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PERFORMANCE STUDY OF A MARINE
EXPEDITIONARY FORCE RADIO SYSTEM

by

Allen L. Noel

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Thesis Advisor: Tri T. Ha

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Performance Study of a Marine Expeditionary Force Radio System

by

Allen L. Noel
Captain, United States Marine Corps
BSEE, The Citadel, Charleston, SC, May 1982

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Author: Allen L. Noel

Allen L. Noel

Approved by: Tri T. Ha

Tri T. Ha, Thesis Advisor

Glen A. Myers

Glen A. Myers, Second Reader

Michael A. Morgan

Michael A. Morgan, Chairman
Department of Electrical and Computer Engineering

ABSTRACT

A computer simulation model of the U.S. Marine Corps Marine Expeditionary Force's high frequency and very high frequency voice radio system was developed. The model's performance, under varying message traffic loads and jamming, was evaluated and compared to two computer models that incorporate telephone switching techniques to access multiple radio circuits. A radio circuit switch mathematical model was developed utilizing an Engset distribution for a telephone exchange to calculate the key parameters and verify the results of the simulation model. Based on the results of the simulation, the implementation of the proposed system is discussed with the goal of minimizing modifications to existing equipment and procedures.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAOC	Anti-aircraft Operation Center
ALT	Alternate
ALTROUTE	Alternative Route
ANGLICO	Air Naval Gunfire Liaison Company
ARTY O	Artillery Officer
BN	Battalion
CATF	Commander Amphibious Task Force
CC	Communications Center
CEO	Communications-Electronics Officer
CHT	Circuit Holding Time
COC	Combat Operation Center
COMMCON	Communication Control
COP	Command Observation Post
CP	Command Post
CSSA	Combat Service Support Area
CSSE	Combat Service Support Element
DASC	Direct Air Support Center
DCS	Defense Communication System
DIV	Division
DS	Direct Support
DTG	Date Time Group
EW	Electronic Warfare
FAC	Forward Air Controller
FCFS	First Come First Serve
FDC	Fire Direction Center

FSCC	Fire Support Coordination Center
FSSG	Force Service Support Group
G2	Intelligence Officer
G3	Operation Officer
G4	Logistics Officer
GS	General Support
HF	High Frequency
HQ	Headquarters
INF BN	Infantry Battalion
INF REG	Infantry Regiment
LF	Landing Force
MACS	Marine Air Control Squadron
MAG	Marine Air Group
MAW	Marine Air Wing
MEF	Marine Expeditionary Force
MDF	Main Distribution Frame
MWSG	Main Wing Security Group
NGF	Naval Gunfire
NTS	Naval Telecommunication System
RECON	Reconnassiance
SYSCON	System Control
TACC	Tactical Air Control Center
TACLOG	Tactical Logistics
TAOC	Tactical Air Operations Center
TECHCON	Technical Control
TP	Test Point

VHF	Very High Frequency
WD-1	Twisted Pair 2-W "Slash Wire"

I. INTRODUCTION

A. BACKGROUND

The last two decades have encompassed a rapid growth and modernization of the communication systems utilized by the U.S. Marine Corps. In particular, the High Frequency (HF) and Very High Frequency (VHF) tactical radios have experienced an infusion of reliable, solid-state transceivers and accessory equipment that has greatly enhanced single channel reliability. The trend over the past decade has been to build better components, i.e., radio, antenna, remote or cryptographic equipment with little attention being given to the voice radio communication system as a whole. This is a natural tendency since voice radio is typically utilized as an independent net or circuit with a minimum number of users. Viewed as a system, the single channel voice radio circuits required to support Marine Expeditionary Force (MEF) operations typically consists of over 400 radios on more than 140 separate frequencies. The physical size of this system prompts the question of what data network techniques, if any, can improve the reliability and capacity of single channel voice radios as a system.

