capability he does not know, and cannot produce, enough work to pay for his presence in the unit.

The only way to eliminate this low production is to train the man. The training is time-consuming and expensive, but it is an absolute essential if the unit is to attain and the Air Force maintain mission ability.

A training program, developed during the author's thesis research and its subsequent implementation into overall communications training, will provide this exposure to the actual situations encountered in day-to-day management of COMMCEN facilities. This training program simulates the operation of a typical USAF COMMCEN and, in a single computer run, represents one week's operation. Thus, in a few short hours of decision making, coupled to the feeding of appropriate inputs to the computer program, several weeks of operation may be simulated, analyzed, and evaluated. The overall problem, then, is that of need for management training. The specific problem, resolved during this study, was that of the development of a course of instruction for communications personnel. This course includes a model (a computerized simulation) and will provide the necessary management experience to substantially shorten the period in which the newly graduated officer is ineffective as a manager.

The general developmental approach for this proposed course (or exercise) was divided between the computer program written for the simulation of the COMMCEN and the lecture presentations. The first problem to be resolved was that of a criterion for a measure of COMMCEN effectiveness. The speed of processing outgoing messages was selected as the standard for this program as this in-station handling time is recognized by communications experts as the indicator of COMMCEN success. Incoming messages are minimally processed, then are immediately ready for pickup. In-station message handling time limitations then are a boundary over which one must not pass. The handling methods and reasons for delay must be explained, to higher communications authority, on each message that is handled in excess of prescribed limits (17).

In the course design, some attention was directed toward the information input and output phases themselves but only as necessary to yield an operational model. This approach gave results that satisfied the main problems. It produced a computer simulation that may be incorporated into the overall USAF communications training program and will thereby provide more realistic training to the fledgling communications officer allowing him to make his mistakes in the classroom rather than in the field.

The motivating force for this project was the requirement of a thesis for a Master of Science degree in the School of Industrial Engineering at the Georgia Institute of Technology. A secondary motivation lies in the writer's desire to better acquaint communications students with some knowledge of what lies ahead, thereby making them more valuable members of the USAF aerospace "team."

Although this research contains many of the elements of a man versus a computer management "game," the simulation and proposed training course are not this exacting. The set of instructions to be programmed into a computer algorithm for such a game is not known for each case of inputs. Instead, the more general Monte Carlo methods of simulation are favored, and thus a highly developed simulation model of the COMMCEN and its manning system is constructed each time the student provides his manpower specifications. From these specifications, the model for the particular COMMCEN is constructed and its operations are analyzed and fed back to the student so that the learning cycle may be extended. In this context then, the term "game-simulation" will be used to describe the interactions of the students, the computer, the training staff, and of course, the model COMMCEN.

Before proceeding with a complete discussion of the game-simulation technique, the term "game-simulation" will be more fully defined and its place in the spectrum of systems analysis techniques described. The principal techniques of systems analysis, arranged in increasing degree of abstraction, are now discussed. The degree of abstraction is small if one is experimenting with the real world or is using observations from the real world for analysis. Geisler chooses to include three kinds of simulations under the general heading of "gaming" (19). They are one-to-one, game-type, and all computer. The mathematical model, a simulation outside the gaming range, involves the greatest degree of abstraction and will not be considered any further in this work.

The three types of simulation have been included under the overall topic of gaming, since human beings may be used as an integral part of any one of these kinds of simulation. The one-to-one kind of simulation is usually a very detailed representation of the system under study and is used for training purposes. An example of this kind of simulation is the laboratory setup used for training operators in the

SAGE air defense control systems. At the other end of the gaming area is the all-computer simulation, in which the system is represented entirely by a digital computer program. Normally, this type of simulation does not involve people, as all decisions and decision rules are contained in the computer program. People can participate, however, and have been utilized in any manner which allows human beings to make certain decisions during the sequence of simulation runs. An example of this type of simulation is the US Army Logistics training conducted at Fort Lee, Virginia (3).

The game-type simulation defined by Geisler may include both games and "game-simulation." It is difficult to draw a fine line between games and "game-simulations." Both techniques involve the use of people or players as an integral part of the simulation process, and either technique may or may not involve the use of a computer. The game may be considered as a simulation which is performed for the purpose of examining and identifying the broad aspects of a conflicting situation (19). Great flexibility exists in the structure of the game and the interest in outcomes is minor. "Game-simulation," on the other hand, is generally used where the interest is in policies for tactical-type decisions; the structure of the game is considerably more formal, and analysis of outcomes is of more importance. This, then, is the case with the COMMCEN "game-simulation" designed in this work.

A more favored method of categorizing simulation, however, is that described by Specht (41) who is also a member of the Rand Corporation. He developed a dichotomy of classes where a model (or situation) is either a conflict type or a non-conflict type. Sub-classes within the major types are categorized as:

I. Verbal

II. People--as an integral part of the model

III. People and computers interacting as a part of the model

IV. Computer

V. Analytical.

Figure 1 displays this classification system and contains examples (from the cited reference) of each classification. Categories II, III, and IV make up the general class of "simulation models" while categories IIc, IIIc, and IVc fit the general term "gaming models."

If conflict is an essential element, then we shall speak of model types Ic, IIc, IIIc, IVc, and Vc. A conflict situation does not, of course, exclude the case of opponents (or players) who have interests in common, i.e., allies. If conflict plays little or no part, then model types Inc, IInc, IIInc, IVnc, and Vnc are used.

In a later section of this thesis, a full description of the COMMCEN itself is forthcoming, but at least a few introductory remarks are now in order. The USAF COMMCEN to be modeled is the teletype facility at Little Rock Air Force Base, Arkansas, the researcher's last duty station preceding his assignment to the Georgia Institute of Technology. This COMMCEN contains all of the facilities familiar to USAF communications personnel: AUTODIN, TWX, WUX, leased commercial as well as government terminals. The physical makeup and operating descriptions of the equipments and facilities listed above are introduced as required.

Once the course design is complete and it has been declared operational, a working test is made on military personnel currently serving at the Georgia Institute of Technology and the results of that test are discussed. Following these, some general conclusions and recommendations are presented to round out the thesis.

MODEL FORM	NO CONFLICT	CONFLICT
I VERBAL	Inc	Ic Some Scenarios Delphi Techniques
II PEOPLE	IInc Command Post Exercise	IIc War Games Crisis Exercise
III PEOPLE AND COMPUTERS	IIInc Logistics Systems Laboratory	IIIc TAGS
IV COMPUTER	IVnc FLIOP SAMSON	IVc STAGE
V ANALYTICAL	Vnc Missile Defense Example	Vc Game Theory

Figure 1. Categories of Model Forms (41)

CHAPTER II

LITERATURE SURVEY

General Information

The quest for the boundaries of knowledge in the area of training by simulation led simultaneously in two major directions, one on the Georgia Tech campus, the other through the Air Force facilities. The first was of the existing literature contained in the Price Gilbert Memorial Library at the Georgia Institute of Technology, which indicated many instances of simulations but few in the communications field. Studies by the Rand Corporation have been performed in this area (4). None has been used in training environments nor has the problem been approached from the standpoint of the man-and-machine combination used in this particular simulation. Existing simulations of communications facilities, such as those by Baran, Boehm, and Smith, focus upon relay station activities rather than those of a tributary station (5,6). The study of the communications system from the smallest separate link (the tributary station) rather than from the whole chain (the network of tributaries and the relay stations) should yield results worth many man-hours and eliminate many trial-and-error experiences to the communications center manager in the field. The second major direction pursued by the investigation during the literature survey was to query the USAF communications training agency as to their needs in the training-simulation areas. Although this action is not precisely a survey of literature, it generally provides answers that are not available locally.

The chief of the communications training branch at the USAF Technical Training Center, Keesler AFB, Mississippi was contacted and the general idea of the research discussed. This communications course director stated that there was a definite need for this type of work and requested that further information concerning the proposed course of instruction (both the simulation and the training exercise) be forwarded to his office. Communications with the training branch (TSDGB) have begun and are continuing. A copy of this thesis and the included program of training will be forwarded to TSDGB for further evaluation, course inclusions, and specific desires of the USAF training staff at that office. Testing of the program, on a larger scale than was carried out at Georgia Tech, prior to full-time implementation will also be handled by TSDGB.

While the actions cited above were in progress, some current literature concerning simulation in general and GPSS-2 in particular was investigated (20,35,39). The readings studied were particularly useful concerning the adaptability and applicability of GPSS-2 to the problem at hand. Many journals were also reviewed for applications of GPSS-2 to environments similar to the COMMCEN (21,32). A survey of pertinent military literature was also conducted to insure that all elements of the USAF tributary COMMCEN were represented (1,2,13). The findings of these surveys appear in the following portion of this chapter.

Simulation

With the advent of the high speed computer in the early 1950's, simulation took a step from the physical model phase, the small scale Monte Carlo analysis, to that stage where direct experimentation with mathematical models was possible. The constraints of step-by-step, plodding arithmetic manipulation were removed by the speed at which the computer processed thousands of calculations. With the invention of computer simulations, countless applications came into being.

Simulation is essentially a technique that involves setting up a model of a real situation and then performing experiments upon the model. This definition is broad, however, and may tie together many seemingly unrelated things such as Link Trainers, business management games, wind tunnel aircraft, electrical analogs, river basin models, and military war games. Naylor (35) on the other hand says: "Simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describe the behavior of a system (or some component thereof) over extended periods of time."

This definition by Naylor is too narrow and too directed at analytical or mathematical models. Some compromise between the extremes should be expressed. For the purposes of this paper and to keep the definition down to "working size," the first definition (setting up a model and performing experiments on it) will be expanded in terms of the model itself rather than simulation in general. In the previously cited work (41), Specht describes a model in E. S. Quade's terms:

Given a set of alternatives (including ones that the analyst

> may have invented in the course of studying the problem) a model is a black box. The analyst has designed the particular box to deal with his particular problem, and he has constructed it to reflect the state of the world of which the alternatives are a part. Into this box as inputs the analyst feeds information about the alternatives, and from the box as outputs comes information about the effectivenesses, plural, and the costs of each of the alternatives. With the help of a criterion, the analyst or the decisionmaker can then rank the alternatives in order of desirability and can select the optimum.

This input-output concept of a model then will be used with the previous definition of simulation whenever the terms are used in this work.

System Analysis

If a scale is imagined for methods of system analysis, analytical approaches might appear at one extreme, experimentation on a real system at another, and simulation somewhere in between. Analytical methods, while most abstract, when applicable are the most efficient. They may indicate explicitly whether an optimal solution exists and is unique. Nature, however, must be frequently distorted to fit into an analytical model. Direct experimentation, at the other extreme, may be necessary because of the difficulty in abstracting a meaningful model of any kind. For example, while preliminary experimentation in agricultural or medical research may be performed in the laboratory, applied tests on the real systems are usually necessary.

Simulation offers a combination of advantages of these extremes. In addition to permitting realistic models that are nonlinear, nonstationary, nondifferentiable, and generally not well behaved, simulation does not require an explicitly stated objective function. Computer simulation allows the engineer to hold all variables except the one under study, constant, a condition he can only approximate in the laboratory. In stochastic computer simulations, the seemingly impossible task of reproducing random events is accomplished by producing sequences of pseudo-random numbers which, though predictable, exhibit every other characteristic of genuine random numbers.

The great disadvantage of simulation is its cost. When a computer is required, programming and operating costs frequently run very high. It is here that the recently developed special purpose simulation languages promise to be of great help.

Simulation Languages

Simulation models can be programmed for a digital computer by using standard higher level programming languages such as FORTRAN or ALGOL. Problems which have any complexity, however, burden the engineer overwhelmingly with programming chores if such languages are used.

Several powerful simulation languages have been developed which allow the engineer to describe his problem or process model in a language closely related to its description in graphical or engineering form. The term digital simulation has been attached to two quite different types of computer languages. The first type deals with discrete serial processes with transactions or events taking place in time, while the second type describes large scale systems and models with complex feedback mechanisms. Three of the digital simulation languages (18) belonging to the first class, which have gained considerable acceptance, are the General Purpose Systems Simulator (21,23) (GPSS), SIMSCRIPT (34), and GASP (27,28). Other special purpose languages of this type include SIMPAC (40), SIMULATE (24), GSP (44), MONTECODE (25), and CLP (15).

There are a very large number of digital simulation languages of the second type. Brennen and Linebarger (8,9) and Clancy and Fineburg (11) have compiled lists of over 50 such languages with information about the characteristics of each and the availability of the simulator programs. The most widely used perhaps is DYNAMO (37) with MIDAS (22) a close second.

Comparison of Simulation Languages

In view of the large number of simulation languages which now exist, a detailed comparison is beyond the scope of this thesis. However, several sources of reference should be mentioned. Krasnow and Merikallio (29) have written a comprehensive comparison of SIMSCRIPT, CSL, GPSS, SYMPAC, and DYNAMO. Teichroew and Lubin (43) have compared SIMSCRIPT, CLP, GASP, GPSS, and SOL. GPSS, SIMSCRIPT, and SIMPAC have also been treated in a paper by Young (47) and Tocher's paper, "Review of Simulation Languages," (44) is a recent publication in this area.

Training by Simulation

One of the early attempts at applying digital simulation techniques to training was described by Stockton (42) following exercises conducted in seven Texas cities. The purpose of these exercises was to evaluate the simulator as a training device for small business management and to evaluate the technique for carrying on the exercises over an extended time period.

Based upon the resulting observations and discussions with participants, Stockton asserts that it is clear such simulations are an effective training medium, if the actions and mistakes of the participants are subject to parallel discussion and analysis. The exercise is conducted over a six month period, but the extended time period of the simulation was not considered a handicap. This is due to the high quality of administration during the "game." There was no lessening of the participants' high level of interest and motivation reported.

Training by digital computer simulation method has also been conducted by the United States Air Force at Wright-Patterson AFB, Ohio. In a simulation entitled MAIN-MAN-X, the maintenance and operations activity of a fighter squadron is simulated by appropriate computer activity and printout. One day of real-time represents one month in mock time. Students play the role of various managers within the aircraft operations and maintenance structure, and they provide input decision information to the computer based upon the role they are playing and the output information from previous runs. The student-furnished information is combined with preestablished "problems," such as grounding the airfleet because of structural failure, thereby necessitating rescheduling of operations, as well as maintenance overtime in certain maintenance areas. The duration of the exercise is five days representing six months of air operations. At the end of this period, the entire class receives critiques of their actions and suggestions toward such improvements in decision making which might result in more effective results. Hopefully, the student carries such improved knowledge back from the three-week temporary assignment at Wright-Patterson AFB.

The United States Army is another subscriber to the training-by-simulation school of thought (3). At Fort Lee, Virginia the US Army Logistics Center uses a number of logistics problem simulators as teaching devices. They are used at the end of training "blocks" in order that the student may apply what he has been taught. All of the simulations cited, at Fort Lee, are of the "game" type, which is preferred (at least by the US Army) to pure analysis of results.

Medical applications of simulation uses in training were cited earlier in this paper. The brainchild of a team of engineers and computer programmers from Aerojet-General's Azusa, California plant and doctors from the University of Southern California School of Medicine is SIM-I, a digital computer controlled manikin (12). The student anesthesiologist will have natural apprehensions if he must learn many hazardous procedures by practicing on living humans. The instructor, who would be constantly looking over the student's shoulder, and on whose judgment the safety of the patient rests, would have even more. Using SIM-I, a machine-manikin-computer hybrid simulator system, the instructor can work under more relaxed conditions while the student still experiences a high degree of realism.

The "nerves" of SIM-I are imbedded sensors, which react to many student-initiated procedures (both proper and improper) or to situations induced by an instructor at the monitor-console. The inputs and outputs of these sensors are processed by a hybrid computer, the real brain and heart of the system, which in turn feeds back signals to activate the many actuators and pneumatic components within the manikin that cause the lifelike reactions. In essence, the manikin serves as a display (that is readily understood by the medical student) and an input device for the computer.

CHAPTER III

OBJECTIVES

As previously pointed out in this report as well as elsewhere in the literature, there exists a definite and identifiable need for training in the management of the COMMCEN before the Air Force officer must actually manage such a facility. This need leads to the specific problem at hand. The proposed management course (a series of lectures, simulation runs, analyses, and critiques), which was developed at the Georgia Institute of Technology, when incorporated into overall USAF technical training, should answer this need and resolve the problem. This thesis will test the hypothesis that it is feasible, practical, and possible to develop the desired course by using simulation techniques when coupled with the author's knowledge of the communications field.

The criteria for testing this hypothesis will lie in two distinct phases. First, if the computer model of the COMMCEN successfully performs (on the computer) as does its real-life counterpart (taken from historical data), it will be termed "operational" and that phase ajudged a success. Secondly, once the model is operational, both a course outline and a scheme for furnishing input and output situations (from the students to the model) will be developed. A test of this course and a measure of its effectiveness will be the responsibility of the USAF Technical Training Center at Keesler AFB, Mississippi. Once the staff of this facility is convinced of the worth of this program, it will be incorporated into the overall US Air Force communications officer program.

The proposed course considers the operation of a single tributary station (the COMMCEN) tied to a network of other stations by a relay facility. This limitation was imposed to allow the course design to be of a size that may be handled by a single researcher. Once this simulation is incorporated into the overall communications training and has been established as worthwhile, further simulations (and the appropriate course work) should be developed. This development can be accomplished by the staff at the Technical Center or by designated researchers. The qualifications necessary for such work would be twofold. First, the researcher should have a background in Tributary Station (TRIBSTA) operations. Secondly, the persons doing this developmental work must be knowledgeable about GPSS. A qualified communications officer could study computer programming in general and GPSS in particular (and therefore satisfy the two requirements) much more easily than a computer programmer could learn communications operations. This point should be kept in mind when selecting personnel for extensions or enlargements of this simulation. Any later extensions should include Tactical Networks of communication as well as Relay Station facilities. They may be developed as separate "blocks" of training under separate simulations (computer programs) or may be incorporated into this proposed program as additions or refinements.

To summarize then, the primary objective of this thesis is to develop a course of communications instruction utilizing simulation techniques. The simulation is limited to a model of a typical tributary communications center.

CHAPTER IV

THE ENVIRONMENT OF THE MODEL

Background

The Communications Center (COMMCEN) at Little Rock AFB, Arkansas is typical of US Air Force centers in the United States. Since the author's most recent experience in communications operations was at this facility and since data for the model were available from there, the Little Rock AFB COMMCEN was selected for modeling. The typicalness of the facility was, however, the primary reason it was chosen for the representation. A few comments describing the environment, the actual facilities, and the system operation in real-life are in order before the model is discussed.

The COMMCEN provides teletype service, primarily for three agencies of the base: the 43rd Strategic Bomber Wing (a B-58 Bomber Wing), the 308th Strategic Missile Wing (Titan II missiles), and the 825th Aerospace Division with its associated base support elements (largely administrative agencies). The service furnished is that of transmission and receipt of teletype messages, through a network of stations, interconnected to other bases (Army, Navy, and Air Force), throughout the world. Incoming messages from this world-wide network are properly annotated and delivered to the base administrative facility (BDAS) which then delivers them to the specified addressee. To achieve the stated ends outlined above, three types of circuits are used, each of which sends and receives messages. They are:

1. Automatic Digital Network (14)
2. Teletypewriter Exchange (13)
3. Western Union (13)

A brief description of each system and an overview of its operating characteristics follows, but for a full description of these systems, the uninformed reader should avail himself of the references.

Automatic Digital Network

The Automatic Digital Network (AUTODIN) is a full time, high speed, leased-line, long-line network of military tributary stations all connected to a series of central relay stations, each by a feeder line. These relay stations are in turn interconnected by trunk lines and by high speed digital computers which automatically accomplish the switching and relay operations at each relay station. The major relay station or Net Control Station (NCS) with operational jurisdiction over AUTODIN operations at Little Rock AFB COMMCEN is the NCS at Tinker AFB, Oklahoma. The COMMCEN at Little Rock AFB has full-duplex, full-period access to AUTODIN; that is, messages may be transmitted and received simultaneously over these facilities at any time of the day or night.

Teletypewriter Exchange

The Teletypewriter Exchange (TWX) is also a network of teletype stations. These stations are a mixture of military and civilian subscribers. Instead of a central connection to a message relay station, messages are transmitted to the distant station by dialing that station's number on a telephone-like dial. Circuitry is then established linking the two stations together and the message is passed from one to the other. When the message is complete, the connection is broken and charges for the transmission are levied in the same manner as those for a long distance telephone call; that is, they are based upon time and distances. TWX is used by the USAF to send and receive messages of non-military agencies and for back-up service if AUTODIN experiences circuit outages. TWX is a half-duplex facility, having the capability only to send or receive messages but not simultaneously. Since this facility services civilian agencies which do not remain "on call" full time, it is a part-time facility and can pass traffic only during certain hours, unless employment as a back-up has been undertaken.