B. PURPOSE

Initial research is directed to the development of a computer model to simulate a MEF HF and VHF voice radio system. The thrust of the study is to identify those access or switching techniques that will enhance overall system performance and to obtain the prerequisites for development of a prototype system. Additionally, the simulation provides some insight into the following requirements:

- Identify the procedures required to access multiple radio circuits based on the originator of the call.
- Identify a switching scheme that does not require modification to existing radio and cryptographic equipment.
- Identify requirements to interface isolated radios with the switching network.
- Identify the techniques available to automatically check radio circuits to provide accurate path availability information to a switching processor.
- Identify a network implementation that will minimize changes to existing operating procedures.

The resulting models were subjected to varying message traffic loads and jamming to provide a comparison of their performance characteristics with the original system.

II. VOICE RADIO SYSTEMS

A. TACTICAL SYSTEMS

The increased complexity of the modern battlefield has continued to place a heavy burden on the communication system to support the tactical commander and his staff, which will be referred to as the customer throughout this document. Voice radio continues to play a key role due to its flexibility and ease of installation whereas telephone and data systems require days to install and lack mobility in a real time sense. During the initial phase of an operation, current doctrine relies heavily on voice radio communications to subordinate units while the Navy supports the embarked units requirements to higher headquarters until shore facilities are established. Once established, voice radio continues to support tactical, fire support and logistical message traffic within the MEF as well as displacements forward. Each radio in a given Command Post (CP) is interconnected at the technical control facility's Main Distribution Frame (MDF). The MDF is the node for all communication trunks into the CP, and its connectivity with the other MDF's within the MEF constitute the communication system.

1. System Configuration

The MDF has as its primary function, the physical, metallic and/or electronic interconnection of all internodal transmission equipment, nodal circuit and message switching equipment, and local user terminals. [Ref. 1:p. 26]

The MDF's function as a node requires that all transmission media be physically wired into the MDF regardless of type. The landing force integrated communication systems of Figure 1 shows the internodal connectivity and hierarchical structure of a typical MEF employment [Ref. 1:p. 23].