Western Union

The Western Union network (WUX) operates in somewhat the same manner as the military message relay systems. However, the relay stations are not computer controlled, and the subscribers are, for the most part, Western Union offices of the commercial telegram variety. (A few military bases such as Little Rock AFB are tied in.) Instead of computerized switching and control, the relay of messages is accomplished by a slower pushbutton, manual (P-51) method which results in much slower overall system handling time. Messages are sent from Little Rock AFB COMMCEN to the city of Little Rock Western Union office. From there they are passed over that company's facilities to the Western Union office responsible for delivery to the addressee station. At that point, the messages may go in telegram format to the ultimate addressee. The machine connecting Little Rock AFB to the downtown station is a manual, keyboard only, device with half-duplex capability. The service is operated only a portion of the 24 hour day unless special provisions have been made.

System Operation

Prior to a discussion of the simulation model in the actual operating environment of a US Air Force COMMCEN, an introduction to the manner in which messages are handled should first be rendered. Later, this background will allow the reader to relate the model to actuality. The method selected for this description is to actually follow the flow of a single transaction (an outgoing message) through the system.

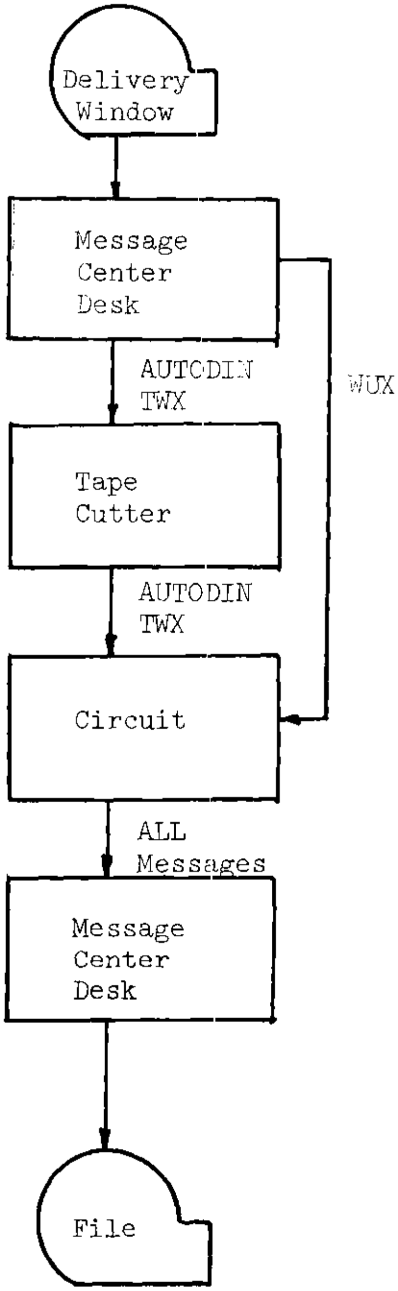
A routine precedence message is first drafted and typed by the originator of the message. It is then carried to the base distribution center (BDAS) where the releasing authority authorizes the transmission; a log is kept citing and verifying such authorizations. Groups of messages are then carried (hourly) to the COMMCEN from BDAS by a courier system. Each "batch" of messages is checked at the COMMCEN for conformity with operating doctrine and receipt is acknowledged by the communications center personnel. Once the message is receipted, it is taken to the message center desk (inside the COMMCEN itself) where it is entered in a log, AF Form 1022, and given a destination routing. Next, a message tape is prepared (punched on paper tape on a tapecutter) and that tape is passed (or taken) to the appropriate circuit where it awaits an idle circuit condition.

When the outgoing circuit becomes idle, the message is transmitted. Following transmission, the send-page copy is torn from the outgoing paper roll and affixed (stapled usually) to the original message form. The tape is hung in a storage rack (where it is retained 24 hours) and the message is returned to the message center desk, where it is "cleared" in the log, annotated as transmitted, and filed. The exception to the above procedures are Western Union messages which, since they are sent manually by direct keyboard, by-pass the tapecutters and proceed from the message center desk directly to the WUX circuit. This outgoing message activity is shown in Figure 2. The physical layout of the facilities is shown in Figure 3. It should be immediately apparent that the equipment is not arranged in the Industrial Engineer's idea of an ideal layout of facilities. This happens, however, to be the arrangement of the Little Rock AFB COMMCEN. This configuration, while not ideal, is typical of the Air Force COMMCEN. The disarrangement is due to piecemeal procurement, installation, and modification of equipment as well as various security rules for physical arrangement of machines which process classified materials.

Incoming messages are handled in much the same manner as outgoing ones, yet in reverse order. A message is received over one of the teletype machines, handed to the message center desk clerk, logged, and then delivered to BDAS by courier. Routine messages are delivered each hour during normal courier deliveries (8AM-7PM during winter duty hours, and 7AM-6PM during the summer). Priority messages (and of course those of higher precedence) are delivered immediately.

Data

Certain data were required to insure that the modeling of the



Delivery Window: Messages arrive at the COMMCEN here. Point of contact to the outside world. Messages are screened and signed for here.

Message Center Desk: Message routings are assigned, logs kept, message handling time computed from here.

Tape Cutter: Message tapes are prepared by perforation of 5 channel paper tape by operator.

Circuit: Message tape is transmitted to distant station for subsequent relay to addressee. Page copy of transmission extracted following the message transmission.

Message Center Desk: Message logs previously "opened" are "closed." Message handling time noted.

File: Tape hung on storage rack. Messages placed into collective files.

Figure 2. System Flow for a Typical Outgoing Message

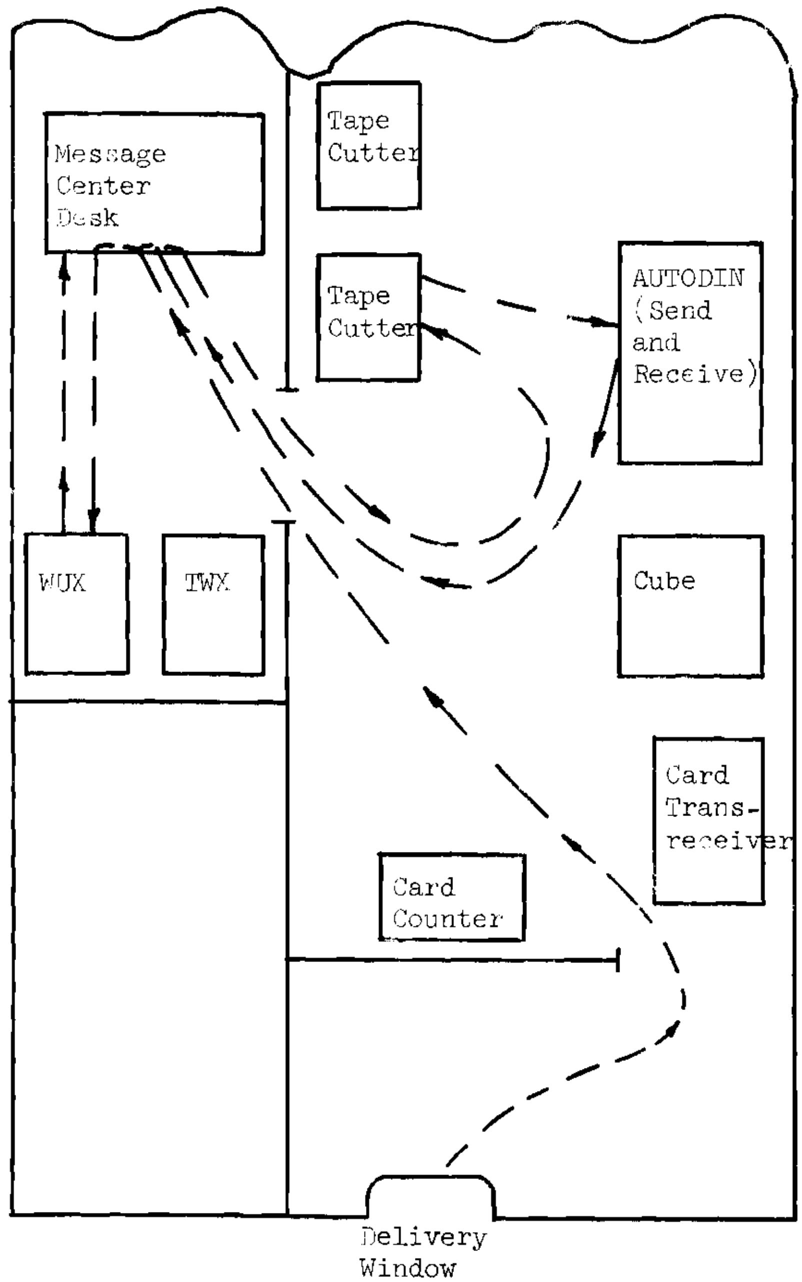


Figure 3. Layout of COMMCEN LRAFB

COMMCEN was realistic and conformed to actuality. Those necessary data for the simulation include:

1. message volume (send and receive) and distribution,
2. message precedence distributions,
3. message routing distributions,
4. message length distributions (incoming and outgoing),
5. manpower availability,
6. equipment operating speeds,
7. tapecutter operation abilities, and
8. manual in-station message handling times.

The necessary data were extracted from actual operational records at Little Rock AFB, Arkansas and were compared to message volume records for other stations with equipment similar (by type or performance) to that for LRAFB. This comparison indicated that the data were indeed representative of the Air Force TRIBSTA and, therefore, could be used in the model being constructed. The data were extracted in the fall of 1968, but correspondence has been periodically exchanged with the Little Rock COMMCEN management staff to insure data are still typical for that installation and, therefore, for most tributary stations. The most recent exchange is dated February, 1969.

Equipment

Before the construction of the model can be discussed, some information about the data and the equipment characteristics must be presented. The equipment to be used in considering this simulation had to be the same as that in the Little Rock COMMCEN. No provisions were to be made for additions or deletions since the equipment considerations were static. It should be recognized by the reader however that, should equipment capabilities be altered (either for study or for the purpose of modeling a changed real-life counterpart), the programming task in the special purpose language, GPSS, would be simple for a programmer with any experience in that method of simulation.

Equipment available for the model were:

1 each ASR set (AUTODIN)

1 each M-19 teletype unit (TWX)

1 each Printer and keyboard unit (WUX)

2 each Kleinschmidt teletype units (tapecutters)

The operating speeds of these teletype equipments are shown in Table 1.

Table 1. Message Processing Speeds

AUTODIN (send)	200 words/min
AUTODIN (receive)	100 wpm
TWX (send and receive)	60 wpm
WUX (send and receive)	40 wpm
Tapecutter operation	40 wpm
Message center operation	1 min/message

Distributions of Messages

The messages that are brought to the COMMCEN for transmission are divided into four classes of precedence (5). These classes are arranged in increasing order of importance and, consequently, in order of handling speed requirements. The classes are: routine (the lowest and slowest), priority, immediate, and flash. The reader unfamiliar with the military precedence system for messages should avail himself of the information contained in the cited literature. Routine messages are delivered to the COMMCEN by courier (as previously described) and the distribution of these deliveries (arrivals) is shown in Figure 4. The three categories of high precedence messages are distributed as shown in Figure 5.

Once a message is received at the message center desk, it is assigned a destination routing. Based upon this routing, the message is transmitted via one of the three facilities available, AUTODIN, TWX, or WUX. The cummulative distributions for this transmission mode and for these assignments are shown in Figure 6.

Messages are usually different lengths. The average message length (both outgoing or incoming) for this particular COMMCEN is 200 groups, although there are large variations from message to message. The distributions of message length are shown in Figures 7 and 8. Figure 7 represents distributions of low precedence traffic message length (usually longer). Figure 8 shows the message length distributions of high precedence traffic.

Precedence distributions for incoming messages are shown in Figure 9. This distribution generally applies to all incoming messages regardless of the circuit over which they were received.

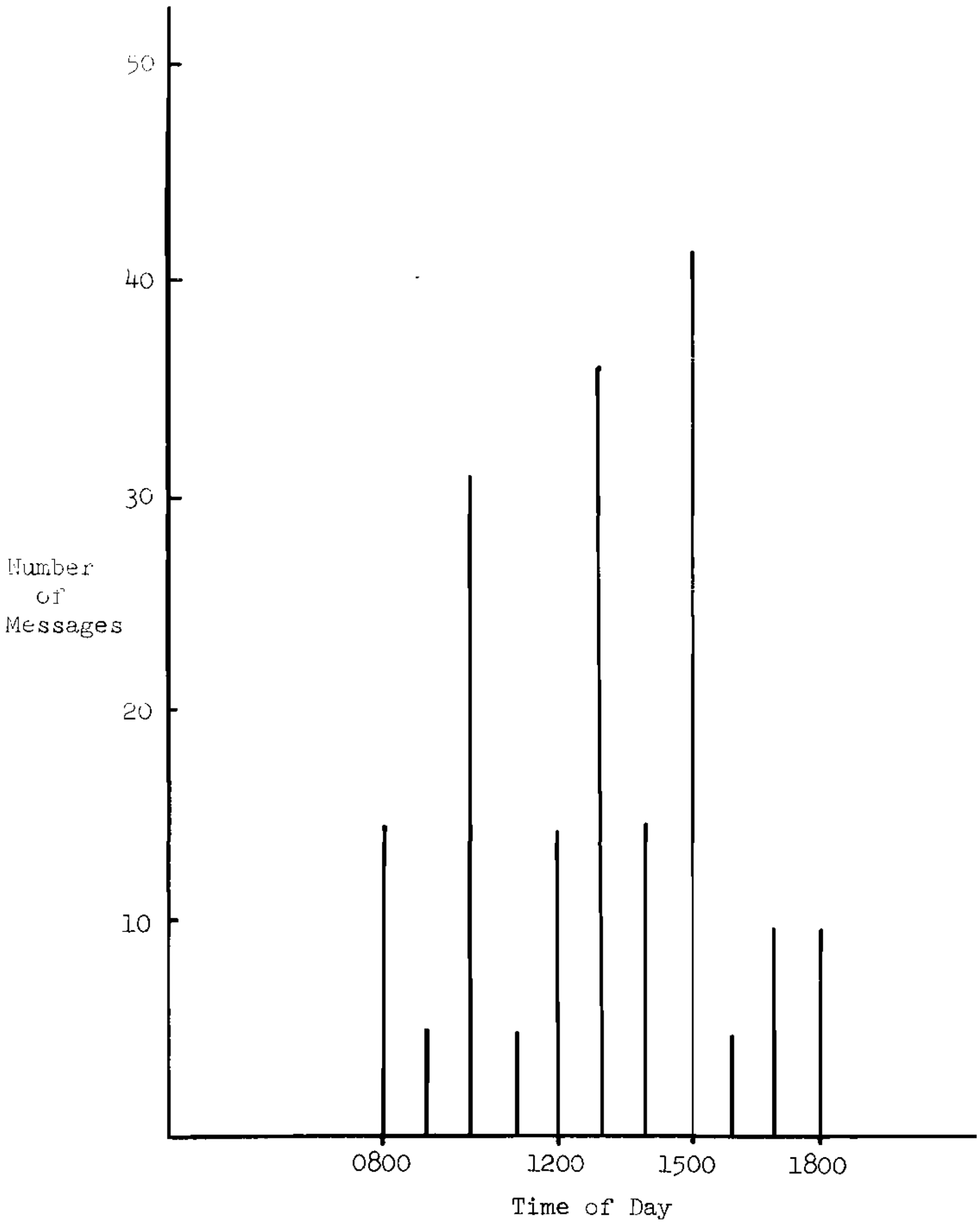


Figure 4. Low Precedence Arrivals at the COMMCEN
(Winter Set "A")

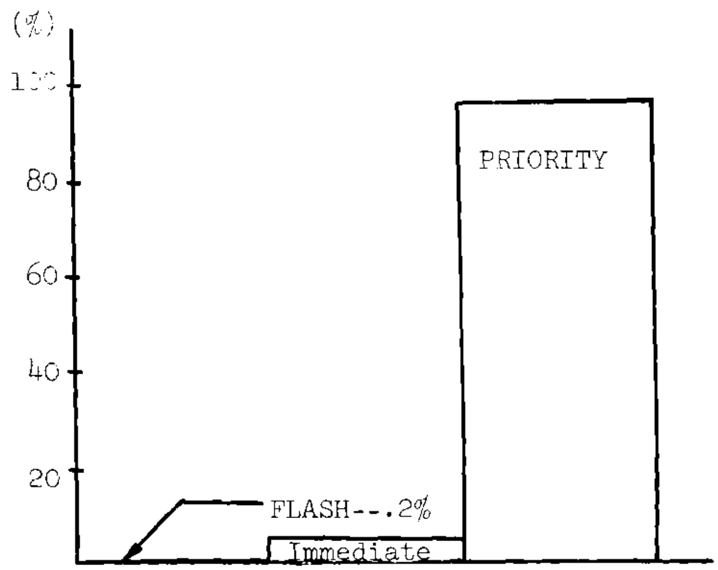


Figure 5. Outgoing Message Distributions, High Precedence (FUNCTION 1)

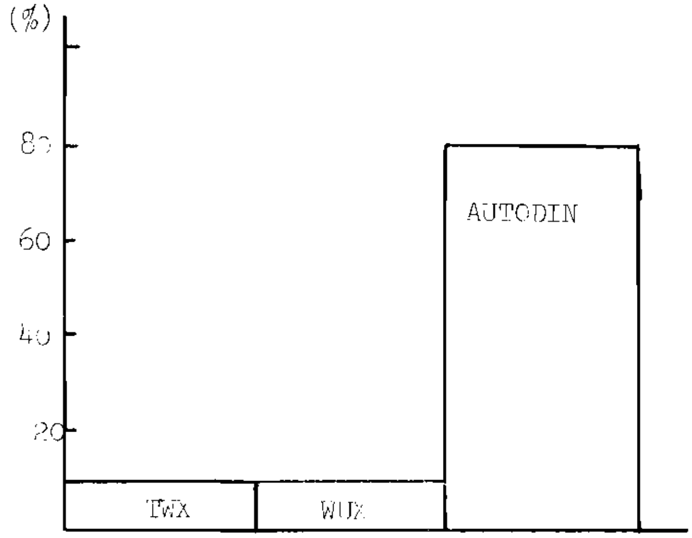


Figure 6. Transmission Mode Distributions
(FUNCTION 2)

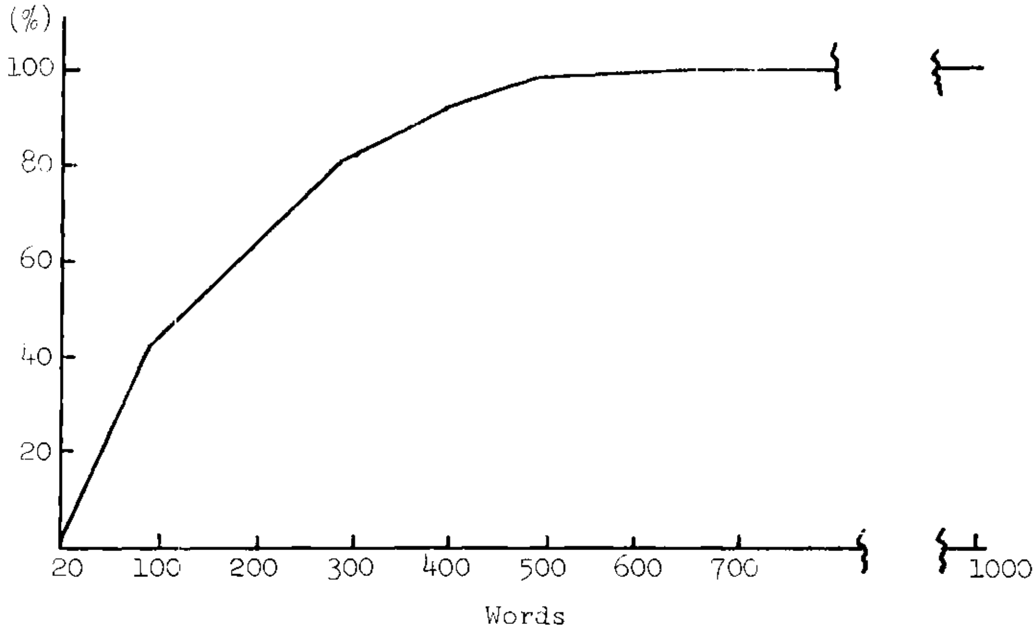


Figure 7. Message Length Distributions, Low Precedence Messages (FUNCTION 4)

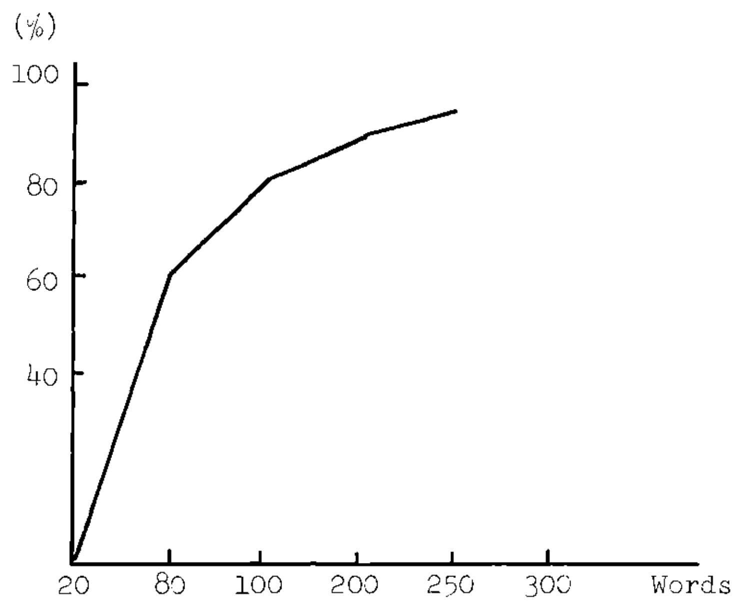


Figure 8. Message Length Distributions, High Precedence Messages (FUNCTION 5)

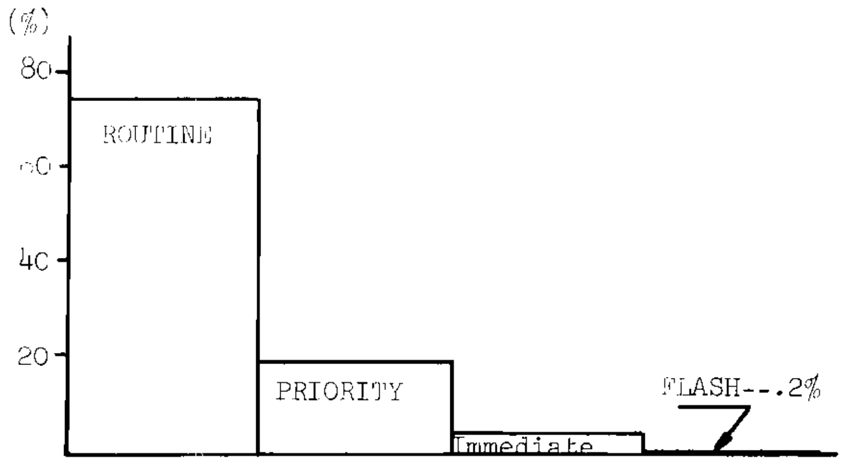


Figure 9. Incoming Message Precedence Distributions (FUNCTION 3)

CHAPTER V

THE COMMUNICATIONS CENTER MODEL

Analogues

A certain amount of background, on the part of the reader, is assumed by the author. Therefore, a discussion of GPSS-2 and the merits of that language or the capabilities of each block in that language will not be presented. Any questions concerning the programming language should be resolved by consulting the UNIVAC Corporation manual UP-4129, a manual for GPSS-2, as this programming language has been implemented on the UNIVAC 1108 computer. Other references were contained in the literature survey chapter of this thesis and a study of these should provide an adequate background in GPSS-2. Answers to questions arising from terminolcgy, practices, or requirements of the United States Air Force (or any Department of Defense Communications Agency for that matter) may be found in the 100 series of Communications-Electronics Doctrine (CED) and, therefore, will not be presented here (14).