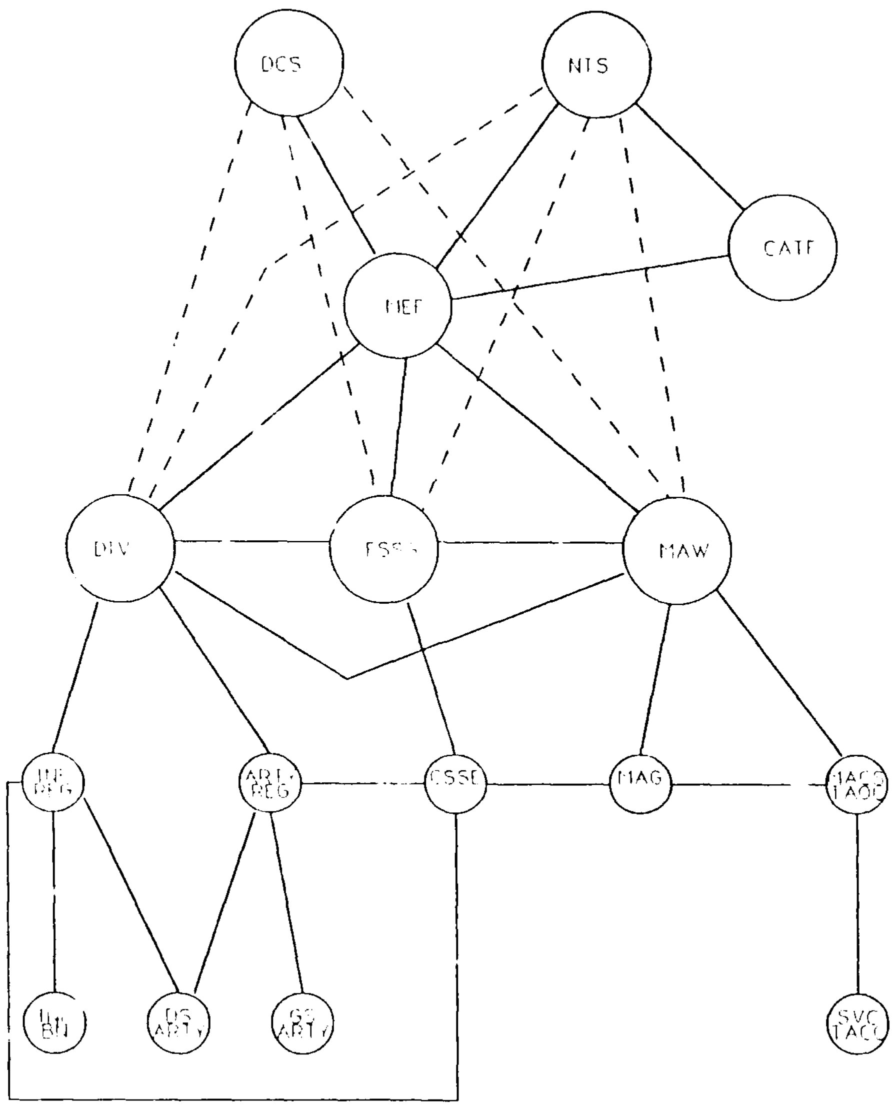

Figure 1. A Typical MEF Network

Figure 1 is also indicative of the connectivity provided by the HF and VHF voice radio system. Radio circuits are established based on the customer's requirement for communication support, and these circuits generally fall into the infrastructure shown in Figure 1. The purpose and composition of these radio circuits are given in Appendix E of Reference 2.

Due to the large electromagnetic signature presented by the transmitters, radios are positioned one to two miles from the CP. The physical structure for all HF and VHF radios is shown in Figure 2 below.

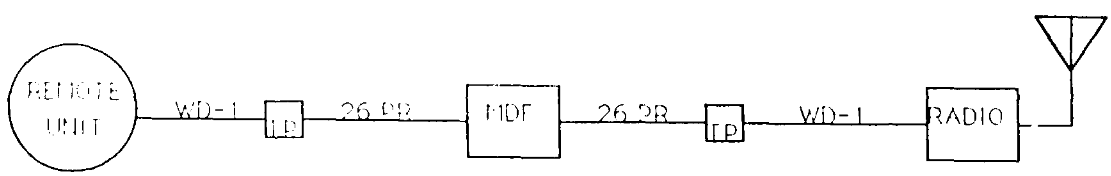

Figure 2. Remoted Radio Circuit

The remote unit is terminated at the customer's position in the Combat Operation Center (COC). The two test points (TP) and the MDF provide the ability to isolate malfunctions. The MDF for the MEF, Division (DIV), Force Service Support Group (FSSG) and Marine Air Wing (MAW) headquarters elements is the AN/TSQ-84 technical control facility. Battalion/squadron units and below do not employ a MDF.

2. System Utilization

A radio circuit or net can be viewed as a time share communication link to multiple nodes. The Communication Electronic Officer (CEO), on the commander's staff, structures the radio circuits to support the unit's scheme of maneuver. Table 1 provides the typical number of radio circuits established to support a MEF.

TABLE 1
MEF RADIO CIRCUITS

	MEF	DIV	FSSG	MAW
VHF	12	14	9	5
HF	13	51	8	29

Radio circuits typically fall into one of four categories:

- Tactical command of the major combat elements and aircraft.
- Fire support circuits for artillery, naval gunfire and aircraft.
- General support for reconnaissance, combat engineers, helicopter support teams, tanks and communications.
- Logistical support for supplies and medical evacuation.

Each category corresponds to a specific customer's area of responsibility within the unit, and circuits of each category type are generally remoted to the same location in the CP. An example of this is all fire support circuits remoted to the ground combat elements fire support coordination center

(FSCC), while the aviation combat element's equivalent is the direct air support center (DASC).

As a general rule, radio circuits are utilized based on the command and control purpose of the circuit and independently of other radio circuits. During circuit outages, the customers will alternatively route (altroute) message traffic on the radio circuits colocated at their position in the CP and rarely utilize a circuit from a different category type. The installation, operation and maintenance of a HF and VHF radio system employed over a large geographical area poses some unique problems to communication personnel.