In general, the GPSS-2 model of the COMMCEN was constructed to allow the following analogues of representations:

1. message deliveries were simulated by ORIGINATE blocks with times and volume based upon the data cited;

2. transaction parameters contain message length, message routing, message mode, temporary information storage, and manpower utilization factors;

3. precedence is assigned to each transaction by use of a PRIORITY block following functional designation;

4. message center desk, tapecutters, teletype machines, and the men themselves are represented by INTERRUPT or HOLD blocks as applicable;

5. statistics concerning the model and each particular "run" are maintained by QUEUE and TABULATE blocks; and

6. logic flow and path routing utilizes COMPARE blocks to route messages according to values contained in the parameters and described by functions.

Model

In the model, before transactions could be created, certain decisions had to be made concerning representations of actual messages. Parameter 2 in each transaction was selected to indicate the routing. The coding for this utilization was P2=0 indicates AUTODIN, P2=1 for TWX, and P2=2 for WUX. Following the generation of a transaction anywhere in the program, the proper routing for that transaction was assigned according to FUNCTION 2. This function is a GPSS-2 functional description of the distributions shown previously in Figure 5. An example of the assignment of this parameter is shown as indicated.

```
30   ASSIGN   2    FN2           32
2    FUNCTION RN1  D3
.8            1    1.0   2
```

Parameter 3 was used to indicate whether a transaction represented incoming or outgoing messages. This use was especially helpful when decisions (in the steps of logic or switching) were to be made or when tabular information was gathered. Assignment of parameter 3 was accomplished by an ASSIGN block when required (when message was to be identified as incoming). P3=0 (no ASSIGN block necessary) represents outgoing or send traffic and P3=1 was used for incoming in the following manner.

331 ASSIGN 3 K1 332

Message precedence was indicated on each transaction by the use of a PRIORITY block which placed a value in the proper location in the transaction to correctly speed up the handling of high precedence traffic. At the same time (in the next block), parameter 4 was used as an indicator for either "high" or "low" precedence paths for tabulation. This parameter was set by use of an ASSIGN block and followed each appearance of a PRIORITY block. Parameter 4 is coded as follows: for low precedence traffic P4=0, for high precedence messages P4=1.

Parameter 1 was used much like parameter 4; that is, to indicate whether a message was a combination of high precedence and outgoing type. Its main difference was that, once the message was transmitted, the precedence (PRIORITY designation) was removed since the mechanics of logging the message to clear it required no urgency once the actual transmission had taken place. The values stored in parameter 3 and distributions used for the PRIORITY blocks were determined by FUNCTIONS 1 and 3, respectively. The functions were generated to represent the conditions shown in Figures 6 and 7 which were presented earlier. A summary of the operations established by the few paragraphs above is presented for clarity. In the sample, also note the use of parameter 5 and variable 1.

```
21   ORIGINATE  1              29       60       50
29   PRIORITY   FN1            31
1    FUNCTION   RN1    D3
.95  1    .998  2      1.0  3
31   ASSIGN     4      K1      600
600  ASSIGN     5      FN5     33
5    FUNCTION   RN1    C6
0    20   .6    80     .8   100  .9  200     .95     250  1.0  300
33   ASSIGN     6      V1      34
1    VARIABLE   P5/K200+K1
```

Parameter 5 represents the length (in words) of a message, both send and receive. On outgoing messages, this length factor, which was obtained from FUNCTION 5, is then divided by the tapecutter capability, by a call on VARIABLE 1 which is appropriate for the tapecutter operating speed of 40 words per minute. The time requirements, now in minutes, are stored in parameter 6 by use of the ASSIGN block.

To create a set of transactions to simulate outgoing message activity, a series of ORIGINATE blocks was used preceding the assignment of all the parameters and priorities just discussed. These ORIGINATE blocks represent the delivery of a batch of messages (or in some cases a single high precedence message) to the COMMCEN. To create the proper timing sequence of delivery, ORIGINATE blocks were "turned on" and "off" each hour to produce the activity described previously and illustrated in Figure 4. A sample of the on-and-off action is presented below, but it is necessarily brief. For a full view of the ORIGINATE actions, the compilation portion of the main program should be studied (see Appendix A).

10	ORIGINATE	481	10	30	1
11	ORIGINATE	541	5	30	1
12	ORIGINATE	601	30	30	1
13	ORIGINATE	661	5	30	1
14	ORIGINATE	721	15	30	1
15	ORIGINATE	781	30	30	1
16	ORIGINATE	841	15	30	1
17	ORIGINATE	901	30	30	1
18	ORIGINATE	961	5	30	1
19	ORIGINATE	1021	10	30	1
20	ORIGINATE	1081	10	30	1

The message center desk, preceded by QUEUE 1, is represented by a HOLD block (facility 1). This type of facility is used to give the effect of the real-life counterpart; that is, when a high precedence message comes into the COMMCEN, it is expedited and processed ahead of others. However, at the message center desk, action time for logging is so short that normally a transaction in progress would not be interrupted. Instead, the high precedence message would be placed "on the top of the pile" thus placing it at the head of the queue. A transaction takes from zero to two minutes at the message center desk, depending upon routing and format.

65	HOLD	1	70	1	1

The tapecutter machines are represented in INTERRUPT blocks. A message under preparation would be halted and delayed by the passage of a higher precedence message. Tape preparation time, as discussed earlier, was calculated by dividing message length (from parameter 6) by operating speed; the result being stored in parameter 6. This time is used to set the facility activity time (by indirect specification) for the tapecutter teletype machines. Note that WUX messages bypass tape cutting; they are sent directly on line and, therefore, no tape is prepared for this type of traffic. A small logic step, using COMPARE blocks, separates this type of traffic. The logic net and the tape-cutter representations are shown below.

75	ADVANCE				BOTH	80	81	
80	COMPARE	P2	NE	K2		85		
81	COMPARE	P2	E	K2		210		
85	QUEUE	4		. . . .	BOTH	115	116	
115	INTERRUPT	2				119		*6
116	INTERRUPT	3				119		*6

From the tapecutters through another logic separation (COMPARE blocks), the appropriate circuit is selected for transmission of the message. QUEUES 5, 8, and 10 indicate message awaiting a circuit condition. AUTODIN, TWX, and WUX machines are represented by the facilities INTERRUPT 4, HOLD 5, and HOLD 6, respectively. Blocks 5 and 6 are HOLD blocks rather than INTERRUPT, as these facilities (TWX and WUX) only process low precedence traffice and are, therefore, serviced on a first-come, first-served basis. Since TWX and WUX are half-duplex circuits, these facilities are also receiving traffic in between outgoing transmissions. This activity is represented by the appropriate ORIGINATE and ASSIGN blocks which are also tied to these transmitter blocks. This receive activity is modeled to include the proper parameter values for incoming message activity. The use of ASSIGN and ORIGINATE has been amply described earlier in the paper, so the example below will show only those blocks which model the facilities themselves. AUTODIN receive activity is independent of the send operation. The receive models for AUTODIN, represented by ORIGINATE blocks, are tied directly into the message center desk representation (HOLD 1), unlike the TWX and WUX receive activity. Before the example cited above is shown, some mention of the indirect specification found in the facility blocks should be made.

Message transmission times for facilities 4, 5, and 6 are calculated in the same manner as those for the tapecutters. The message length, parameter 5, is divided by the appropriate operating speed, by employment of VARIABLE blocks representing particular facility speed, and the result is stored in parameter 7. Activity time is then taken by a call on parameter 7 at the proper time. The example of this operation coupled with the facility activity follows.

```
34   ADVANCE                            BOTH 35    36
35   COMPARE     P2    E    KO             37
37   ASSIGN      7     V2                 to circuit
2    VARIABLE    P5/K200+K1
36   ADVANCE                            BOTH 38    39
38   COMPARE     P2    E    K1             40
40   ASSIGN      7     V3                 to circuit
3    VARIABLE    P5/K60+K1
39   ASSIGN      7     V4                 to circuit
4    VARIABLE    P5/K30+K1

160  INTERRUPT   4                         161    *7     AUTODIN
190  HOLD        5                         200    *7     TWX
235  HOLD        6                         235    *7     WUX
```

All transactions pass through a small logic network between the circuits and the message center desk. In this network, statistics are compiled for outgoing traffic, both low and high precedence, with regard to handling time. This information is connected in TABLE blocks 1 and 3. Next, the precedence is removed, since once the message has departed the station (transmitted on the circuit), there is no hurry to get the page copy filed. All messages next pass through the message center desk

(HOLD 1 again) where they are either logged and delivered or filed. Either course of action is determined by a small logic step at the end of the program. Incoming message data are collected in TABLE 2 and the simulation run is complete with regard to machine operation. The logic steps cited and the tabulation devices are shown below.

```
270   ADVANCE                                BOTH   271   272
271   COMPARE     P3    E     K0                    335
272   COMPARE     P3    NE    K0                    274
274   HOLD        1                                 276
276   ADVANCE                                BOTH   277   278
277   COMPARE     P3    E     K0                    280
278   COMPARE     P3    E     K1                    281
279   TABULATE    1                                 276
280   TERMINATE
281   TABULATE    2                                 300
300   TERMINATE
335   ADVANCE                                BOTH   336   337
336   COMPARE     P4    E     K0                    279
337   COMPARE     P4    NE    K0                    338
338   TABULATE    3                                 340
340   PRIORITY    0                                 276
```

The tables generated by the above blocks, which call on TABLE, are described by the following cards in the program.

```
1   TABLE   M1   0   60   8
2   TABLE   M1   0   60   8
3   TABLE   M1   0   5    10
```

The output produced by the TABLE blocks is the standard GPSS display. TABLE 1 produces a history of in-station message handling time for low precedence messages. This table is divided into one hour (as indicated by the 60 in the "Z" field) categories; therefore, the results are easily analyzed and compared to established standards. TABLE 2 displays the same information for incoming messages that TABLE 1 did for outgoing and is, therefore, arranged in the same manner with 60 minute intervals.

TABLE 3 is only slightly different from the others. This table lists the in-station handling time for outgoing high precedence messages. It is divided into increments of five minutes so that the high precedence message flow may be closely scrutinized. Samples of these tables are contained in Appendix A under the heading "Program Output."

Thus far, nothing has been said about the modeling of the men who operate the machines previously described. To represent the function of man interacting with the machine activity of the COMMCEN, a series of SEIZE, ASSIGN, and RELEASE blocks was used around each of the facilities that has been described throughout this chapter. The system operates in the following manner. A transaction is created (as described earlier) in an ORIGINATE block. It receives its appropriate parameter values and looks for an available man. Once a man (who is represented by INTERRUPT 10 through 14) is available, he is selected by use of the SEIZE block. An ASSIGN block is then used to show which man was seized by placing that man's number (10 through 14) in the applicable parameter (parameters 8 through 13). The manpower facility is then held until the machine (represented earlier by INTERRUPT or HOLD blocks) has been used and the transaction passes the proper RELEASE block. Each facility in the model is preceded by a series of "manpower" operations. This links the man to the machine and insures that, each time a facility is called, a man will be available to operate it. This manpower representation is shown below for a typical module.

85	QUEUE	3		ALL	90	94
90	SEIZE	10			100	
91	SEIZE	11			101	
92	SEIZE	12			102	
93	SEIZE	13			103	
94	SEIZE	14			104	
100	ASSIGN	9	K10		110	
101	ASSIGN	9	K11		110	
102	ASSIGN	9	K12		110	
103	ASSIGN	9	K13		110	
104	ASSIGN	9	K14		110	
110	QUEUE	4		BOTH	115	116
115	INTERRUPT	2			119	*6
116	INTERRUPT	3			119	*6
119	RELEASE	*9			120	

The model of the COMMCEN is complete now to the point of simulating both the actions of man and machine and, as described, requires both to operate. The simulation is now ready to run during the production phase of the project.

A generalized flow chart of the model is shown in Figure 8. This is in actuality a skeleton of the model before the manpower modules were added. To integrate the man element into this flow chart, each facility in Figure 10 is altered (as described in the preceding paragraph) by the addition of the manpower series of blocks. This alteration is shown in Figure 11 for a typical facility. The additional complexity of the model caused by the man factor is readily apparent. A basic assumption about this addition of man (and the forthcoming "manpower" modules) was that each man in the COMMCEN possessed the same skill or operational ability. The men then were interchangeable.

A fully detailed flow chart was produced by a call on the FLOW feature of GPSS-2. Although not included in this report proper, this detailed flow was carefully checked by the primary programmer and others

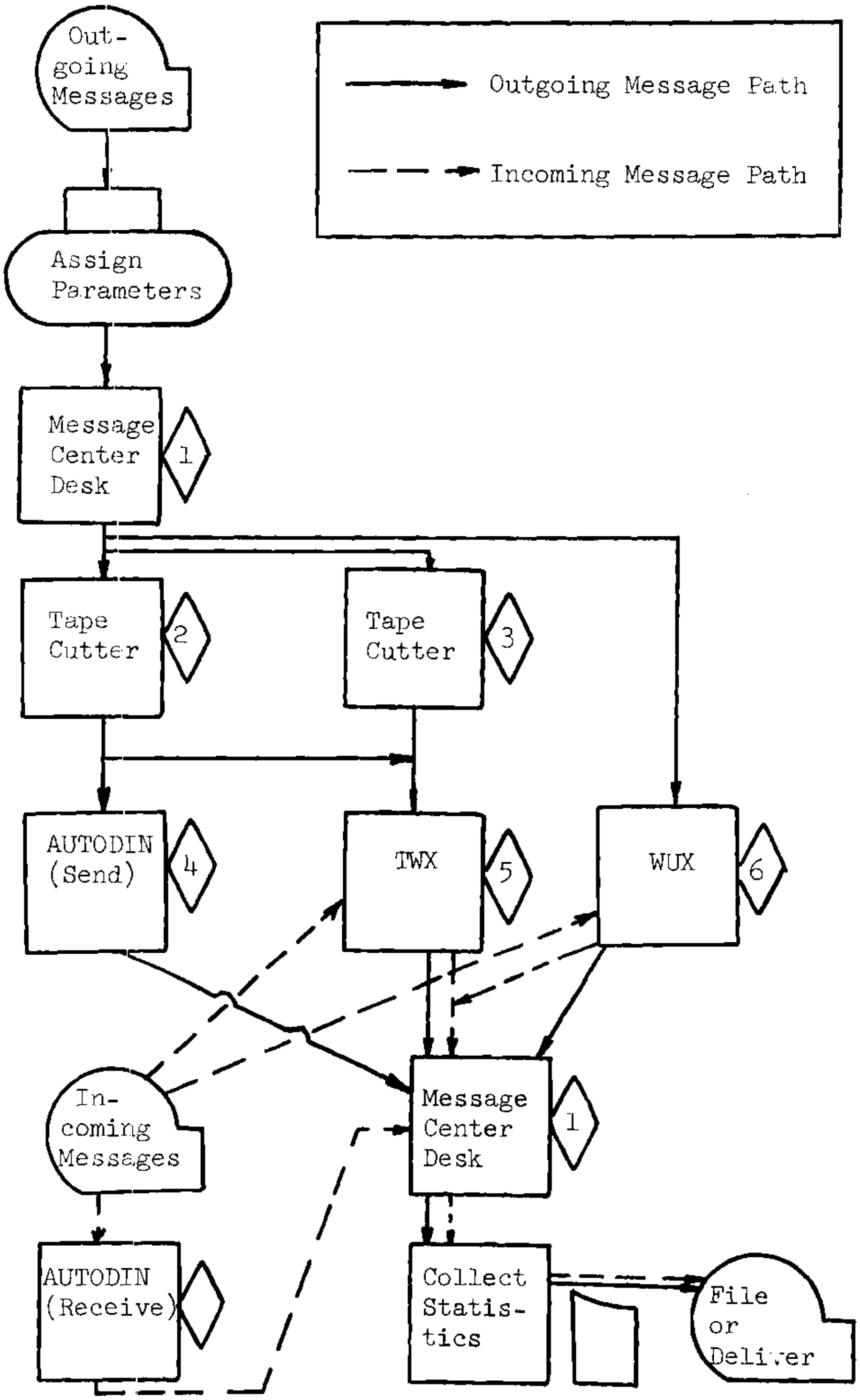


Figure 10. The Basic Model

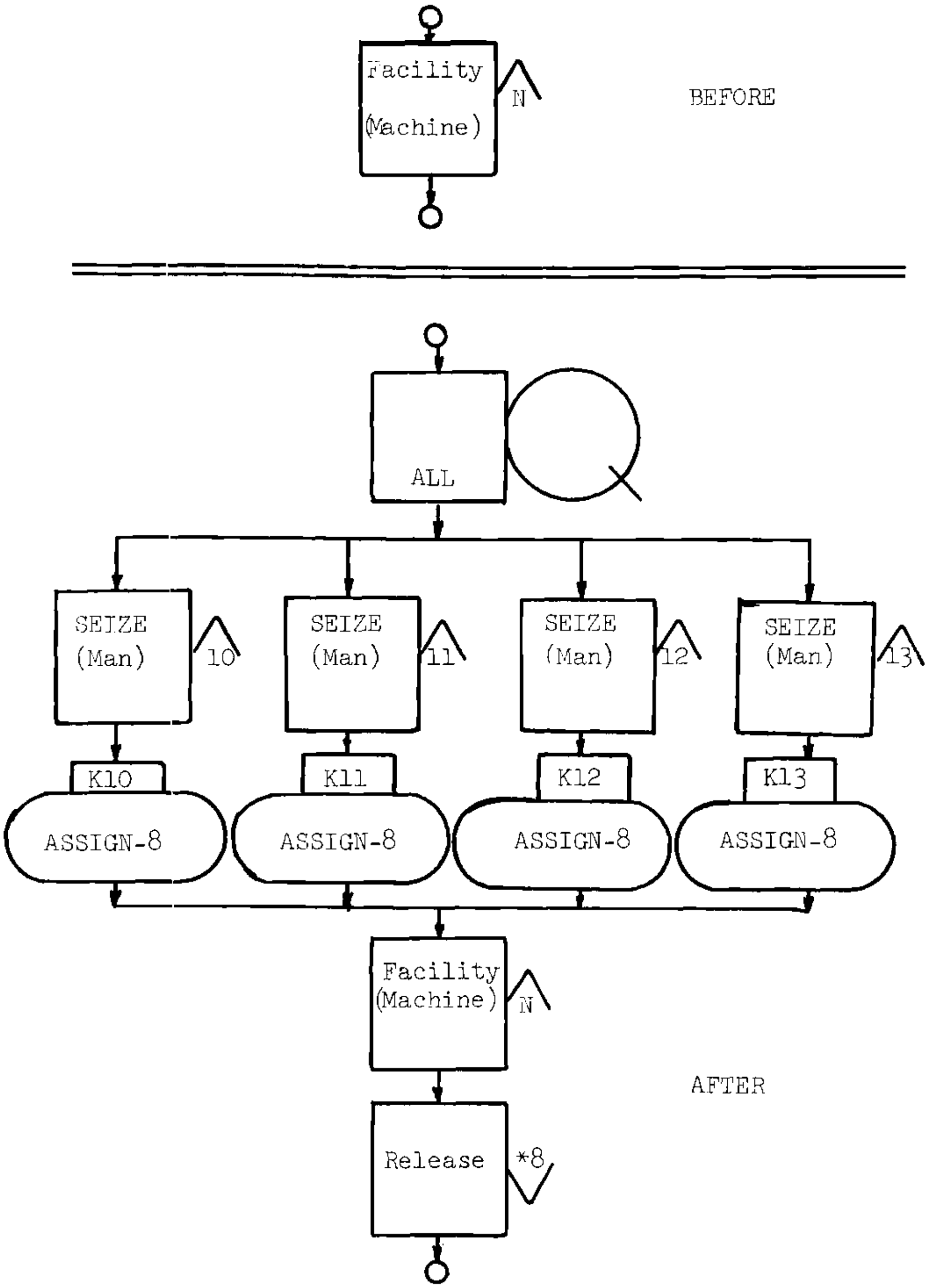


Figure 11. Effect of the Man Factor upon a Facility

in order to find instances of either circular reasoning or possible "loops" in coding. None were so noted.

All of the preceding discussion was based upon operation of the simulation for a single day. The ORIGINATE blocks, for both send and receive traffic, are based upon only one 24 hour run. Furthermore, as described at the beginning of the run, all queue lengths would be zero with no transactions (messages) in progress; therefore, all men and machines would be available. This condition normally only exists in the actual COMMCEN on Monday morning. It occurs then because no low precedence traffic is initiated over the weekend and few messages are received. This slack period gives all of the queues time to empty, and the facilities are often idle during the weekend period. The problem faced by the modeler was, then, not to show just the Monday operation but rather the operation for the entire week.

The solution to this problem was found by adding complexity to the model. ORIGINATE blocks were added in order to introduce messages to the system for an entire week. This was accomplished on both send and receive activity by adjustment of the times of origination to expand operation to the seven day span. Tuesday activity began at clock time 1921 (absolute), Wednesday at 3361, etc.

To collect message handling statistics for each day of the week, START and RESET run cards were employed with one day intervals represented by 1440 minute run periods. The model, as so described, now begins operation on Monday and runs through midnight of that night. Statistics for Monday are displayed and Tuesday statistics are begun. Transactions in queues at the end of the day or those currently in process are carried over into the next day's statistics and the entire week is run. A sample of the START and RESET series is shown below.

```
START          1440          MONDAY
RESET
START          1440          TUESDAY
RESET
START          1440          WEDNESDAY
etc.
```

Once these changes were introduced, the model was ready for test runs. A complete compilation of this final version of the COMMCEN model is included in Appendix A for consolidated reference.

Verification of the Model

Once the model was operational and capable of production runs under different message length assignments, precedence distributions, message batch arrivals, and manning considerations, these items were then varied to insure that the model acted in the same manner as did the actual Little Rock COMMCEN under similar circumstances. Without a complete discussion of all the tests rendered, it is sufficient to state that the model reacted to the changed stimuli as does the LRAFB COMMCEN in actual practice. Longer message length resulted in longer transaction times and greater in-station handling time. Increasing the number of high precedence messages caused longer in-station times, even though the high precedence messages passed through the system without additional delay.

These tests verified both the precedence assignments (PRIORITY blocks) as well as the protypical actions of the INTERRUPT blocks. During test runs, selected transactions were followed through the model and in each instance the transaction followed the predetermined path, performing as predicted. Following this series of tests, the model was declared operational and production of data was begun under various manpower load factors. To produce the varying manpower loading, a unique method of modularity was built into the model. This feature and its use is discussed in the next section.

Manpower Modules

The programmer who wrote the computer simulation (the author) was familiar enough with its construction to vary the manpower considerations by simply rewriting those blocks which represented men. Once other personnel, such as communications school staff members, assume the duties of running the program, such ease of change will be missing. The apparent need was a series of modules (decks of punched cards) which could be added to the main body of the program and which could be changed by someone totally unfamiliar with the operation of GPSS-2 and of the internal structure of the model.

Several systems were considered and implementation attempted. The final selection was an indexed card file of small decks, which allows the manpower to be varied by merely inserting the deck which indicates the desired manning strength levels and hours of duty. The insertion location is well marked on the edge of the cards in the main program, and appropriate operating instructions have been written to guide the novice user. These instructions are itemized in the portion of this paper dealing with operation of the model and will be furnished to the operators of the scenerio.

To facilitate the desired modularity, the maximum number of men (five) were provided with the basic model. The changes to it were then made by selectively removing some of the availability. The minimal case studied was that of only two men on duty around the clock. For security and electrical safety reasons, manning below that point was considered to be unsound management.

It must be remembered that, in the earlier discussion in this chapter, men were represented by blocks INTERRUPT 10 through INTERRUPT 14. To remove one of these blocks from accessibility by the main program, an ORIGINATE block produces a single transaction at the time the block is to be removed. A very high PRIORITY (greater than 3, the maximum in the model) is given the transaction, and the desired man (facility) is accessed with a HOLD block. The transaction time through the facility is made the same number of minutes the facility is to be lost, up to 10080 in the case of a reduction in manning amounting to a total of four men.

In the representations of actual operations, part-time worker employment was also considered. Should a facility (man) go "on duty" then "off duty," as would the typical booster operation, the high priority disrupting transaction would occupy the facility during hours of "off duty" time and be shunted to a "dummy" facility during the period representing the man's duty hours. These dummies are represented, when necessary, by facilities 20 and 21 and are accessed by INTERRUPT blocks. Once the duration of the run was surpassed or the necessity ended for removing the man, the high priority transaction was sent to a TERMINATE block. Samples of full time manpower loss and of part-time loss follow.

370	ORIGINATE	0	1	371	1	
371	PRIORITY	4		372		
372	HOLD	14		373	10080	
373	TERMINATE					
380	ORIGINATE	0	1	381	1	
381	PRIORITY	4		382		
382	HOLD	12		383	960	MON IDLE
383	HOLD	20		384	480	MON DUTY
384	HOLD	12		385	960	
385	HOLD	20		to 392		
392	HOLD	12		393	2880	WEEKEND
393	TERMINATE					

The module method of changing the manpower requirements proved so successful in varying the operating conditions that the same method was used to represent a lunch break for the day shift personnel during the week. The booster personnel were assumed to have eaten prior to reporting for duty. Two hours lunch for one man was modeled rather than one hour for two men because of the ease of programming. The net result is the same, that is, loss of two man-hours from 1100 to 1300 daily. In the following sample of the lunch routine, a man is represented by HOLD 10 and facility 22 is a "dummy" used during duty periods for man number 10.

601	ORIGINATE	660	1	602	1	
602	PRIORITY	4		603		
603	HOLD	10		604	120	MON LUNCH
604	HOLD	22		605	1320	
605	HOLD	10		to 611	120	TUE LUNCH
611	HOLD	10		612	120	FRI
612	TERMINATE					

Security

The Communications Center simulation by computer is destined to be run in an academic or "game" type of environment even though the model will not be run as a game itself. Past experience with industrial or business games has established the desirability of several sets of input information (26). Such information should be provided to insure one group of students does not merely "pass-on" information to the next but rather that each class learns by data analysis and decision making. This idea was extended beyond the mere mixing of input functional values, the original solution to this problem.

The method presently employed in the teaching sessions and contained in the model "package" is discussed next. Four sets of data, all similar to the basic set (ORIGINATE blocks 10 through 20, 500 through 545) yet containing some differences, are available to the instructor. Message Center Registers (AF Form 1022) have been developed to coincide with each set of these data. The Communications school issues a set of Message Center documents to the class and insures that the cards appropriate for those documents are inserted in the computer deck prior to its running.

The insertion is accomplished by placing a module group of cards into the marked location in the main program in the same way that changes are made to the manpower elements of the program. A set of cards is provided to model the message arrivals at the COMMCEN during winter duty hours (normal day 0800-1700) or summer duty hours (0700-1600). Another set of each (set "B") is furnished with slightly different arrival rates. The same sort of deck, set "A" or set "B" will be used for an entire class cycle. Another set of ORIGINATE cards will be selected for use by the following class to prevent overexposure of any particular set of data.

Set "A" was presented earlier in this thesis as the message ORIGINATE blocks (representing outgoing messages) which trigger the response of the model. An example of set "B" is shown below for contrast and to point out the basic similarities and operational differences in these sets of punched cards. The Message Center Registers that coincide with these arrival distributions are shown in Appendix B.

10	ORIGINATE	481	5	30	1
11	ORIGINATE	541	10	30	1
12	ORIGINATE	601	25	30	1
13	ORIGINATE	661	20	30	1
14	ORIGINATE	721	10	30	1
15	ORIGINATE	781	30	30	1
16	ORIGINATE	841	10	30	1
17	ORIGINATE	901	25	30	1
18	ORIGINATE	961	10	30	1
19	ORIGINATE	1021	10	30	1
20	ORIGINATE	1081	10	30	1

It was not the objective of this thesis to model a COMMCEN for analytical purposes. At this point, however, it should be noted that this model could be used for COMMCEN analysis with regard to both manpower and equipment requirements. The modularity of the working model gives it a flexibility that is highly desirable to the investigator of message handling delays. Other Communication Centers could be easily simulated by coding and inserting their message arrival data into this model and the resultant outputs then analyzed for whatever special purpose the investigator had in mind. Future studies would concern themselves solely with the results of data runs since the analogies and representations required for COMMCEN simulations have now been established. Work of this type, that is, the analysis for its own sake, is not considered in this work (as noted earlier) but would be of special interest to the Communications staff at the Training Center. Their particular areas of interest would be in simulations with regard to standardization, staffing, and in-house operations problems.

Once the security modules were complete and tested for operationality, the model would be certified as completely operational and data runs could be conducted to model the COMMCEN operation.

CHAPTER VI

RESULTS OF TEST RUNS

Model Sensitivity

In his article on the nature of simulation, Dalkey (16) states precisely the central theme of this chapter.

> It should be reiterated that a simulation is only a part of the over-all system analysis. Usually, simulation will be concerned with the effectiveness computation. The simulation model needs to be supplemented with an evaluation technique. This last is usually referred to as "analysis of results," but a great deal more is involved than mere tabulation.

Dalkey further states that analyzing the voluminous information generated is normally a major task. These observations became especially apparent in this simulation.

Prior to a run of the model to furnish output information for analysis, the computer simulation was run for the purpose of studying just how sensitive the representation was to varying stimulation. To observe this phenomenon, message ORIGINATE blocks were varied to represent from 155 low precedence messages, in increments of 10, up to 185 of them. The variations took place during the same "week's" run with all other factors in the model being held constant. The effect of various manpower availabilities was examined under the loading just described.

Preceding a discussion of the various manpower configurations, a definition of terms relating to manpower should be presented since this terminology will continue in use throughout the remainder of this work.

To the experienced communications officer, this review will be "old hat," but to someone encountering these terms for the first time, the various concepts can become confusing.

Rotating Shifts--An arrangement of manpower resources for facilities that must be manned 24 hours per day. Since each man must have some off-duty time, the "normal" rotation is nine days or duty, three days off, where the duty days are arranged so that each man works three days of each tour of duty (i.e., three days 0800-1700, three days 1700-2400, three days 2400-0800, then three days off). The nine-on three-off schedule is not absolute, but the concept of rotating shifts of some sort is the standard practice.

Balanced Shifts--Rotating shifts where each shift has the same number of men and no men report for duty at odd hours.

Booster Shifts--Those shifts which augment the regular shift. The booster may be one or more men that come in at regular or odd duty hours.

Unbalanced Shifts--Those shifts which are not balanced, that is, those which use booster personnel.

Under manpower conditions of rotating two-man shifts, the model remained saturated, at times experiencing queue length (messages waiting for a man to become available to handle them) as high as 123 messages. Message handling times remained continually in excess of those desired and, in several cases, over 50 percent of the messages handled exceeded the six hour handling time goal. The results of this activity are not tabulated as two-man shifts under normal message arrival conditions will be presented later in this chapter.

Of particular interest under the variable load (arrivals) stimulation was the operation, under rotating three-man shifts, the traditional manning for the Little Rock AFB COMMCEN. When the lower level of message arrivals was tested in the model under this manning, 90 percent were processed in less than four hours. An increase of 10 messages did not change this percentage from the four hour handling time, but an increase of still another 10 (to 175) raised the 90 percent processed mark to six hours. Another increase of 10 to 185 messages so saturated the system that seven hours or more were required to process 12 percent of the traffic. Clearly then under three-man shifts, the saturation point was 170 messages and beyond that the delays increased at a very rapid rate. Table 2, which follows, illustrates the situation just discussed.

The rapid increase of handling time, when message load was increased, was apparent under manning configurations of four- and five-man rotating shifts although due to surplus manpower no excessive delays were experienced. The point has been made; therefore, no further tabulation of these data will be made although they are available should inquiry into this aspect of the simulation be desired. One further remark on loading will suffice to point out the sensitivity thus described. When, under four-man shifts, message load was increased by 20, from 155 to 175, the 90 percent point in handling was increased from under two to over four hours, truly prototypical of man. Once he (man) has reached his operational limitation in a given situation, his efficiency falls off at a rapid rate. Time after time the author has observed men, working at near capacity, raise their error rate and decrease production.

Table 2. In-station Delay, Low Precedence, Outgoing Messages

	Full-time Three-man Rotating Shifts				
Hrs In-station	Monday	Tuesday	Wednesday	Thursday	Friday
1	33	30	38	39	33
2	37	41	47	53	14
3	41	30	34	26	21
4	34	17	28	32	13
5	10	13	18	0	10
6	0	22	1	0	62
7	0	20	1	0	32
+ 7	0	0	0	0	0
Totals	155	175	165	160	185

Background for Test Runs

In this project, the information to be subjected to analysis was collected by exercising the model under several situations which represented different manpower configurations. Had bottlenecks appeared during these runs which were caused due to a shortage of equipment, additional equipment blocks and configurations would have been investigated. No such constraints were apparent during the runs; therefore, no equipment changes were studied. The variations in manpower produced ample evidence to direct attention to that area for improvement. A discussion of the production runs of the model is contained in the remainder of this chapter.

Balanced Shifts

The first set of runs was made under the US Air Force standard balanced shift guidelines; that is, rotating shifts with the same number of men per shift. The assumption is also made that the standard nine-days-on-duty three-days-off, rotating three days at a time, will be enforced throughout any given operational period under study. This assumption is not as constraining as it might first seem since other shifts, such as eight-days-on two-off, would apply equally well as long as the manning remains constant for the period under study. The model is valid for other duty hours too, such as rotating twelve-hour shifts. The net result in all these changes is not the model whose operation remains representative, but rather the total number of men that the particular data run represents. The same run under eight-hour-duty hours (the standard for Communications Centers in the United States) as run for 12 men available, would represent a COMMCEN in a combat zone, working twelve-hour shifts with a net manpower availability of nine men. The results would be valid for each as long as the two communications centers under study were physically the same with regard to equipment. Since the data runs at hand were to represent a typical base within the United States, data production runs were made using models and manpower modules for four five-man shifts, four four-man shifts, four three-man shifts, and four two-man shifts. The output information from these data runs was edited and is presented graphically in Figure 12.

Under the Speed of Service Criteria specified in the Defense Communication Agency (DCA) Circular 70-4, two manpower distributions produced message handling times within allowable limits (17). These manning assignments were the four four-man and four five-man shifts which represent a total of 16 and 20 men, respectively. Could fewer men do the same job if unbalanced shifts were established? If they could, the result would be a saving in manpower and would point out an optimum, near optimum, or one of several near optimum distributions of men.

Unbalanced Shifts

To find an answer (if there were one) to the above question of optimum shift manning, shift configurations were investigated which somewhat balanced the manpower to the workload. A constraint of no less than two men on duty on any given shift was imposed for the twin reasons of security and safety. Several manning distributions with one booster were studied. Data runs were conducted with the basic two-man rotating shift and a single booster reporting for duty at the times indicated in Table 3.

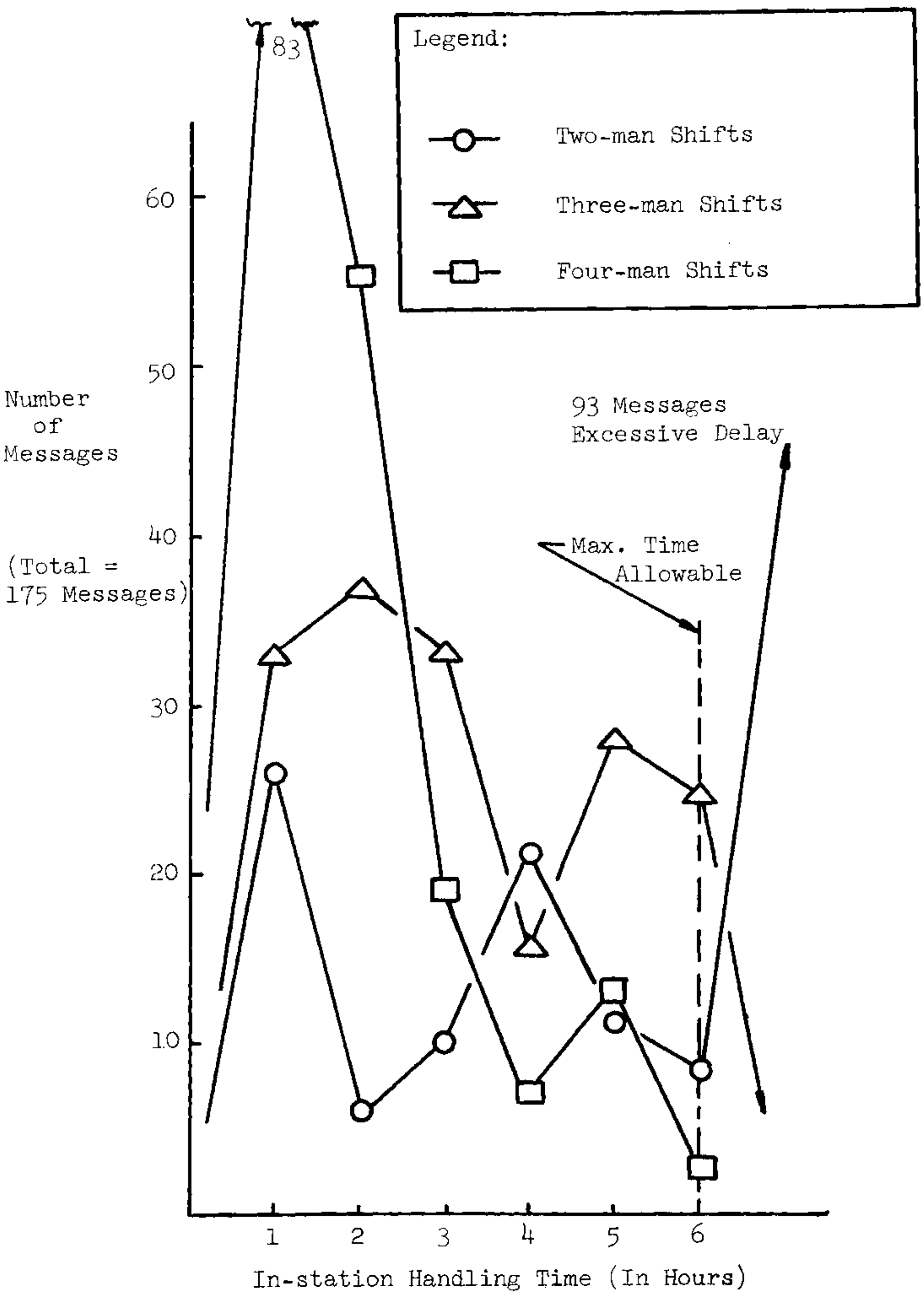


Figure 12. Manpower Effect, Balanced Shifts

Table 3. Booster Hours for Two-man Shift with One Booster Data Run

Run Number	Booster Hours
1	1000-1800
2	1100-1900
3	1200-2000
4	1300-2100
5	1400-2200
6	1500-2300
7	1600-2400

Since rotating three-man shifts were unable to cope with the incoming message flow to the message center, it was unreasonable to expect fewer men to handle it. Some experience with unbalanced shifts was required and some general conclusions were drawn from the analysis of these runs. One observation worth reporting shows that, when the backlog was allowed to accumulate before the booster man came on duty, the delays just got worse even with the extra help. On the other hand, when the booster was on duty before the peak load (or saturation point), his assistance enabled the men on duty to at least "hold their own" for a while before they were overwhelmed by the work load. This effect was, then, an overall lessening of delay under these conditions. Since all runs illustrate very excessive delay, no graphical presentation of this information is deemed necessary. The data runs are available should another investigator become interested in this phase (operation under saturation conditions).

The next manpower configuration studied was that of three-man rotating shifts and one booster at various hours. The reasoning behind this study was, if three men could "almost" handle the traffic load (the balanced shift case) what help would one more man be to them if available at the necessary time? Data runs were made as before with the basic three-man shift around the clock and a single booster present for duty at the hours indicated in Table 4.