B. COMMON PROBLEMS

Circuit outages are reported by the customer to System Control (SYSCON) for correction. SYSCON assigns restoration priorities and coordinates the corrective effort via the Technical Control Facility (TECHCON) which utilizes the MDF to identify the malfunction. It is common practice to maintain a standby HF and VHF transmitter to replace high priority circuits during an outage until the problem can be identified and corrected. With the majority of the circuits being remoted to separate locations within the CP, a customer limits the number of alternate paths in which the message traffic can be sent. This problem was encountered in exercise

Solid Shield 89 which resulted in the following conclusion [Ref. 3:p. 2]:

> While installation in this manner permits staff officers/principles direct access to the radio as desired, decentralized control of radio communications is inefficient from a communication perspective. Specific problems include the inability of the radio supervisor to adequately supervise/assist radio watchstanders and the inability to effectively altroute messages over other available radio nets if a particular staff sections radio net is inoperative.

Decentralization of remoted radio circuits places a heavy burden on SYSCON to maintain 100 percent readiness on all radio circuits due to the customer's inability to use another radio circuit during outages. The standby transmitter can be useful, but it still requires time to patch into the existing system and it can only support one customer at a time.

Another typical problem is that SYSCON does not have real time knowledge of the status of the system until notified by the customer or watchstander that there is a problem. As a general rule, radio circuits that are sitting idle will not work once a customer has message traffic for that circuit. Communication personnel constantly provide fill to offset this problem in the form of radio checks which are basically ineffective and not worth the undesirable electromagnetic signature produced. A computer model was developed to analyze the system as a whole and specifically to address these communication control (COMMCON) problems associated with VHF and HF radio circuits.

III. SIMULATION MODEL

A. METHODOLOGY AND ASSUMPTIONS

The MEF radio system is modeled using "SIMSCRIPT II.5" language trademarked by CACI Products Company on a UNIVAX computer. The model consists of 348 customers sending message traffic of varying lengths on 60 radio circuits. The computer program is provided in Appendix A. A total of four scenarios are derived from the model.

- Non-network Model
- Partial Network Model
- Full Network Model
- Modified Non-network Model

A radio circuit consists of two or more customers that send voice message traffic over a single frequency or link. Being simplex in nature, each radio on the circuit is capable of transmitting message traffic to one or all of the other radios. Only one radio may transmit at a time. The radio watchstander maintains a queue of messages by first-come-first-serve (FCFS) and one of four message precedences -- flash, immediate, priority and routine. Procedures call for the interruption of a transmission in order to pass higher precedence traffic, but this is not included in the simulation.

The non-network model establishes 348 customers, each having access to a single radio. The radio circuits, extracted from Reference 2, are selected on the criteria that they will typically be wired into the unit's MDF. Local security, convoy control and battalion/squadron-size unit's radio circuits, are excluded from the model. The customers assigned to each radio circuit are annotated in Appendix A. Each radio circuit is modeled independently. Figure 3 represents the computer model of a single circuit with multiple customers.