Table 4. Booster Hours for Three-man Shift with One Booster Data Run

Run Number	Booster Hours
1	1000-1800
2	1100-1900
3	1200-2000
4	1300-2100
5	1400-2200
6	1500-2300
7	1600-2400

All of the manpower assignments where three men plus a booster were tested produced message handling data within the desired limits. No messages took over six hours to clear the COMMCEN no matter how it was manned. Output from the week's run was edited to yield "average" handling times over that period for each configuration. Table 5, which follows, is a composite of average message handling times for the system cited. The run number column coincides with the run number and booster hours listed in Table 4.

Table 5. Outgoing Low Precedence Message Handling Times

Run Number	Three-man Shifts, One Booster Number of Messages Handled (in hours)						
	1	2	3	4	5	6	+6
1	57	56	28	19	10	5	0
2	57	51	30	20	12	6	0
3	35	56	47	16	14	6	0
4	29	38	53	29	20	3	0
5	29	31	43	30	34	3	0
6	33	32	52	30	20	5	0
7	37	36	32	33	27	7	0

The "best" results in message handling time were obtained from runs 1, 2, 3, and 4. A graphical comparison of these runs is made in Figure 13. These results further substantiate the author's contention that, when the booster shift is present for duty ahead of the high traffic volume, better in-station handling times (lower overall) are achieved than when the booster arrives with a full day's work stacked up for him.

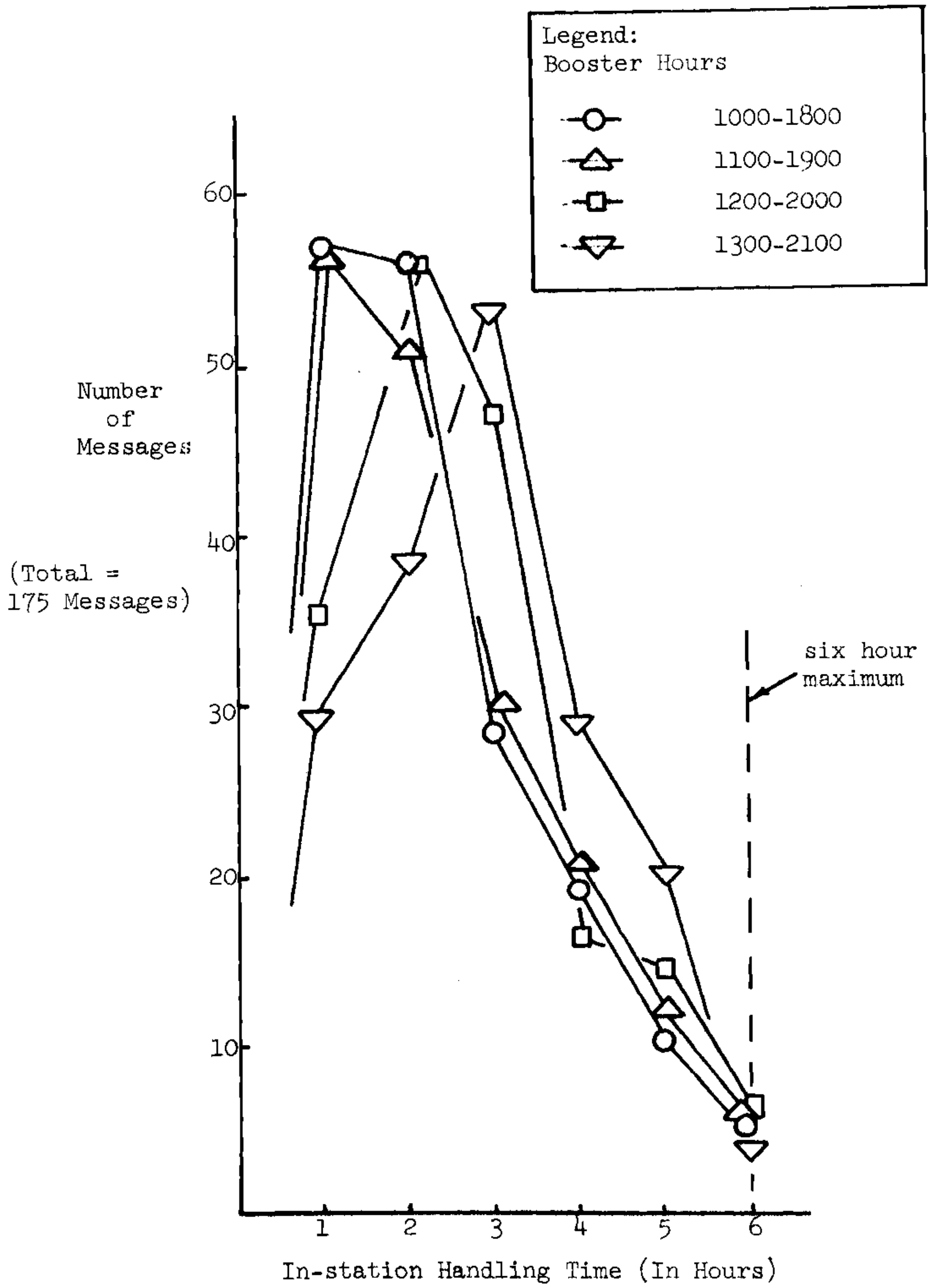


Figure 13. Manpower Effect, Three-man Shifts Plus One Booster

To decide what constituted "best" results, mentioned in the preceding paragraph, message handling times for the first three hours of handling time were studied. The first three runs (booster beginning duty at 1000, 1100, and 1200) were substantially the same; therefore, the first two hours were examined, then only the first hour. The order of effectiveness of manpower allocation was clearly established when a total of 13 men was available to the COMMCEN. Three men, full-time, with a booster from 1000-1800 was declared to be the optimum manpower distribution.

How could cases be handled where 13 men were not available and eight-hour-duty tours were still desirable? Could fewer men handle the load if the booster idea were extended to another plain? The next set of exercises of the model was conducted to examine these questions. The basic two-man, eight-hour rotating shift was again employed, this time with two boosters. To find the optimum scheduling, all combinations of two men plus two boosters were run on the computer. The runs made, and subsequently studied, are listed in Table 6. As with previous data runs, the output for those in this table was edited and examined. Average handling times for the week's run under the particular configuration were calculated and average message handling times for the various runs were collected. This collection appears in Table 7.

Analysis from the data runs listed in Table 7 indicated only two manpower configurations that kept message handling time within the six hour limit imposed by the guidelines cited earlier. Those two runs were made under manpower distributions of two rotating shifts and two boosters, a total of 10 men. The booster shifts were 1000-1800 and 1300-2100 for

Table 6. Booster Hours for Two-man Shift
with Two Booster Data Runs

Run Number	Booster Hours	
	Man #11	Man #13
1	1000-1800	1000-1800
2	"	1100-1900
3	"	1200-2000
4	"	1300-2100
5	"	1400-2200
6	"	1500-2300
7	"	1600-2400
8	1100-1900	1100-1900
9	"	1200-2000
10	"	1300-2100
11	"	1400-2200
12	"	1500-2300
13	"	1600-2400
14	1200-2000	1200-2000
15	"	1300-2100
16	"	1400-2200
17	"	1500-2300
18	"	1600-2400
19	1300-2100	1300-2100
20	"	1400-2200
21	"	1500-2300
22	"	1600-2400
23	1400-2200	1400-2200
24	"	1500-2300
25	"	1600-2400
26	1500-2300	1500-2300
27	"	1600-2400
28	1600-2400	1600-2400

Table 7. Outgoing Low Precedence Message Handling Times

	Two-man Shifts, Two Boosters						
Run Number	Number of Messages Handled (in hours)						
	1	2	3	4	5	6	+6
1	63	55	17	14	16	4	7
2	40	58	26	21	16	4	9
3	44	59	30	19	12	5	6
4	32	47	38	21	26	12	0
5	30	41	40	18	32	12	1
6	33	38	41	20	27	12	3
7	33	39	34	15	31	20	3
8	33	55	33	19	22	4	9
9	28	52	34	20	26	10	1
10	27	39	44	25	22	12	4
11	27	34	46	27	29	10	2
12	27	30	41	24	35	16	2
13	27	23	35	31	39	14	0
14	26	29	53	19	32	16	1
15	27	17	50	32	22	23	1
16	24	10	43	29	33	27	8
17	27	11	50	30	29	23	5
18	26	12	47	32	29	24	7
19	25	8	39	36	28	35	5
20	24	10	37	37	41	25	3
21	26	5	29	36	38	36	4
22	23	9	34	32	32	31	14
23	28	6	30	41	37	30	3
24	26	6	14	40	37	40	12
25	25	6	15	37	38	36	19
26	23	7	14	40	33	47	11
27	25	7	12	36	36	45	13
28	27	5	9	27	25	41	44

the optimum schedule, and 1100-1900 and 1600-2400 for the second best handling. Criteria for "best" handling times were: no messages over six hours in-station delay and, once this first test is passed, the results of the shift with the fewest messages handled in the three to six hour delay period were cited as the superior arrangement.

Three other shifts deserve comment as well. They are the shifts with boosters 1100-1900 and 1200-2000, 1000-1800 and 1400-2200, and 1200-2000 and 1300-2100. A study of the handling times for these shifts indicates that they are close to the optimum shift but not within the prescribed limits. The tendency of so many "good" configurations in those hours (those shifts in which men reported for duty around the middle of the day) led the author to believe this time was the key. The question was, if only one more man could be added to a shift, if he could be used in conjunction with some of these near best shifts, and furthermore if he could report for duty at the lunch hour (1100), could dramatic changes take place in the handling times that have just been listed?

The answer was found in the results of the next set of tests. The five best sets of runs, just discussed, were bolstered by still another man and the runs listed in Table 8 were made on the computer. Results of these runs were scrutinized in the same manner as all earlier data runs. The in-station handling time was now distributed as shown in Table 9.

The effect of the one extra man was immediately obvious. Runs which were taking four hours to clear 65 percent of their messages were now processing this volume within two hours. Occasional long messages

Table 8. Booster Hours for Data Run Where 11 Men Are Available

Run Number	Booster Hours		
	Man #12	Man #13	Man #14
1	1000-1800	1300-2100	1100-1900
2	1100-1900	1600-2400	1100-1900
3	1100-1900	1200-2000	1100-1900
4	1000-1800	1400-2200	1100-1900
5	1200-2000	1300-2100	1100-1900

Table 9. Outgoing Low Precedence Message Handling Times

	Two-man Shifts, Three Boosters						
Run Number	Number of Messages Handled (in hours)						
	1	2	3	4	5	6	+6
1	53	82	22	5	11	4	0
2	34	72	33	13	12	9	0
3	34	78	37	15	7	5	0
4	42	69	32	11	15	4	0
5	26	45	48	28	26	2	0

caused some excessive delay (still within the DCA criteria), but over 90 percent of the messages were handled within four hours. The increase in system effectiveness points out dramatically the value of the right man available at the right time. It is interesting to note that the ranking of the five shifts did not change with the addition of a booster. The author felt that, with some of the congestion removed earlier in the day, the shift with the later booster might advance in rank. Instead, the same general trends prevailed, which further validated the axion "Make the boosters available when the work load is received and you achieve the best operations."

The integration of these concepts and field test results into a training program was the next concern. The application and presentation of these methods and ideas were as important as the actual tests and experiments themselves. Chapter VII discusses this phase of the project.

CHAPTER VII

USE OF THE SIMULATION

Course Contents

The background and environment for the model, the analogies used in its design, and the results of test runs have all been presented. It is now time to move forward and discuss the contents and workings of the course of instruction.

On the last class day of the COMMCEN operations block of training, the students will be given an outline of the simulation exercise. This outline will take the form of the standard Student Study Guide (SSG). The SSG is divided into separate parts, as presented in this portion of the thesis, but the complete guide is extracted from the separate parts and assembled into a package. The SSG is divided into one hour lectures each with an X prefix (for experimental) and each with its own identifying number. Each lecture description in the SSG contains three parts: the reading assignment, optional reading, and an outline of the lecture itself. The remainder of this chapter describes the lectures, the operation of the computer package, a test run of the course, and finally implementation of the simulation into the overall Communications Officer course. Extracts from the proposed SSG are now discussed.

X0001: Introduction to Simulation

You will:

1. Discuss areas to be covered.

2. Discuss historical development of simulation and training by simulation.

3. Discuss reasons for training by use of simulation techniques.

4. Define various terms in the field of simulation.

5. List four classes of simulation and give an example in each.

READING ASSIGNMENT: Computer Simulation Techniques, Naylor, et al., pp. 1-20 (35); "System Simulation--A Fundamental Tool for Industrial Engineering," Malcolm, D. G., Simulations in Social Science, pp. 138-150 (30).

OPTIONAL READING: "Simulation of Economic Systems," Orcutt, G. C., Simulations in Social Science, pp. 94-103 (36); Systems and Simulation, Chorafas, Dimitris N., pp. 1-45, 147-154 (3); "Use of Computer Simulations in Logistics Management Training," Ameen, David A., AD 623 233, US Dept. of Defense Logistics Conference, Vol. II-9.

The above lecture gives the student an introduction to the general field of simulation. Terminology and definitions are presented as is the history of the field and of applications in the training area. The required reading discusses more than 15 answers to "why simulate." A system of classification of models is presented that enables the student to classify various types of simulations.

X0002: Introduction to Simulation Games

You will:

1. Discuss the history and theory of simulation games.

2. Discuss differences between zero-sum and nonzero-sum games.

3. Discuss some of the uses for games.

4. Discuss some of the abuses of games.

READING ASSIGNMENT: "Game Theory," Nagin, et al., Data Processing Digest, March 1966, pp. 2-12 (33); "Management Games: An Answer to Critics," Nanus, Burt, The Journal of Industrial Engineering, Nov-Dec 1962, pp. 467-469 (34).

OPTIONAL READING: Theory of Games and Economic Behavior, Von Neuman and Morgenstern, pp. 1-14, 46-48 (46).

This lecture and discussion ties the fields of gaming and simulation together and further extends the student's available terminology by establishing definitions in Game Theory. Pitfalls in gaming are pointed out as areas to avoid in game design as are some current abusive practices. By clearly defining and illustrating uses and excesses in the field of gaming, the instructor will give his students some insight into the planning and design of the game in which they are to participate.

X0003: Introduction to GPSS

You will:

1. Discuss several computer simulation languages.

2. Discuss the block type concept.

3. Discuss transaction properties.

4. Discuss specific block types.

5. Discuss program output.

6. Trace transactions through a simple sample problem.

READING ASSIGNMENT: Computer Simulation Techniques, Naylor, et al., pp.

239-242, 248-278 (35); UP 4129, General Purpose Systems Simulator, UNIVAC, Sections 1 and 2 (20).

OPTIONAL READING: "Computer Simulation: Discussion of the Technique and Comparison of Languages," Teichroew, Daniel, Communications of the ACM, Vol. 9, Issue #10, Oct 1966, pp. 723-742 (43); "A Users Experience with Three Simulation Languages," Young, Karen, System Development Corp. TM-1755/000/00 (47); "Review of Simulation Languages," Tocher, K. D., Operational Research Quarterly, XVI, June 1965 (43).

This portion of the program introduces the student to the simulation language in which the program is written, in order to facilitate his reading of the run output and compilation sheet. Suggestions for course (or computer program) improvement should originate during this phase and be formally stated and written up at the end of the exercise.

X0004: Description of the Environment--Little Rock AFB

You will:

1. Discuss the support mission of the base communications center.
2. Review operations of AUTODIN, TWX, and WUX equipment.
3. Review the tapecutter and message center desk activities.
4. Discuss physical layout of LRAFB COMMCEN.
5. Trace message flow through the COMMCEN.

READING ASSIGNMENT: ST X0004. ST on COMMCEN Operations.

OPTIONAL READING: UP 4129, General Purpose Systems Simulator, UNIVAC, Section 3 (20).

The preceding presentation gives the student a feel for the artificial environment in which he will be gaming. At the same time, he is introduced to an actual operational US Air Force communications facility, an experience that will be very valuable to him when he encounters his first duty in the field. The reading assignment, ST X0004, is a student text which has been extracted from Chapter IV of this thesis. Following the exposure to both the simulation and the COMMCEN settings, the student should be ready for the next step, a discussion of the model itself.

X0005: Description of the Model

You will:

1. Develop a flow chart of COMMCEN operations in terms of GPSS symbols.

2. Discuss the addition of the man element in regard to the basic model developed in part 1.

3. Discuss the characteristics, capabilities, and limitations of input information.

4. Discuss the characteristics, capabilities, and limitations of output information.

5. Explain procedures for extending the run of the model from a one-day to a one-week simulation.

READING ASSIGNMENT: ST X0005, Model Description; UP 4129, Section 3.

OPTIONAL READING: Computer Simulation Techniques, Naylor, et al., pp. 23-43 (35).

In this brief exposure to the model, the student will see how the program developer envisioned the model under which the "game" will be conducted. While no special insight (for the solution of various problems later given the students) is given, an understanding of the manner in which the designer modeled the environment is provided, which is an asset when the student is analyzing his own runs and sorting through the various analogies and representations. ST X0005 is the Chapter V portion of this thesis and will meet the necessity, at the student level, for documentation of the model's workings.

X0006: Analysis of Message Handling at LRAFB

You will:

1. Discuss message flow rate (arrivals at the COMMCEN) at the Little Rock facility.

2. Discuss information contained in AF Form 1022.

3. Discuss criteria for communications center effectiveness in processing outgoing messages.

4. Extract data on in-station message handling time from logs.

READING ASSIGNMENT: CED 100-21, as extracted.

OPTIONAL READING: Systems and Simulation, Chorafas, D. M., pp. 18-26 (10).

Once this particular session is complete, the student will have at his disposal the ability to analyze message center logs for information concerning message arrivals at the COMMCEN. He should relate these arrivals to work load and thereby derive the key to the problems which will be presented in simulation later, i.e., tie the manpower to the work load. Secondly, the student will study the message handling logs and extract in-station message handling time. This is the criterion by which the COMMCEN is judged in effectiveness. Message handling times in excess of six hours are unacceptable. Those manning distributions which produce times below this maximum delay are compared for "best" results. "Best" results are those distributions which, under the same load, produce the most messages with the least delay.

X0007: Rules of Play During the Simulation

You will:

1. Discuss the rules of the forthcoming "play" of the game-simulation.

2. Become familiar with formats for requesting necessary information.

3. Participate in a question and answer session concerning the method of inputs and the posting of duty schedules.

READING ASSIGNMENT: "Management Games: An Answer to Critics," Nanus, Burt (Review this assignment), pp. 2-12 (34); DCA Circular 70-4 Speed of Service Criteria (17); ST X0007, Rules of the COMMCEN Simulation.

The rules of the game are contained in Table 10, which follows. These rules establish procedures for submitting schedules and other information, as specified, to the umpire. The format used will provide a realism to the "game" that it would not otherwise acquire. Should the first few tests indicate "loopholes" in the rules, they will be modified accordingly.

X0008: First Scheduling Exercise

You will:

1. Receive forms necessary to analyze message flow in the COMMCEN.

2. Receive manpower availability levels.

3. Design and submit shift schedules for COMMCEN manning.

READING ASSIGNMENT: None.

The first schedule will give the student ample men to handle the

Table 10. Rules of the COMMCEN Simulation

1. All men are to work a minimum of eight hours per day.

2. Duty hours in excess of eight hours (for any given man) will require written consent of the commander (the umpire).

3. Rotating shifts will provide for one shift on "break" at all times.

4. Straight shift personnel will not work on weekends.

5. Temporary assistance from personnel outside the COMMCEN (such as temporary supervisor assistance) is prohibited.

6. Special reports may be requested from umpire (as necessary). Request will be in the form of a memo, "Instructed my NCOIC of teletype operations to furnish me with hourly breakdown of outgoing message arrivals at the COMMCEN," or other suitable data requests as necessary.

7. There will be two men present for duty in the COMMCEN at all times for reasons of safety and security. The only exception to this rule is during the lunch break (1100-1300) when the NCOIC may satisfy the second man requirement. He may not process messages; he is only to observe the operations and thus satisfy the two-man requirement.

8. Shift schedules to be posted will be given to the umpire no later than five minutes before the end of the class hour in which they are due. The schedules will be of the general form:

Table 10. Rules of the COMMCEN Simulation (Concluded)

Duty Hours	Day of the Month											
	1	2	3	4	5	6	7	8	9	10	.	. .
0800-1600	A	A	A	D	D	D	C	C	C	B	B	B
1600-2400	B	B	B	A	A	A	D	D	D	C	C	C
2400-0800	C	C	C	B	B	B	A	A	A	D	D	D
Break	D	D	D	C	C	C	B	B	B	A	A	A

A Shift - 3 men

B Shift - 3 men

C Shift - 3 men

D Shift - 3 men

Booster Shift - 1 man at 1300-2100

Remarks: The remarks section will not be posted on the shift bulletin board but will contain information to the umpire as to why you have selected the schedule used.

Specific justification for exceptional hours will appear in this space.

message flow regardless of the schedule imposed. Its primary purpose is to familiarize the student with the forms and data used. Sixteen men will be made available and no problems are expected in traffic control. The instructor will assemble the run decks (as described later in this chapter) and produce the necessary data. He will then scan the output for glaring errors and will rerun any data suspect of machine failure.

X0009: Analysis of Run #1

You will:

1. Examine your output run sheet from the simulated week of operation.

2. Report on excessive delays.

3. Discuss ways to improve the message handling.

READING ASSIGNMENT: None.

The analysis of the first runs will be accomplished by the students following a demonstration of a sample run analysis furnished by the instructor. Message delays in Table 1 (i.e., Table 1 of the GPSS output) in excess of six hours (360 minutes in the format used) should be discussed. Facility utilization should be examined to point out any "jammed" equipments or manpower modules. Queue tables should be examined to locate bottlenecks in the flow. A diagnosis should be made citing whether the reason for delay was a wait for a man or a wait for a machine. If extreme blockage of the system is noted, an analysis of the transaction count may be necessary. This specialized analysis should be performed by an experienced GPSS programmer. Methods of improving the service should be introduced. Excessive delay of incoming messages should be discussed by student response of the type: "Excessive incoming message delay before messages were ready for delivery. Established SOP for speeding incoming message processing."

X0010: Second Scheduling Exercise

You will:

1. Receive new manpower availability levels.

2. Design and submit shift schedules for COMMCEN manning based upon the cited levels.

READING ASSIGNMENT: None.

Drawing from his experience on the first schedule and the data he analyzed in its critique, the student should be able to produce a schedule near optimum if the manpower level is unchanged. The level of manning is reduced from 16 to 13 men by giving information to the class that, effective next Monday (in the simulation), three men will be sent TDY to support a South East Asia (SEA) deployment. Duration of TDY is 90 days; therefore, no replacements can be furnished and the organization will have to cope with the problem from within its own resources. Workable solutions include those which utilize the booster shift principle in their design. The instructor (umpire) will collect the schedules and assemble the simulation decks from them as before.

X0011: Analysis of Run #2

You will:

1. Examine your run sheet from the simulated week of operation.

2. Report on any excessive delays.

3. Discuss ways to improve the message handling.

READING ASSIGNMENT: None.

Should any student have missed the necessity for booster or unbalanced shifts, the reduction in manning to 13 men will point this out to him. If he has merely extracted his three TDY men from the rotating shifts, he will encounter excessive delays in the in-station handling time that are output in the last run. Several booster shifts will be shown to the student with a description of their effectiveness and, finally, an optimum schedule presented for the 13 man level.

X0012: Third Scheduling Exercise

You will:

1. Receive new manpower availability levels.

2. Design and submit shift schedules for COMMCEN manning based upon these levels.

READING ASSIGNMENT: None.

Manpower levels are now reduced to 10 men by furnishing the students with the following information: "One airman was killed in an automobile accident over the weekend. His replacement forecast is 60 days. One more TDY to SEA, no replacement available." The ingenuity of the students should be taxed to the utmost in the search for a shift that will handle the work load under these extreme conditions. Only two booster configurations will remain within the in-station delay allowances. Some students will try the twelve-hour shifts plus boosters. This action will be allowed only when fully justified and when the calendar period of twelve-hour shift operations is specified. As before, the umpire will collect the schedules and set up the computer runs.

X0013: Analysis of Run #3

You will:

1. Examine your run output from the simulated week's operation.

2. Report on excessive delays.

3. Discuss ways to improve the message handling.

READING ASSIGNMENT: None.

The results which the student will receive will probably not contain satisfactory handling times as only two of the 28 combinations of men under the limits of 10 men available were able to produce this end. Any student who, with proper justification, went to twelve-hour shifts, should have achieved success. These two points will be contrasted and discussed. Sample runs will be exhibited to show this effect.

X0014: Critique of Simulation Training

You will:

1. Write a critique of the entire simulation exercise, the administration, and the staff.

2. Point out areas where the model is incomplete.

3. Describe improvements to the course work and/or reading assignments.

READING ASSIGNMENT: None.

These unsigned critiques will be screened by the staff conducting the simulation training for possible suggestions for course revisions. Ideas with special merit, rule changes, or presentation of material will be changed as deemed practical and necessary.

How to Operate the Model as Packaged

The punched card deck for running the model on the computer is stored in an empty box in which cards were received from the manufacturer. The box is compartmentalized and indexed in the following manner. One section of the box contains the master run deck. Another section contains all the message originate modules which vary the outgoing message rate. This section is indexed into the classes cited earlier in this report: winter duty hours set A, winter duty hours set B, summer duty hours set A, and finally summer duty hours set B. Section three of the file contains all of the various manpower modules. These modules are duplicated for men numbers 11 and 13 (for multiple booster running) and are indexed so that any mixture of facilities can be withdrawn immediately for use. Figure 14 shows the makeup of the master file and illustrates its portability.

To prepare the "run-time" deck, the following sequence of steps is performed. The master deck is withdrawn from the file. Next, a set of message originate cards (which coincide with the AF Form 1022 issued to the student) is extracted from the file. At the location marked by the tab index card labeled "originate cards," the message originate card module is inserted and the tab card withheld from the deck. The manpower modules which coincide with the student-specified schedule are next extracted from the master file and placed in the run-deck in the location marked by the tab card marked "manning modules." This tab card is also retained for later use. The program running deck is now assembled and ready to be input to the card reader. This final assembly is shown in Figure 15.

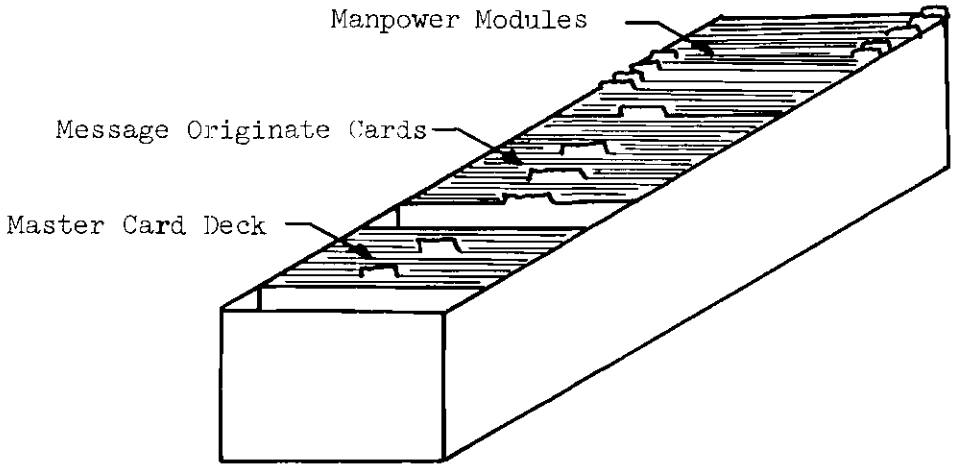


Figure 14. Master File

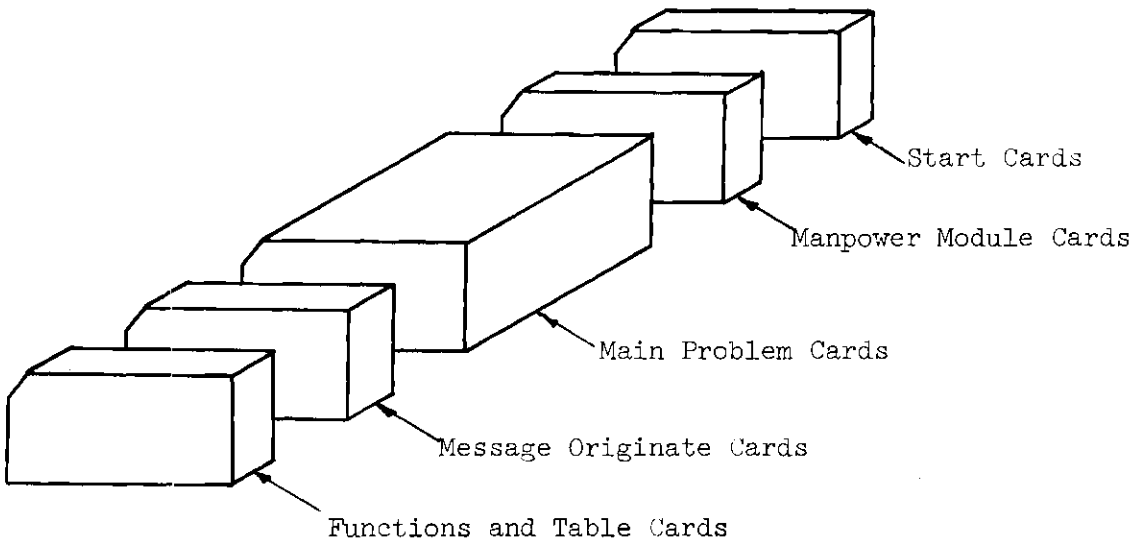


Figure 15. Program Running Deck

Once the run is complete and the deck and output returned to the instructor, the deck is "broken down" by reversing the building process. The modules are located in the running deck between the colored-ink bands on the master deck. They are withdrawn, refiled in the file box, and the tab cards inserted into the master deck. Then it is returned to the master file box and the package is stored until required for subsequent use.

How well does this program, as written and presented, work? Does it actually give the student an understanding about scheduling and COMMCEN operations? These questions and others will be answered in the next section, when conducting an actual test and training session are discussed.

A Test of the Training

The first problem to be resolved in a test of this training and game-simulation was upon whom would the program be tested? A test of the course was extremely desirable no matter how limited this test might be. To find someone who would be "typical," while a simple matter in the field or at the USAF Technical Training Center, was a difficult problem in the university environment. One could not use students at random, no matter how many volunteered, as they were simply not typical of USAF officers undergoing training at the communications school. Neither could other USAF officer students be used, although some were available, since they had all been active in the field and an exercise of this type to a trained communicator would be trivial and the results of no value.

Fortunately, one officer studying at the Georgia Institute of Technology (as a USAF contract student) possessed the necessary requisites. The officer in question was an Air Force second lieutenant, an AFIT student, studying for his master of science degree from the school of Information Science. His background (as an enlisted man in the USAF) was in weather operations; therefore, he was familiar with teletype equipment, its description, and how it operated (as would be a student at the communications school), but he had never actually worked in a COMMCEN or with the equipment itself. Again, the parallel to the communications school had been found. Furthermore, and perhaps most important, the officer in question was willing to undergo the training and participate in the game-simulation. The arrangements were now set for the test of the course work and accompanying simulation exercise.

In preparation for the training, student manuals were manufactured by making a xerox copy of appropriate chapters of this thesis. Rules of the game were also duplicated. Other required literature was withdrawn from the Price Gilbert Memorial Library at Georgia Tech and given to the volunteer student. A complete copy of the student manual was furnished to him. Lectures, lessons, and critiques were presented in the order and method discussed in the earlier portion of this chapter.

The first lecture sessions to be presented to the student (or to a class) are primarily background and familiarization lessons. For this reason, during this stage of training, the emphasis is placed on the reading assignments with comprehensive question and answer sessions following the instructor's review of the required reading. The relationship developed in the one-man test of the course contents was more of a pupil-teacher or tutoring one than that of a formal class, although the instructor only answered questions (as would be done in a regular class session) following the lecture portion of the presentation.

When all introductory material had been presented, the model discussed, and the environment firmly engrained in the student's mind, the first problem was given to him. He was told he was the newly assigned Officer-in-Charge (OIC) in an operational COMMCEN and that the recent arrival of several teletype operators necessitated a revised schedule for the teletype operations section. AF Forms 1022, which contained traffic handling data typical for the COMMCEN operation, were furnished. The student had already been shown how to analyze these forms; he was told to post (turn in) a new schedule for teletype operations by the end of the class hour. He was informed that 16 men were available for COMMCEN operations.

In response to the request for a new schedule, the student generated a shift revision which used the 16 available men on a four men per shift, four rotating shifts schedule. His reasons for developing this particular schedule centered around the flexibility of any given shift. No matter what local conditions arose (training, leave, etc.), the COMMCEN would have, on the average, most of its men available. The nine-on-three-off schedule is typical for USAF shift workers and every attempt would be made to adhere to this scheduling.

The deck for running the model based upon this schedule was assembled by the student in order to point out its ease of use, although the instructor could not have taken this action in a regular classroom. The results of the computer run were furnished to the student and an analysis, of the type presented earlier in this paper, was conducted. The schedule and manpower distributions (behaving as the author had predicted) were able to handle all messages within the six hours allowed. Special emphasis was given to the Friday traffic flow which showed the system becoming extended.

Following the Student Manual presentation by outline, the next task given the mock-student was that of reduced manning. The instructor told him "you have been ordered to deploy three of your teletype operators to support a SEA support activity. Duration of this TDY is 90 days. No replacements are available. Design and publish a shift schedule effective Monday morning." The revised schedule was due by the end of that class period. Under these conditions, the student manager chose an alteration of the basic schedule. He removed one man from each of the four rotating shifts. Three of these four men were used to support the TDY. The fourth man was assigned as a booster with duty hours 1000-1800 five days per week. The idea of a boosted operation was familiar to the trainee as he had spent some time on shift work (in the weather station) where this type of augmented duty also occurred. The computer decks were again assembled and the run made. Analysis of the output of this run revealed that the results achieved were very near those predicted earlier in the discussion concerning three-man shifts with a single booster. The student was shown a slightly better arrangement for the booster, 1100-1900 instead of 1000-1800; however, the results of the run as made were entirely satisfactory. All messages passed through the COMMCEN within the established limits. Early in the week when traffic was light, the bulk of the messages (90 percent) was processed in four hours or less. Near the end of the week (Friday), the number of messages in the five to six hour category increased sharply. It was noted that the model using the 13 men on a shift schedule which followed the message arrival schedule was able to handle the same volume (in the same time) as the 16 man arrangement. The only significant difference was in the amount of idle time on the schedule with more men.

To test the program's limitations and the student's ability and progress with scheduling, the next problem posed was the one discussed in X0012: "One airman in your section was killed in an automobile accident over the weekend. His replacement forecast is 60 days. One departed on 30 day emergency leave. One more TDY to SEA was levied with no replacement available. Your strength in teletype operations is now 10 men." If he were to achieve any stimulation from extreme conditions, this manpower availability would provide it and tax the student to the utmost. The ability of the student to handle this problem would indicate some measure of the effectiveness of the course.

The resultant shift schedule was quite surprising. The author had expected either a variation of the straight shift with boosters or a well justified twelve-hour shift schedule. Instead, the student submitted a schedule which placed three men on day shift, three men on swing shift, two men on midnight shift and a booster from 1200-2000. The booster worked a five day week (because his hours were peak load, he was allowed more time off), and the other eight men worked a six day week. Their days off were provided, on a rotating basis, by the tenth man or by taking one of the weekend days off (when only two men were required for duty).

Since this schedule was completely unexpected, some difficulties might be expected in programming it for the computer. The flexibility of the module manpower system reaffirmed itself, however, and no difficulties were experienced. The only change in the setup for the master deck was to create a manpower routine which "removed" availability, from the three-men-on-all-shifts configuration, of a single man during the midnight shift. This then, once programmed, represented the 3-3-2 arrangement of men for the straight shifts and the standard booster routine was inserted into the program for the 1200-2000 shift.

The results of this ingenuity were gratifying. The program was run and the output analyzed as before. All messages had an in-station handling time of less than six hours and were, therefore, within acceptable limits. The traffic handling during lighter load periods (i.e., early in the week) was exceptionally good, with all outgoing messages handled in under four hours. These results were all achieved with only 10 men available. It was felt that morale would remain relatively high, since all personnel were still working only eight hours per day and each man was off at least one day each week. Occasionally (every third week), two days off would be scheduled.

Since it would be explained to the men that the manning was at this level only temporarily and since the hardship was in direct support of the effort in Viet Nam, a degradation of spirit was not expected. The key to successful operation would be in fully and carefully explaining the situation to the airmen.

During all of the computer runs of the simulation in this student-scheduled portion of the simulation, it was noted that at no time were any high precedence messages delayed in the system. An in-station handling time of 30 minutes or less was achieved on all outgoing messages of this type with the mean at the 10 minute handling time level. Nor were delays accepted on incoming traffic in order to process the outgoing flow. In short, the COMMCEN simulation did follow the prototype.

Following the final analysis of the student schedules, the trainee was shown the optimum schedules for 10 and 11 men. The advisability of discarding the standard eight hour rotating shifts in favor of those which match the manpower to the work load was also pointed out. This tactic, when implemented by the student in the final run, produced such favorable results that it was decided to stress this feature and this method in both a course summary and in future course presentations. Following this final talk, the student officer was asked to critique the course and discuss points which he felt might be discarded as well as those worthy of retention. His comments appear below.

> The time and effort required for this course was reasonable and worthwhile. The most notable characteristic of the course is the emphatic way it points out the relationship between manpower and work load. The fact that work scheduling should be viewed as a factor of work load is often overlooked in application. No small fringe benefit of the course is the exposure of the student to the concepts and literature of simulation, but more important is the opportunity it offers the student to use simulation as a management tool and to gauge its power.

These comments demonstrated the success of the course to the author and proved that it did, indeed, achieve his original aims and intentions. With this test of the training completed, the next topic to be discussed is that of the course implementation at the USAF technical school.

Implementation at the Communications School

At the Keesler AFB Communications Training Center, two courses are conducted for Air Force officers to give them the skills necessary to manage communications facilities. The first is the basic Communications Officer Course (3031). This course, directed at the junior officer, teaches the student something of the many communication devices and facilities in use by the U.S. Air Force. Maintenance and management of resources are other phases of this training. An introduction to data processing is also included, as are various navigational aids (both operations and maintenance), as well as the operation and use of certain security devices.

The second course of interest for possible implementation of the suggested training program is the Staff Communications Officer Course (3011). The purpose of this course is to take the trained Communications Officer at the operational level and convert him to a staff officer whose area of expertise is communications. The emphasis in the staff level course is on an increased awareness of the "system" and overall role of communications. The student level is more concerned with planning and long range goals than day-to-day operations of facilities. Duty assignments following this instruction are apt to include more headquarters type duty and less of field operations.

To realize its full potential, the proposed course of instruction (including the "game-simulation" exercise) should be incorporated into the basic Communications Officer Course (3031). At this level, the training will produce the desired result, i.e., create some operations experience for the novice communications officer. Using this program in the staff course (3011) would pose few operational problems to these experienced officers though it would validate or reenforce their knowledge by allowing them to employ experience, gained in the field, on the model. Far greater savings can be realized by using this block with the 3031 course.

Some pitfalls must be avoided when actually implementing the course. Nanus cites the following as the most flagrant of abuses of simulations and training games (34).

1. Using games strictly for entertainment of public without clearly warning the participants that the training value of a game, which is not part of a larger, carefully planned educational context, will be very small. Much of the criticism levied against games has come from participants who had unhappy experiences in one or two carelessly run exercises.

2. Using a "game" for a course before its parameters have been thoroughly tested. Too many games used today can be "beaten" by unreasonable strategies.

3. Designing a "game" before its objectives have been clearly defined. This was a particularly common problem in the early days of game design, but even now games are being built by mathematicians and operations research specialists with insufficient guidance by educators. The result is games which are more "sophisticated" than necessary or too difficult to handle administratively.

4. Permitting a "game" to be used before complete documentation of its model and computer program is available.

The author believes that enough attention was given to the model design for criticisms 2, 3, and 4 not to be raised against this program of instruction. The school staff at Keesler AFB must guard against the first abuse. As the program is implemented into the 3031 course, a project officer should monitor carefully the initial introductions of course material to the students. Feedback of student attitudes and experiences in the course critiques should indicate areas in which either the lecture, the model, or the analysis is weak. The critique of the course is mandatory. Although the students' papers need not be signed, an entire hour is devoted to the critique since it is deemed very important. Careful analysis of class comments and attitudes should reduce occurrences of the first cited abuse.

The actual establishment of this course will depend upon two things. First, the "fit" of this program into the overall training; a determination which will be made when the school staff analyzes this thesis and establishes a time-table for its integration into the 3031 course. The second item concerning implementation is the availability of a computer upon which MAPGPSS may be compiled or translated. At present, Keesler AFB does not have a compiler or translator for GPSS for any computer on base. Two UNIVAC 1108 computers are available at Slidel, Louisiana, 40 miles west of Keesler. These computers are used in support of project Mariner. Since they are basically the same computer as the Georgia Tech UNIVAC 1108 and are operating under the same executive system, the addition of a MAPGPSS compiler (or the software translator of that language) to one of these computers would be a minor problem. Until suitable arrangements can be made to bring GPSS to Keesler AFB, a working arrangement can be established with the project

Mariner group to support temporarily the requirements of Keesler. These arrangements and the necessary coordination should be handled by the project officer assigned as monitor. The project should have a monitor (of implementation) assigned in the early phases just as it later needs the one cited for student feedback.

To implement the course, if the Slidel computers are to be used, it is suggested that remote input/output programs could be used; a remote unit could be located in a convenient staff office at Keesler AFB. The main program could be stored on disc or tape; the only messages from the remote unit that would be necessary would be ones to specify the desired message originate module and manpower requirements. This remote installation and implementation would be a simple conversion of the executive system of the UNIVAC 1108, once GPSS was available to that machine. This method of implementation might some day be extended to include the GRAIL/GPSS system in which inputs would be drawn on a console/reader with a light pencil.