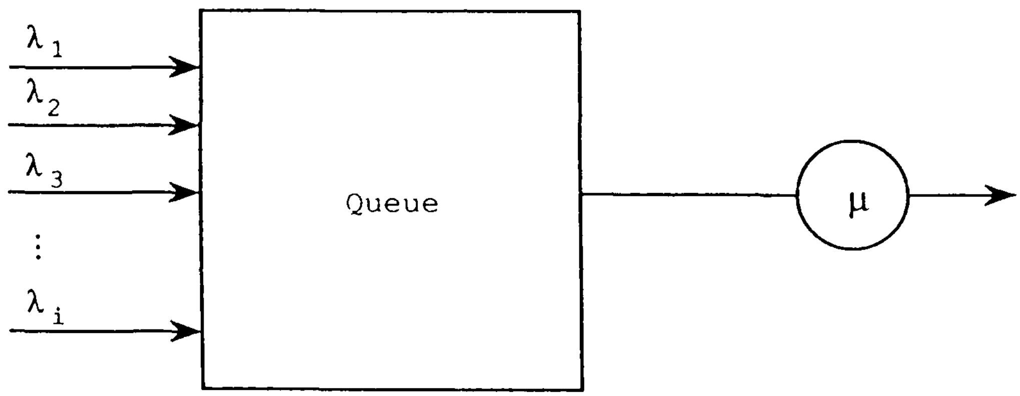

Figure 3. Radio Circuits to Model

Messages drafted by the customer are assumed to arrive at the radio operator according to a Poisson process with rate λ . The parameter μ is called the service rate and represents the rate (in messages served per unit time) during which time the server operates when busy [Ref. 4:p. 126]. In the actual system, each radio operator maintains a separate queue in which messages are filed by high precedence and low date time group (DTG). DTG is simply the time and date of the message origination. The assumption of a single queue is valid since in practice the radio operator designated as net control polls each radio operator for the precedence of his/her waiting or queue traffic and directs the station with the highest priority to transmit its traffic. The service rate directly correlates to the time required to transmit a message and has an exponential probability distribution with mean $1/\mu$ minutes.

The model generates messages for each customer according to the mean interarrival time provided in Appendix C. The message is passed to the routine "processor," given the originator of the message and assigned an associated DTG. Based on a uniform distribution, the message is arbitrarily assigned a precedence. Statistics utilized are based on personal experience as current data was not available. The length of the message is exponentially distributed with mean $1/\mu$. Since each radio is capable of transmitting traffic to one or all of the radios on the circuit, message addressees are not assigned to each message. To compensate for the additional time required to send a message to multiple addressees, the length of the message is randomly increased up to one minute. Based on the originator of the message, the message is queued for transmission on the assigned circuit. Preemptive interruption of a message being transmitted is not permitted.

The Partial Network model is identical to the non-network model except that a customer has access to multiple identical radio circuits. An example is that Landing Force (LF) Command Net 1 provides connectivity to the MEF, DIV, FSSG and MAW main distribution frames. Identical radio circuits include LF Command Net 2, LF Alert/Broadcast, and LF Communication Coordination Net. The message is automatically transmitted via any of the four radio circuts to the MDF of the respective addressees. Based on the originator of the message, a switch accesses the correct remote from the receiving MDF. Unique radio circuits continue to operate in an independent mode, thus the title Partial Network.

Expanding the system to implement a full network, the radio circuits are modified to maximize identical circuits. Additionally, the system is capable of simultaneously transmitting the same message over multiple radio circuits. The number of customers and message mean interarrival times remain the same as the original model. Circuits are reconfigured to reflect category type which result in a requirement for 59 additional radios and associated equipment.

The modified non-network model reflects the standard procedure of activating additional radio circuits to alleviate message backlog. Seven radio circuits are added with the mean interarrival time averaged over the existing and backup circuit. A total of 58 additional radios are required to implement this system.

B. KEY PARAMETERS

The model maintains statistical information on the utilization of each circuit, the average queue length, the standard deviation of the queue length, the mean waiting time and the standard deviation of the waiting time. Circuit utilization is the percentage of time that the circuit is actually sending message traffic. Queue length is the number of messages queued or waiting to be transmitted. The waiting time is the amount of time that a message waits in the queue before being transmitted. This parameter is particularly important since it is an indicator of overall system performance. Associated delays in a communication system include processing, propagation and transmission time. The first two are fixed by the communication hardware employed and nature. Transmission time is directly proportional to the length of the message which is determined by the customer. The network design can only have an impact on the waiting time that a message spends being queued for transmission. Large waiting times indicate that the network cannot keep pace with the arriving messages and a traffic jam results at the queue. Low waiting times indicate a robust system that effectively passes message traffic, and it is the key parameter emphasized in the results of the four models.

The mean interarrival times were assigned to each customer based on the radio circuit utilized by that customer. Numbers reflect the time interval between successive messages being generated by the customer. Lacking data on current radio circuit utilization, mean interarrival times are assigned lower values for fire support and tactical circuits with corresponding higher values for general support and administrative traffic. As mentioned in the preceding section, mean interarrival times are held constant for three of the four models to provide an overall system performance comparison.

The mean service time $1/\mu$ was given a range of values from one to three minutes in half-minute intervals and the models are run for each value. Corresponding higher values of the mean service time reflect an increased length of the message which requires longer transmission times. This was incorporated into the model in the form of circuit holding time (CHT) of the message.