An alternate solution to the problem of implementation would be not to run the student's schedule "live." Instead, his proposed schedule would be collected by the instructor and the coincidental computer run taken from the available master file of computer runs already made. At present, there are 47 runs available under the winter A set of data, and a library of runs for winter B, summer A, and summer B could be developed in approximately two weeks. Given preferential handling on the computer, this time could be reduced even further. Therefore, the only runs that would be made at Slidel or elsewhere would be those employing "abnormal" combinations of booster hours or those needed to replace sheets that were physically worn out. Computer access of one or two days a month should suffice for this method of course implementation.

The final determination in these matters must be made at Keesler AFB, in the working environment, by the people who will be using the course. It is entirely possible that some major changes will take place in the whole program if the school staff modifies the course of the "game-simulation." Student feedback may disclose a new issue which must be resolved locally. A conclusion to this idea is beyond the scope of this thesis, but the issue is worthy of mention in order to create an awareness of its existence.

A final few words concerning course implementation are in order. The issue to be discussed is that of developing actual lesson plans for each of the lectures that is to be presented. The course outline contains general guidelines and ample references; however, the lesson plans themselves must emanate from the actual instructors who are to present the material. Familiarity with the contents of the course gained from this procedure is invaluable. This method of deriving lesson plans is a standard one in the Air Training Command and has proven most successful many times.

Once the course and "game-simulation" is merged into the 3031 program, the aim of this thesis is complete; all that remains is to sum up these writings with some general conclusions and recommendations for the program and its future.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Several points concerning the "game-simulation" method of training became apparent to the people involved in this program. This portion of the thesis will be used to collect, sort, and summarize some of these thoughts.

In a business or war game, the outcome is shown in the form of "which side has won." In "game-simulation," the investigator is interested in answers to more specific problems, such as the effects of various tactical policies or the feasibility of a proposed system of modifications to an existing system (19), which has certainly been the case in the COMMCEN exercise. Whether the student "won" by finding the optimum shifts or "lost" because he had excessive delays is of little importance. The relevant question is "What did the student learn from the "game-simulation"? If he achieved a new insight into resource management, an ability to analyze, a feel for scheduling, and a taste of what "real-world" communications management mean, then the exercise is an unqualified success.

The author believes that the course designed during this thesis work truly achieves the above ends. Although it is virtually impossible, especially at this level, to measure the effectiveness or success of a training program, it is the personal opinion of this officer that the "game-simulation," the model itself, and the course work, all yield the desired benefits. The objectives cited earlier in this paper have been met. When the training program is implemented, the result should be a more comprehensive overall communications course. Therefore, a more versatile communications officer should emerge, one equipped with the ability to handle any of the various scheduling situations which might arise, because he has been confronted with similar circumstances while receiving training.

The author is not alone in this belief. The officer (mock-student) who participated in the test of this training made several revealing comments in his critique in support of the program. As an independent, outside voice, this trainee also stated his support for the contents of the program and cited its potential value.

Another school of thought would argue with the "its not whether you won or lost but how you played the game" doctrine. Those who defend this other point of view declare that, since the students will be producing the same general type of output, someone will compare that output. That is, someone in the Technical Training School will match the results of two student outputs and say that one student is the "better" communications officer because he had a more successful set of results with his schedules. Is this a fair procedure? Only the school staff in the school environment can say. The author has presented his case more for a single dedicated man in an isolated case. Perhaps it would be better to compare results when "mass" training is involved. These questions will not be answered here; instead the author's opinions, already given, appear. However, such questions should at least be raised. The final decision on this issue must rest with the course administrator not with the designer or programmer.

Still another topic worth discussion, especially for those persons who will do future works of the "game-simulation" type, is a summary of the phases through which this project was stepped. During the design phase, the objectives of the exercise were set, the policies and organizational structures of the simulated system were set down, and the experimental design was chosen. During the modeling phase, the environment in which the simulated system will operate (i.e., the important parts of the system which will not be represented in detail but will be simulated by a computer) was defined, the necessary data collection was accomplished, and the detailed description of each of the organizations and their interactions was set down. Computer programs were prepared, the forms to be used in the exercise were drawn up, and all necessary rules for the operation of the system were described. These latter tasks of preparing computer programs, forms, rules, and the data collection have been found to be by far the most time consuming of all. The "mock-up" or testing phase of the program is a running of the simulation model for the purpose of making the final adjustments and changes to the system that were not foreseen during the modeling phase. The operations phase is the actual running of the experiment, with students under "gaming" conditions. The final phase is the analysis of the results (of the learning experience) by a careful survey of the student critiques that were prepared in the last hour of the exercise. It is this final phase which, to a large degree, indicates the difference between the "game" and a "game-simulation." The above steps may be summarized in the following manner:

1. design phase
2. modeling phase
3. testing phase
4. operations phase
5. analysis phase.

When this outline is compared to those of other games, simulations, and "game-simulation" developments, the resemblance is remarkable. The comparison of the above phases to those of "classic" simulations of Bonini, Stockton, Chorafas, and others leads this author to conclude that a method of procedure for system simulation design has been described for any system. The extension of these principles to other areas beyond that of communications is inescapable, and the same plan of game development should apply for any system and its game-simulation.

One conclusion reached by this observer was directed toward the boundaries of the problem itself. Many of the basic principles (i.e., in-station handling time is related to station efficiency) are directed by current Communications Electronics doctrine. A problem apparently lies, not in the difficulty of modeling the situation as it exists, but rather in the doctrine and the rules it establishes. Rather than a static precedence system, Baran (4) advocates one based upon "utility" of message contents. The discussion around this theory is contained in the material cited, but it appears to the author that the entire precedence doctrine should be studied in depth with these ideas in mind. The course developed under this thesis, however, was built to conform with existing guidelines and regulations and so the issue of dynamic precedence will be pursued no further. The limitations on this work and on the author were such that a study-in-depth could not be accomplished in the time available.

Recommendations

Before any specific recommendations are stated concerning this course or about simulation (or "game-simulation") techniques, some background comments are in order concerning these topics. General agreement on claims about training involving use of simulation models or management gaming is found in the following areas (34).

1. A "game-simulation" training program can provide a degree of involvement of participants in the learning situation which exceeds that usually attained by other teaching techniques in the field of management and this, according to current learning theory concepts, is desirable.

2. "Games" can be used to demonstrate principles of management relating to the interaction of decision areas over time better than static techniques such as lecture or case study.

3. Properly designed and administered "games" can provide extremely effective demonstrations of the application of certain time related management tools such as budgets, forecasts, or scheduling, and the capabilities of electronic computers in rapid data analysis and report preparation is invaluable.

4. "Games" are useful as simulated task situations for certain types of organizational research relating to communications, leadership, group structure, decision making, and related concepts.

5. The process of building a "game" often provides useful in-

sights into the relationships existing in the system being simulated.

Some limitations must also be kept in mind when using these techniques. The most obvious of these is cost. "Games" should not be used if some other training technique can satisfy the need with less expense. It is the author's belief that the program developed in this study is the most economical method of presenting this utilization of resources training. One should not forget the value of the time of the participants, since they are middle or higher executives. If this training can substantially reduce the on-the-job-training time for communication center managers, then the expenditure of large sums of money to support it can be justified. Only through a validation of training and training effectiveness, by use of testing, can the worth of this program be judged. If this training package is implemented, a test of the effectiveness of the training should be designed and conducted by the Communications Training Staff. Such a test is beyond the resources of the author, but he feels that this training program, training by "game-simulation," should be judged in relation to other available teaching techniques and measured by the same standards. Only in this way can the cost (or value) in dollars, of this program or any program, be measured.

Once the recommended implementation is complete, it is further recommended that the computer program be enlarged and refined to include circuit outages. This modification can be introduced by creating an outage module which removes the circuit facility instead of the manpower facility, as was done in the manning module section of the program. This outage module would remove the facility which represents the circuits by "forcing" a high precedence, dummy transaction into the facility to be lost. Once the period of outage is past, the dummy transaction can be terminated. The module could be programmed as follows.

```
615     ORIGINATE    XXX   1          616     1
616     PRIORITY     6                617
617     HOLD         YYY              618     ZZZ
618     TERMINATE
```

In the sample above, XXX is the time the outage is to occur, YYY is the number of the circuit (or piece of equipment) simulating outage, and ZZZ is the duration of the outage. X, Y, and Z could be indirectly specified to come "on" and go "off" according to some function, if an outage function can be described from live data. This problem should present no challenge to the experienced GPSS programmer once the data are available. Since outages cannot be predicted (other than on-line scheduled maintenance) by the manager of the prototypical Communications Center, the same conditions must exist within the confines of the course. The student cannot be expected to alter his manpower to cope with an outage situation, but this introduction of realism into the problem would give him an example of "the best laid plans of mice and men . . . ." type of realism.

A logical extension in the degree of sophistication of the computer model would be in the introduction of variation into the message arrivals at the COMMCEN. One of the assumptions basic to the present model is that messages arrive at the COMMCEN on the hour during the working day. This precision, even if it exists at Little Rock due to the proximity of the headquarters building, is doubtful throughout the Air Force. To establish a more meaningful system, one of arrivals near the schedule yet not exactly on the hour, would be of little challenge to the qualified GPSS programmer. The ORIGINATE block representing message arrivals can be "turned on" at intervals distributed around the hour with each "on" time selected by a "draw" from a random number generator.

Still a third area worth considering when the model is to be further extended toward the "real-life" situation is presented. An assumption basic to the model was that all men are interchangeable, that is, they all have the same skills and abilities. Even though this is basically true, some differences exist in these men. One teletype operator's typing speed might be the 40 words per minute used in the model, the next would type 20 words per minute or even 60 words per minute. A version of the program which utilizes "skill" as a parameter would be another step toward the prototype COMMCEN.

These next logical steps toward realism are recommended once the overall program has been successfully implemented and has satisfied the school staff at Keesler Training Center. There is a pitfall that must not be overlooked when programming these refinements, however. As the computer program becomes more realistic, the "game" becomes harder to play and even more difficult to administer. The modeler is creating a laboratory simulation for study, stimulation, and analysis but only by sacrificing some of the ability for play of the game. The aim to obtain ease of play and administration must be retained, and the programmer or other researcher must be certain of the implications of his actions when he refines and re-refines the basic model.

One of the limitations of either gaming or game-simulation, recognized by experts in the field (19), is the possibility that the participants may carry away from the training session incorrect of unwarranted conclusions. For example, the instructor in this course would not want his students to conclude that, because in this particular model manpower should be spread evenly, it is ALWAYS best to do so. Nor would he want his class to ALWAYS sacrifice the fast message handling times at the expense of only a few delayed messages merely because they "won" the game by doing so. On the other hand, the instructor WOULD want them to retain the methods of analysis they used in reaching these conclusions. Other limitations have been advanced and are well documented elsewhere (35).

In summary then, the author recommends that the implementation of this course of instruction and the accompanying "game-simulation" be accomplished in the environment for which it was designed. This implementation should be followed by an in-depth effectiveness test of the program and a value decision should be made, at that point in time, as to whether or not this aspect of training should be retained. It is felt that the program will prove its worth and that this decision will be in favor of its retention in the training arsenal of the United States Air Force Air Training Command.

APPENDICES

APPENDIX A

SAMPLE COMPILATION LISTING AND OUTPUT

```
LOC    NAME          X      Y      Z      SEL    NBA    NBB    MEAN   MOD    REMARKS


       JOB
*
*
*
 1     FUNCTION      RN1    D3            DISCRETE RANDOM HIGH PRECEDENCE ASSIGNED
 .95   1     .998    2      1.0    3
 2     FUNCTION      RN1    D3            DISCRETE RANDOM MESSAGE ROUTING ASSIGNED
 .8    0     .9      1      1.0    2
 3     FUNCTION      RN1    D4            DISCRETE RANDOM INCOMING MSG PREC ASGD
 .75   0     .95     1      .998   2      1.0    3
 4     FUNCTION      RN1    C10           CONTINUOUS MESSAGE LENGTH
 0     20    .4      100    .6     200    .8     300    .9     400    .98    500
 .99   600   .995    700    .998   800    1.0    1000
 5     FUNCTION      RN1    C5            CONTINUOUS MESSAGE LENGTH HIGH PREC
 0     20    .6      30     .8     100    .9     200    .95    250
 1     TABLE         M1     0      60     8      TIME LOW PREC IN SYSTEM (OUTGOING)
 2     TABLE         M1     0      60     8      TIME INCOMING MSG IN SYSTEM
 3     TABLE         M1     0      5      10     TIME HIGH PREC IN SYSTEM (OUTGOING)
*
*
*
*
*
* THIS SET OF ORIGINATE BLOCKS IS SET 'A' WINTER DUTY HOURS.
*
* FOLG BLOCKS ARE OUTGOING ROUTINE MSGS DELIVERED ON THE HOUR.
*
 10    ORIGINATE  481   10            30           1                 MONDAY
```

SAMPLE COMPILATION LISTING AND OUTPUT (Continued)

```
 11     ORIGINATE   541   5                    30         1
 12     ORIGINATE   601   30                   30         1
 13     ORIGINATE   661   5                    30         1
 14     ORIGINATE   721   15                   30         1
 15     ORIGINATE   781   30                   30         1
 16     ORIGINATE   841   15                   30         1
 17     ORIGINATE   901   30                   30         1
 18     ORIGINATE   961   5                    30         1
 19     ORIGINATE   1021  10                   30         1
 20     ORIGINATE   1081  10                   30         1
*
*
* THIS PORTION OF PROGRAM ORIGINATES LOW PRECEDENCE MESSAGES FOR TUESDAY THROUGH
* FRIDAY. HIGH PRECEDENCE MESSAGES ARE CONTINUOUS THROUGHOUT THE WEEK. MESSAGES
* ARE BOTH SEND AND RECEIVE, ALL FACILITIES.
*
*
* SEND TRAFFIC TUESDAY ACTIVITY,LOW PRECEDENCE.
*
 500    ORIGINATE   1920  10                   30         1
 501    ORIGINATE   1980  5                    30         1
 502    ORIGINATE   2010  25                   30         1
 503    ORIGINATE   2100  5                    30         1
 504    ORIGINATE   2160  15                   30         1
 505    ORIGINATE   2220  25                   30         1
 506    ORIGINATE   2280  25                   30         1
 507    ORIGINATE   2340  30                   30         1
 508    ORIGINATE   2400  5                    30         1
 509    ORIGINATE   2460  15                   30         1
 510    ORIGINATE   2520  10                   30         1
*
*
```

SAMPLE COMPILATION LISTING AND OUTPUT (Continued)

```
*WEDNESDAY ACTIVITY
*
 512  ORIGINATE   3360  10                  30          1
 513  ORIGINATE   3420  5                   30          1
 514  ORIGINATE   3480  30                  30          1
 515  ORIGINATE   3540  10                  30          1
 516  ORIGINATE   3600  15                  30          1
 517  ORIGINATE   3660  25                  30          1
 518  ORIGINATE   3720  20                  30          1
 519  ORIGINATE   3780  30                  30          1
 520  ORIGINATE   3840  5                   30          1
 521  ORIGINATE   3900  10                  30          1
 522  ORIGINATE   3960  15                  30          1
*
*
*THURSDAY ACTIVITY
*
 523  ORIGINATE   4800  10                  30          1
 524  ORIGINATE   4860  5                   30          1
 525  ORIGINATE   4920  25                  30          1
 526  ORIGINATE   4930  10                  30          1
 527  ORIGINATE   5040  25                  30          1
 528  ORIGINATE   5100  25                  30          1
 529  ORIGINATE   5160  15                  30          1
 530  ORIGINATE   5220  35                  30          1
 531  ORIGINATE   5280  5                   30          1
 532  ORIGINATE   5340  10                  30          1
 533  ORIGINATE   5400  15                  30          1
*
*
```

```
*FRIDAY ACTIVITY
*
 535  ORIGINATE   6240  15                  30          1
 536  ORIGINATE   6300  5                   30          1
 537  ORIGINATE   6360  30                  30          1
 538  ORIGINATE   6420  5                   30          1
 539  ORIGINATE   6480  15                  30          1
 540  ORIGINATE   6540  35                  30          1
 541  ORIGINATE   6600  15                  30          1
 542  ORIGINATE   6660  40                  30          1
 543  ORIGINATE   6720  5                   30          1
 544  ORIGINATE   6780  10                  30          1
 545  ORIGINATE   6840  10                  30          1
*
*
*
*
*THIS BLOCK GENERATES OUTGOING HIGH PRECEDENCE MSGS.
*
 21   ORIGINATE   0                         29          60    50
*
*
*
*THE FOLG BLOCKS ARE INCOMING MSGS.
*TWX AND WUX ARRIVE RANDOMLY
*
 22   ORIGINATE   0                         320         60    50    TWX
 23   ORIGINATE   481   8                   330         120   60    WUX MONDAY
*
*
*
*AUTODIN MSGS INCOMING
```

```
*
 24   ORIGINATE   0     30                  310         6      5     MONDAY
 25   ORIGINATE   181   14                  310         30     10
 26   ORIGINATE   601   40                  310         6      5
 27   ORIGINATE   841   45                  310         4      3
 28   ORIGINATE   1021  140                 310         2      1
*
*
*
*HIGH PRECEDENCE ASGMT OUTGOING MSGS
*
 29   PRIORITY    FN1                       31
 30   ASSIGN      2     FN2                 32
 31   ASSIGN      4     K1                  600
*
*
*
*MESSAGE LENGTH ASSIGNED
*
 600  ASSIGN      5     FN5                 33
 32   ASSIGN      5     FN4                 33
*
*
*
*TAPE CUTTER TIMES COMPUTED AND PLACED IN PROPER PARAMETER
*
 33   ASSIGN      6     V1                  34
 1    VARIABLE    P5/K40+K1
*
*
*
```

```
*TRANSMISSION TIMES ASSIGNED
*
 34   ADVANCE                           BOTH  35    36
 35   COMPARE     22     E  KO                37
 37   ASSIGN      7      V2                   41
 2    VARIABLE    P5/K200+K1
 36   ADVANCE                           BOTH  38    39
 38   COMPARE     P2     E  K1                40
 40   ASSIGN      7      V3                   41
 3    VARIABLE    P5/K60+K1
 39   ASSIGN      7      V4                   41
 4    VARIABLE    P5/K30+K1
*
*
*
*THIS BEGINS THE MESSAGE CENTER DESK ACTIVITY
*
 41   QUEUE       1                      ALL  46    50                   AWAIT MAN
 46   SEIZE       10                          51
 47   SEIZE       11                          52
 48   SEIZE       12                          53
 49   SEIZE       13                          54
 50   SEIZE       14                          55
 51   ASSIGN      8      K10                  60
 52   ASSIGN      8      K11                  60
 53   ASSIGN      8      K12                  60
 54   ASSIGN      8      K13                  60
 55   ASSIGN      8      K14                  60
 60   QUEUE       2                           65                         AWAIT MACHINE
 65   HOLD        1                           70          1     1
 70   RELEASE     *8                          75
 75   ADVANCE                           BOTH  80    81
 80   COMPARE     P2     NE     K2            85
 81   COMPARE     P2     E      K2            210                        TO WUX
*
```

SAMPLE COMPILATION LISTING AND OUTPUT (Continued)

```
*
*TO TAPECUTTERS
*
 85   QUEUE       3                         ALL  90    94                 AWAIT MAN
 90   SEIZE       10                             100
 91   SEIZE       11                             101
 92   SEIZE       12                             102
 93   SEIZE       13                             103
 94   SEIZE       14                             104
 100  ASSIGN      9     K10                      110
 101  ASSIGN      9     K11                      110
 102  ASSIGN      9     K12                      110
 103  ASSIGN      9     K13                      110
 104  ASSIGN      9     K14                      110
 110  QUEUE       4                         BOTH 115   116                AWAIT MACHINE
 115  INTERRUPT   2                              119         *6
 116  INTERRUPT   3                              119         *6
 119  RELEASE     *9                             120
*
*
*
*TO CIRCUITS
*
 120  ADVANCE                               BOTH 121   122
 121  COMPARE     P2    E     K0                 160                      TO AUTODIN
 122  COMPARE     P2    E     K1                 165                      TO TWX
 130  QUEUE       5                         ALL  135   139                AWAIT MAN A-D
 135  SEIZE       10                             145
 136  SEIZE       11                             146
 137  SEIZE       12                             147
 138  SEIZE       13                             148
 139  SEIZE       14                             149
```

145	ASSIGN	10	K10		155			
146	ASSIGN	10	K11		155			
147	ASSIGN	10	K12		155			
148	ASSIGN	10	K13		155			
149	ASSIGN	10	K14		155			
155	QUEUE	6			160			AWAIT MACHINE
160	INTERRUPT	4			161		*7	AUTODIN XMIT
161	RELEASE	*10			270			GO FILE ROUTE
165	QUEUE	7		ALL	170	174		AWAIT MAN-TWX
170	SEIZE	10			176			
171	SEIZE	11			177			
172	SEIZE	12			178			
173	SEIZE	13			179			
174	SEIZE	14			180			
176	ASSIGN	11	K10		185			
177	ASSIGN	11	K11		185			
178	ASSIGN	11	K12		185			
179	ASSIGN	11	K13		185			
180	ASSIGN	11	K14		185			
185	QUEUE	8			190			AWAIT MACHINE
190	HOLD	5			200		*7	TWX
200	RELEASE	*11			270			GO FILE ROUTE
210	QUEUE	9		ALL	215	219		AWAIT MAN-WUX
215	SEIZE	10			221			
216	SEIZE	11			222			
217	SEIZE	12			223			
218	SEIZE	13			224			
219	SEIZE	14			225			
221	ASSIGN	12	K10		230			
222	ASSIGN	12	K11		230			
223	ASSIGN	12	K12		230			
224	ASSIGN	12	K13		230			
225	ASSIGN	12	K14		230			

SAMPLE COMPILATION LISTING AND OUTPUT (Continued)

```
 230  QUEUE       10                          235                     AWAIT MACHINE
 235  HOLD        6                           240        *7           WUX
 240  RELEASE     *12                         270                     GO FILE ROUTE
*
*
*
*TO MESSAGE CENTER DESK FOR CLEARING OF SEND TRAFFIC
*
 250  QUEUE       11                    ALL   251   255               AWAIT MAN MCD
 251  SEIZE       10                          257                     (SEND TRF TO
 252  SEIZE       11                          258                     BE CLEARED AND
 253  SEIZE       12                          259                     REC TRF)
 254  SEIZE       13                          260
 255  SEIZE       14                          261
 257  ASSIGN      13    K10                   265
 258  ASSIGN      13    K11                   265
 259  ASSIGN      13    K12                   265
 260  ASSIGN      13    K13                   265
 261  ASSIGN      13    K14                   265
 265  QUEUE       12                          274                     AWAIT DESK
 270  ADVANCE                          BOTH   271   272
 271  COMPARE     P3    E     K0              335
 272  COMPARE     P3    NE    K0              250
 274  HOLD        1                           275        1      1
 275  RELEASE     *13                         276
 276  ADVANCE                          BOTH   277   278
 277  COMPARE     P3    E     K0              280
 278  COMPARE     P3    E     K1              281
 279  TABULATE    1                           250
 280  TERMINATE                                                       FILE OUTGOING
 281  TABULATE    2                           300
 300  TERMINATE                                                       DELIVER INCMG
*
```

SAMPLE COMPILATION LISTING AND OUTPUT (Continued)

```
*
*
*
*
*END OF SEND SIMULATION
*
*RECEIVE ACTIVITY BELOW
 310  ASSIGN      3     K1                 311                  A-D
 311  PRIORITY    FN5                      250
 320  ASSIGN      2     K1                 321                  TWX
 321  ASSIGN      3     K1                 322
 322  ASSIGN      5     FN4                323
 323  ASSIGN      7     V3                 165                  END TWX
 330  ASSIGN      2     K2                 331                  WUX
 331  ASSIGN      3     K1                 332
 332  ASSIGN      5     FN4                333
 333  ASSIGN      7     V4                 210                  END WUX
 335  ADVANCE                        BOTH  336   337
 336  COMPARE     P4    E     K0           279
 337  COMPARE     P4    NE    K0           338
 338  TABULATE    3                        340
 340  PRIORITY    0                        250
*
*
*
*
*
*RECEIVE ACTIVITY FOR  WUX.
*
 550  ORIGINATE   1921  8                  330         120  60  TUESDAY
 551  ORIGINATE   3361  8                  330         120  60  WED
 552  ORIGINATE   4801  8                  330         120  60  THUR
```

```
 553  ORIGINATE   6240  8                      330         120   60    FRI
*
*
*RECEIVE ACTIVITY FOR AUTODIN.
*
*
 560  ORIGINATE   1440  30                     310         6     5     TUESDAY
 561  ORIGINATE   1620  14                     310         30    10
 562  ORIGINATE   2040  40                     310         6     5
 563  ORIGINATE   2280  45                     310         4     3
 564  ORIGINATE   2460  140                    310         2     1
 565  ORIGINATE   2880  30                     310         6     5     WEDNESDAY
 566  ORIGINATE   3060  14                     310         30    10
 567  ORIGINATE   3480  40                     310         6     5
 568  ORIGINATE   3720  45                     310         4     3
 569  ORIGINATE   3900  140                    310         2     1
 570  ORIGINATE   4320  30                     310         6     5     THURSDAY
 571  ORIGINATE   4500  14                     310         30    10
 572  ORIGINATE   4920  40                     310         6     5
 573  ORIGINATE   5160  45                     310         4     3
 574  ORIGINATE   5340  140                    310         2     1
 575  ORIGINATE   5760  30                     310         6     5     FRIDAY
 576  ORIGINATE   5940  14                     310         30    10
 577  ORIGINATE   6360  40                     310         6     5
 578  ORIGINATE   6400  45                     310         4     3
 579  ORIGINATE   6580  140                    310         2     1
 580  ORIGINATE   7200                         310         60    30    SAT & SUN
*
*
*
*
```

```
*THIS ROUTINE SIMULATES LUNCH BREAKS THROUGHOUT THE ENTIRE WORKWEEK.
*
*
 601  ORIGINATE  660  1              602        1
 602  PRIORITY   4                   603
 603  HOLD       10                  604        120        MONDAY LUNCH
 604  HOLD       22                  605        1320
 605  HOLD       10                  606        120        TUESDAY
 606  HOLD       22                  607        1320
 607  HOLD       10                  608        120        WEDNESDAY
 608  HOLD       22                  609        1320
 609  HOLD       10                  610        120        THURSDAY
 610  HOLD       22                  611        1320
 611  HOLD       10                  612        120        FRIDAY
 612  TERMINATE
*
*
*
*
*THIS ROUTINE BUSIES OUT MAN NR 12.
*
 455  ORIGINATE  0    1              456        1
 456  PRIORITY   4                   457
 457  HOLD       12                  458        100080
 458  TERMINATE
*
*
*THIS ROUTINE PUTS MAN ON BOOSTER SHIFT FROM 1100 UNTIL 1900. MAN NR 14.
*
 420  ORIGINATE  0    1              421        1
 421  PRIORITY   4                   423
 423  HOLD       14                  424        660
 424  HOLD       23                  425        480
```

SAMPLE COMPILATION LISTING AND OUTPUT (Concluded)

```
425  HOLD       14                        426       960
426  HOLD       23                        427       480
427  HOLD       14                        428       960
428  HOLD       23                        429       480
429  HOLD       14                        430       960
430  HOLD       23                        431       480
431  HOLD       14                        432       960
432  HOLD       23                        433       480
433  HOLD       14                        434       3180
434  TERMINATE
*
*
*
*
*
*
*
     START                  1440               MONDAY

CLOCK TIME  REL      1440                ABS       1440
```

PROGRAM OUTPUT

FACILITY NR	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRANS
1	.5299	730	1.05
2	.4090	117	5.03
3	.2931	81	5.21
4	.1554	179	1.49
5	.1264	47	3.87
6	.1208	22	7.91
10	.7215	377	2.76
11	.6582	330	2.78
12	1.0000	1	1440.00
13	.6181	326	2.73
14	1.0000	146	9.86
22	.4708	1	678.00
23	.3333	1	480.00

QUEUE NR	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES
1	82	23.75	212	19
2	2	.00	212	19
3	1	.00	198	146
4	2	.06	198	131
5	1	.00	179	179
6	2	.02	179	158
7	8	1.78	47	29
8	2	.02	47	29
9	4	.94	22	10
10	1	.00	22	9
11	5	.37	517	312
12	4	.45	517	184

TABLE NUMBER 1

ENTRIES IN TABLE 185

MEAN ARGUMENT 193.714

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
0	0	.00	.0
60	36	19.46	19.5
120	17	9.19	28.6
180	33	17.84	46.5
240	10	5.41	51.9
300	61	32.97	84.9
360	27	14.59	99.5
OVERFLOW	1	.54	100.0

PROGRAM OUTPUT (Concluded)

TABLE NUMBER 2

ENTRIES IN TABLE 305 MEAN ARGUMENT 16.384

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
0	17	5.57	5.6
60	265	86.89	92.5
120	7	2.30	94.8
180	7	2.35	97.0
240	2	.66	97.7
300	6	1.97	99.7
360	1	.33	100.0

REMAINING FREQUENCIES ARE ALL ZERO

TABLE NUMBER 3

ENTRIES IN TABLE 27 MEAN ARGUMENT 7.111

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
0	0	.00	.0
5	12	44.44	44.4
10	10	37.04	81.5
15	4	14.81	96.3
20	1	3.70	100.0

REMAINING FREQUENCIES ARE ALL ZERO

FUTURE RANDOM NUMBER SEED IS (OCIAL) 271436201625

APPENDIX B

SAMPLE MESSAGE CENTER LOG

COMMCEN MESSAGE REGISTER

	INCOMING	STATION	DATE	PAGE
X	OUTGOING	LRAFB - COMMCEN	WINTER "A"	1

CCN/SSN	PREC	FILE TIME	DATE TIME GROUP	CLASS	MESSAGE IDENTIFICATION NO.	GROUP COUNT	TO (Stations)	CLEARED			REMARKS
								TO	TIME	CLERK	
1	P	0035	0025	S	1-0001	205	AUTODIN	A123	0045	12	
2	P	0115	0105	U	1-0002	45	A-D	A124	0128	22	
3	P	0245	0235	U	1-0003	120	A-D	A125	0248	13	
4	O	0310	0300	U	1-0004	175	A-D	A126	0320	12	
5	P	0428	0420	C	1-0005	185	A-D	A129	0438	12	
6	P	0535	0520	U	1-0006	80	A-D	A132	0540	13	
7	P	0638	0630	U	1-0007	95	A-D	A133	0645	22	
8	P	0702	0645	U	1-0008	125	A-D	A140	0710	12	
9	R	0800	1500	C	1-0013	250	A-D	A142	0815	7	
10	R	0800	1610	U	1-0009	405	TWX	B002	0812	7	
11	R	0800	1730	U	1-0015	510	A-D	A150	0819	7	
12	R	0800	1615	U	1-0010	305	A-D	A151	0825	7	
13	R	0800	1755	U	1-0012	325	A-D	A152	0700	7	
14	R	0800	1810	U	1-0011	110	A-D	A154	0905	7	
15	R	0800	1550	S	1-0014	80	A-D	A156	0920	7	
16	R	0800	2200	U	1-0019	255	WUX	C001	0840	7	
17	R	0800	1635	U	1-0016	405	A-D	A157	0950	3	
18	R	0800	1705	U	1-0018	880	A-D	A158	1000	3	
19	R	0800	1615	U	1-0017	125	A-D	A161	1005	7	
20	R	0800	1935	U	1-0020	235	TWX	B004	0955	7	

AF FORM DEC 64 1022 PREVIOUS EDITION OF THIS FORM WILL BE USED UNTIL EXHAUSTED.

GPO : 1966 O—239-523

APPENDIX C

BLANK FORM USED FOR SCHEDULING

Duty Hours | Day of the Month

	1	2	3	4	5	6	7	8	9	10	11

A Shift-- _____Men

B Shift-- _____Men

C Shift-- _____Men

D Shift-- _____Men

E Shift-- _____Men

Booster Shift

Hours:

REMARKS: Specific justification for exceptional hour arrangements appear in this space.

BIBLIOGRAPHY

Literature Cited

1. Allied Communications Publication (ACP) 121, Department of Defense, 1965.

2. Allied Communications Publication (ACP) 127C USAF Supp., Department of Defense, 1966.

3. Ameen, David A., Use of Computer Simulations in Logistics Management Training, AD 623 233, U.S. Department of Defense Logistics Conference, Vol. II-9, Arlie Conference Center, Warrenton, Virginia, May 1965.

4. Baran, Paul, On Distributed Communications: I. Introduction to Distributed Communications Networks, The Rand Corporation, RM-3420-PR, August 1964.

5. Baran, Paul, On Distributed Communications: IV. Priority, Precedence and Overload, The Rand Corporation, RM-3688-PR, August 1964.

6. Boehn, B. W., A Computer Simulation of Adaptive Routing Techniques for Distributed Communications Systems, The Rand Corporation, RM-4782-PR, February 1966.

7. Bonini, Charles P., Simulation of Information and Decision Systems in the Firm, Markham Publishing Co., Chicago, 1967.

8. Brennen, R. D. and Linebarger, R. N., "An Evaluation of Digital Analog Simulator Languages," IFIP 1965 Proceedings, Vol. II, 1965.

9. Brenner, R. D. and Linebarger, R. N., "A Survey of Digital Simulator Programs," Simulation, Vol. 3, No. 6, 1964.

10. Chorafas, Dimitris N., Systems and Simulation, Academic Press, New York, 1965, pp. 1-45, 147-154.

11. Clancey, John J. and Fineburg, Mark S., "Digital Simulation Languages: A Critique and a Guide," AFIPS Conference Proceedings, Vol. 27, Part I, 1965, pp. 23-36.

BIBLIOGRAPHY (Continued)

12. Clark, A. P., Loberman, H. and Hoyt, L. A., "SIM-I, The Model Patient," Datamation, August 1968, pp. 33-39, 78.

13. Communications Electronics Doctrine (CED) 2200, AFM 100-22, Department of the Air Force, 1965.

14. Communications Electronics Doctrine (CED) 2100, AFM 100-21, Department of the Air Force, 1965.

15. Conway, R. W., Delfousse, J. J., Maxwell, W. L., and Walker, W. E., "CLP-The Cornell List Processor," Communications of the ACM, VIII, April 1965.

16. Dalkey, Norman C., "Simulation," Systems Analysis and Policy Planning, The Rand Corporation, 1965.

17. "Defense Communications System Speed of Service Criteria," Defense Communications Agency Circular 70-4, Defense Communications Agency (DCA), 1961.

18. Freeman, D. E., "Programming Languages Ease Digital Simulation," Control Engineering, Vol. II, No. 11, pp. 103-106, 1965.

19. Geisler, Murray A. and Ginsberg, Allen S., Man-Machine Simulation Experience, The Rand Corporation, P-3214, August 1965.

20. General Purpose Systems Simulator, UNIVAC, UP 4129, 1966.

21. Gordon, G., "A General Purpose Systems Simulator," IBM Systems Journal, Vol. 1, No. 1, pp. 18-32, 1962.

22. Harnett, R. T., et al., MIDAS Programming Guide, AD 430 982, Wright-Patterson AFB, Ohio, 1964.

23. Herscovitch, H. and Schneider, T. H., "An Expanded General Purpose Simulator," IBM Systems Journal, Vol. 4, No. 3, pp. 174-183, 1965.

24. Holt, Charles C., et al., "Program SIMULATE, A Users and Programmers Manual," Social Systems Research Institute, University of Wisconsin, 1964.

25. Kelly, D. H. and Buxton, J. N., "Montecode - An Interpretive Program for Monte-Carlo Simulations," The Computer Journal, V, 1962.

BIBLIOGRAPHY (Continued)

26. Kibee, Joel M., Craft, Clifford J., and Nanus, Burt, Management Games, Reinhold Publishing Company, New York, 1961, pp. 41-48.

27. Kivat, Phillip J., "GASP - A General Activity Simulation Program," Project No. 90 17-019(2), Applied Research Laboratory, U.S. Steel, Monroeville, Pa., 1963.

28. Kivat, Phillip J. and Colker, Alan, GASP - A General Activity Simulation Program, The Rand Corporation, P-2864, 1964.

29. Krasnow, Howard S. and Merikallio, Reino A., "The Past, Present and Future of General Simulation Languages," Management Science, XI, November 1964, pp. 236-267.

30. Malcom, Donald G., "System Simulation - A Fundamental Tool for Industrial Engineering," Simulation in Social Science: Readings, Ed. Guetzkow, Prentice Hall, Inc., Englewood Cliffs, N. J., 1962, 138-150.

31. Markowitz, H. M., et al., SIMSCRIPT: A Simulation Programming Language, Prentice Hall, Inc., Englewood Cliffs, N. J., 1963.

32. McNelis, D. C., "Telecommunications System Design," Paper for IEEE Convention, March 1968, 1968.

33. Nagin, Rhoda P. and Sisson, Roger L., "Game Theory," Data Processing Digest, Vol. 12, No. 3, March 1966, pp. 2-12.

34. Nanus, Burt, "Management Games: An Answer to Critics," The Journal of Industrial Engineering, Nov-Dec 1962, pp. 467-469.

35. Naylor, Thomas H., et al., Computer Simulation Techniques, John Wiley and Sons, Inc., New York, 1966, pp. 1-20.

36. Orcutt, Guy H., "Simulation of Economic Systems," Simulation in Social Science: Readings, Ed., Guetzkow, Prentice Hall, Inc., Englewood Cliffs, N. J., 1962, pp. 138-150.

37. Pugh, Alexander L., DYNAMO Users Manual, The M.I.T. Press, Cambridge, Mass., 1963.

38. Renshaw, R. J., The Game Monoplogs, The Rand Corporation, RM-1917-1-PR, May 1957, Revised March 1960.

39. Shubick, Martin, "Simulation of the Industry and the Firm," American Economic Review, L, No. 5, Dec 1960, pp. 908-919.

BIBLIOGRAPHY (Continued)

40. SIMPAC Users Manual, TM602/00/000, Systems Development Corporation, Santa Monica, Calif., 1962.

41. Specht, R. D., "The Nature of Models," Systems Analysis and Policy Planning, The Rand Corporation, Santa Monica, Calif., 1965, pp. 211-226.

42. Stockton, John R., Simulation Training for a Small Business Executive, Bureau of Business Research, University of Texas, Austin, Texas, 1963.

43. Teichroew, Daniel and Lubin, John F., "Computer Simulation: of the Technique and Comparison of Languages," Communications of the ACM, Vol. 9, Issue No. 10, Oct 1966, pp. 723-742.

44. Tocher, K. D. and Hopkins, B. A., "Handbook of the General Simulation Program, Mk II," Report No. 118/ORD 10/TECH, United States Steel Companies, Ltd., Sheffield, England, 1964.

45. Tocher, K. D., "Review of Simulation Languages," Operational Research Quarterly, XVI, June 1965.

46. von Neuman, John and Morgenstern, Oskar, Theory of Games and Economic Behavior, Princeton, N. J., 1963, pp. 1-14, 46-48.

47. Young, Karen, A Users Experience with Three Simulation Languages (GPSS, SIMSCRIPT and SIMPAC), Systems Development Corporation, TM-1755/000/00, 1963.

Other References

Andersen, Lee F., A Comparison of Simulation Case Studies and Problem Papers in Teaching Decision Making, Northwestern University, Evanston, Illinois, 1964.

Baran, Paul, Communications, Computers and People, The Rand Corporation (P-3235), 1965.

Burdick, D. S. and Naylor, T. H., "Design of Computer Simulation Experiments for Industrial Systems," Communications of the ACM, Ed., Teichroew, Vol. 9, No. 5, May 1966, pp. 329-339.

Cohen, Kalman J. and Rhenman, Eric, "The Role of Management Games in Education and Research," Management Science, Vol. 7, No. 2, June 1961, pp. 131-166.

BIBLIOGRAPHY (Continued)

Cremeans, John E., "The Trend in Simulation," Computers and Automation, Jan 1968, pp. 44-48.

Development of Man-Machine Simulation Techniques, The Rand Corporation (P-1945), March 1960.

Dresher, Melvin, Games of Strategy, Prentice Hall, Inc., Englewood, Cliffs, N. J., 1963.

Fishman, George S. and Kiviat, Philip J., Digital Computer Simulation: Statistical Considerations, The Rand Corporation (RM-5387-PR), November 1967.

Grodsky, Milton A., "Man-Machine Simulation," Prospects for Simulation and Simulators of Dynamic Systems, Ed., Shapiro and Rogers, MacMillan and Co., Ltd., London, pp. 88-103.

Haverty, J. P., GRAIL/GPSS: Graphic On-line Modeling, The Rand Corporation (P-3838), June 1968.

Henry, P., "How to Train by Simulation," Sales Management, Vol. 99, November 20, 1967, pp. 62-65.

Kiviat, Philip J., Development of New Digital Simulation Languages, The Rand Corporation (RM-3348-PR), April 1966.

Nielsen, Norman R., "Computer Simulation of Computer System Performance," Proceedings of the 22nd ACM (1967), Vol. 10, No. 5, 1967.

Plattner, John W. and Herron, L. W., Simulation: Its Use in Employee Selection and Training, American Management Association, Personnel Division, 1962.

Reitman, Julian, "The User of Simulation Languages - The Forgotten Man," Proceedings of the 22nd ACM (1967), Vol. 10, No. 5, 1967.

Ruiz-Pala, Ernesto, Avila-Beloso, Carlos, and Hines, William W., Waiting-Line Models, Reinhold Industrial Engineering and Management Science Series, 1967.

Shepard, Alan B., Training by Simulation, Washington, Smithsonian Institute, 1965.

Tocher, K. D., The Art of Simulation, D. Van Nostrand Company, Inc., Princeton, N. J., 1963.

BIBLIOGRAPHY (Concluded)

Thorelli, Hans B., et al., International Operations Simulation with Comments on Design and Use of Management Games, Free Press of Glencoe, 1964.