IV. MODEL ANALYSIS

A. MODEL VALIDATION

Each model is run with varying mean service times under ideal conditions. Ideal conditions do not account for any other circuit outage or nonavailability except for messages blocked by the transmission of another message. A jamming routine was then added to each model which was recomputed under the same statistical conditions of the first run. The jamming routine randomly selects ten percent of the available circuits and blocks all message transmission for 20 minutes. It then randomly picks another ten percent throughout the program run which is set at 24 hours of simulated time. The graphical model of a single radio circuit in Figure 3 is expanded for access to multiple radio circuits to provide a mathematical model to verify the results of the simulation model.

The simulation model consists of a basic algorithm to implement a single radio circuit with multiple customers. Each customer or input is either idle for an exponential length of time $1/\lambda$ or generates a message with exponential circuit holding time of average length $1/\mu$ [Ref. 5:p. 518]. The message originator then determines which circuits are available for transmission of the message, i.e., the model acts as a circuit-switch exchange to one or more radio circuits. This is identical to a telephone switch with multiple inputs and outputs as shown in Figure 4.

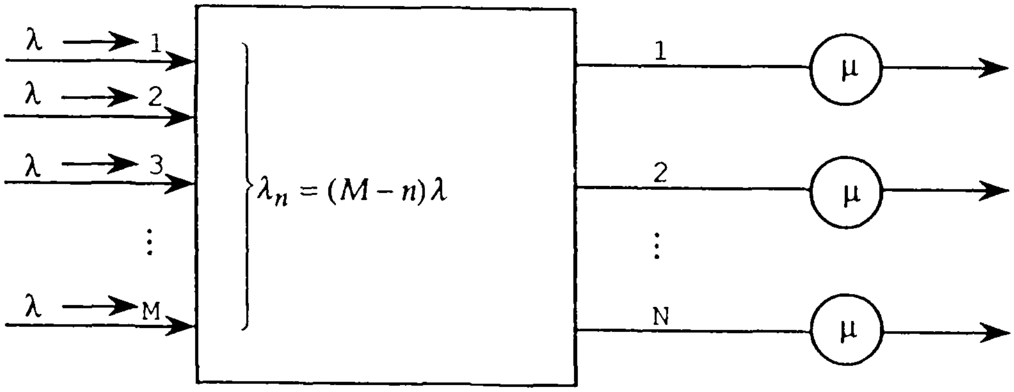

Figure 4. Engset Distribution Model

With the arrival of a message, it is assigned one of the available outgoing circuits or queued if all N circuits are occupied. The switch behaves statistically like a birth-death process, with arrival (birth) rate and departure rate μ_n when n message are being transmitted. The state of the system is denoted by n. Specifically, it is apparent that the two state-variable rates are given respectively by

$$\lambda_n = (m - n)\lambda \qquad \begin{cases} 0 \le n \le N \\ N \le M \end{cases} \tag{1}$$

and

$$\mu_n = n\mu \qquad 1 \le n \le N \tag{2}$$

The state-probability balance equation is given by

$$\mu_{n+1}p_{n+1} = \lambda_n p_n \qquad n \ge 0 \tag{3}$$

with p_n the probability that there are n messages being transmitted. Solving Eq. 3 iteratively gives for p_n:

$$p_n / p_0 = \prod_{k=0}^{n-1} \lambda_k / \prod_{k=1}^{n} \mu_k \qquad (4)$$

which can be written as;

$$p_n / p_0 = \left(\frac{\lambda}{\mu}\right)^n \binom{M}{n} \qquad (5)$$

where the second term is a binomal distribution for the number of combinations of M objects taken n at a time. [Ref. 5:pp. 518-519]

Applying the probability normalization condition

$$\sum_{n=0}^{N} p_n = 1 \qquad (6)$$

Eq. 5 to determine the unknown probability p_o, derives the Engset distribution for the probability p_n of the number of messages being transmitted:

$$p_n = \left(\frac{\lambda}{\mu}\right)^n \binom{M}{n} / \sum_{n=0}^{N} \left(\frac{\lambda}{\mu}\right)^n \binom{M}{n} \qquad 0 \le n \le N \qquad (7)$$

Define P_Q as the probability that all circuits are fully occupied. Then $P_Q = p_N$ for N < M. [Ref. 5:p. 519]

When the system is fully occupied, the message arrival rate is given by Eq. 1. The arrival rate averaged over all states is given by: [Ref. 5:p. 520]

$$\lambda_T = \sum_{n=0}^{N} \lambda_n p_n \qquad (8)$$

Utilizing the Engset distribution provides two key unknowns in calculating the average waiting time of the system; P_Q and λ_T . For the multiple server system, the circuit utilization factor ρ is given by

$$\rho = \frac{\lambda_T}{N\mu} < 1 \qquad (9)$$

The average time W a message has to wait in the queue is [Ref. 4:pp. 135-136]:

$$W = \frac{\rho P_Q}{\lambda_T(1-\rho)} \qquad (10)$$

The mean waiting time is calculated for circuit switching models which accessed from one to five radio circuits for mean service times from one to three minutes and compared to the simulation models's output. Figure 5 depicts the deviation between the calculated and measured values.

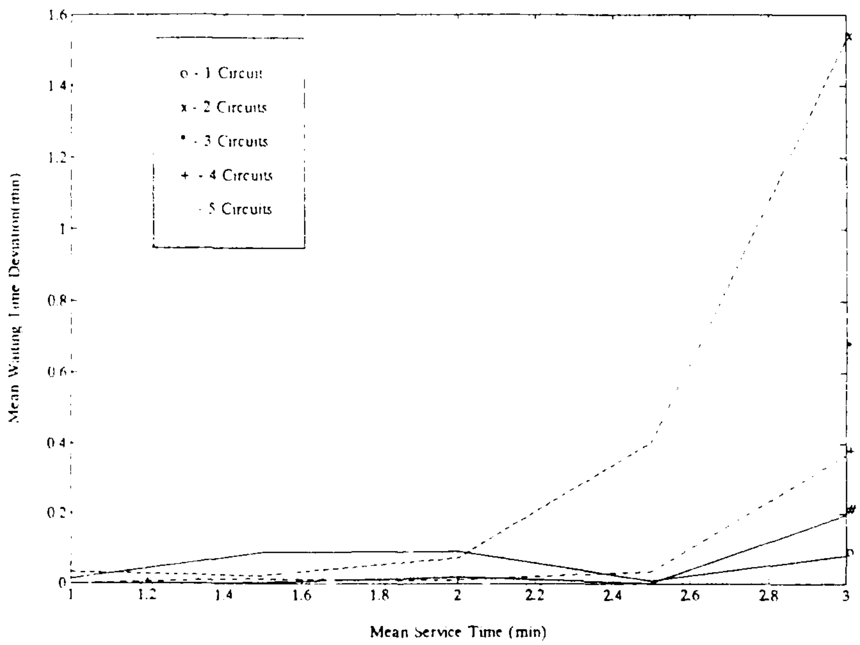

Figure 5. Simulation Error

As shown in Figure 5, error rates for multiple access of up to five circuits are below ten percent for mean service times below 2.5 minutes. At 2.5 minutes, the switching scheme for two radio circuits produced an unacceptable error rate of 40 percent with the other four schemes being below four percent. Based on these results, the simulation was not run at a mean service time of three minutes. The non-network and modified non-network model employ only the one circuit switch. Partial network has seven 2-circuit combinations while the full network has three. This is only 19 percent of the available circuits, but the large error does make the results for a 2.5 minute mean service time suspect.

B. RESULTS

Table 2 provides the results from each model for first the ideal case and secondly with jamming. The mean waiting time in queue is W, and σ_w is the standard deviation of the waiting time.

TABLE 2
SIMULATION MODEL RESULTS

Service Time (MIN)		Non-Network (SEC)	Partial Network (SEC)	Full Network (SEC)	Mod Network (SEC)
Ideal Conditions					
1.0	W	1.562	0.607	0.187	1.065
	σ_w	7.115	2.305	1.197	4.313
1.5	W	2.475	0.988	0.501	1.541
	σ_w	11.052	3.388	2.089	5.576
2.0	W	10.006	1.320	0.966	1.964
	σ_w	46.784	3.329	2.798	6.959
2.5	W	14.871	1.729	2.040	2.573
	σ_w	66.383	3.653	5.178	9.078
Jamming					
1.0	W	1.790	0.939	0.795	1.360
	σ_w	3.857	2.813	2.704	3.610
1.5	W	645.755	1.804	650.318	1.648
	σ_w	1474.640	4.284	1746.427	4.130
2.0	W	3453.753	6.044	8738.936	61.301
	σ_w	7571.157	29.273	15262.162	278.875
2.5	W	8901.044	2758.628	28700.520	624.276
	σ_w	15373.580	5540.148	36510.838	1660.112

The table is provided to give the complete results of each model with the inclusion of the standard deviation of the waiting time. Figure 6 provides the results under ideal conditions. The full and partial networks maintain a mean waiting time below 2.1 seconds over all mean service times which is well below the original non-network system.

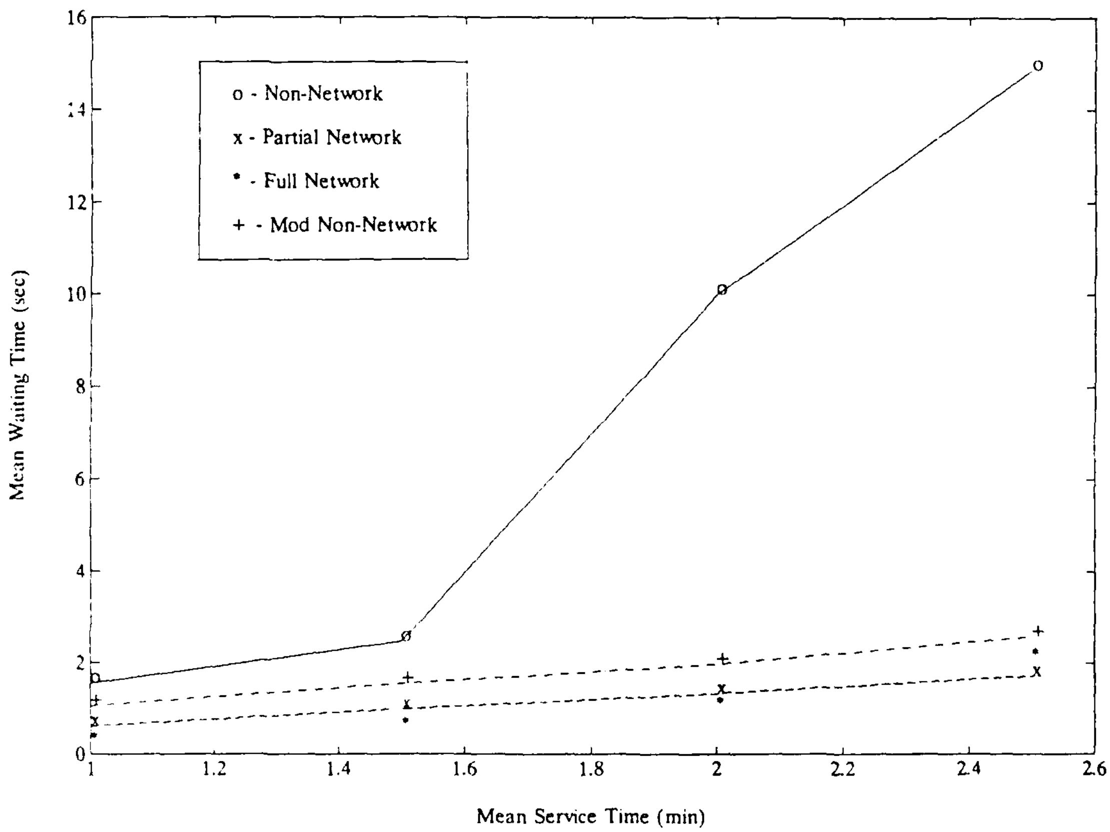

Figure 6. Ideal Condition Results

Under jamming of ten percent of the available circuits, the partial and modified non-network performed best as shown in Figure 7. Results indicate that partial switching is superior to the other three models. This is significant since the partial network utilizes a switching scheme to supplement the original system without additional radios. The modified non-network model requires 58 additional radios to provide a slight performance gain in the jamming case at a mean service time of 2.5 minutes.

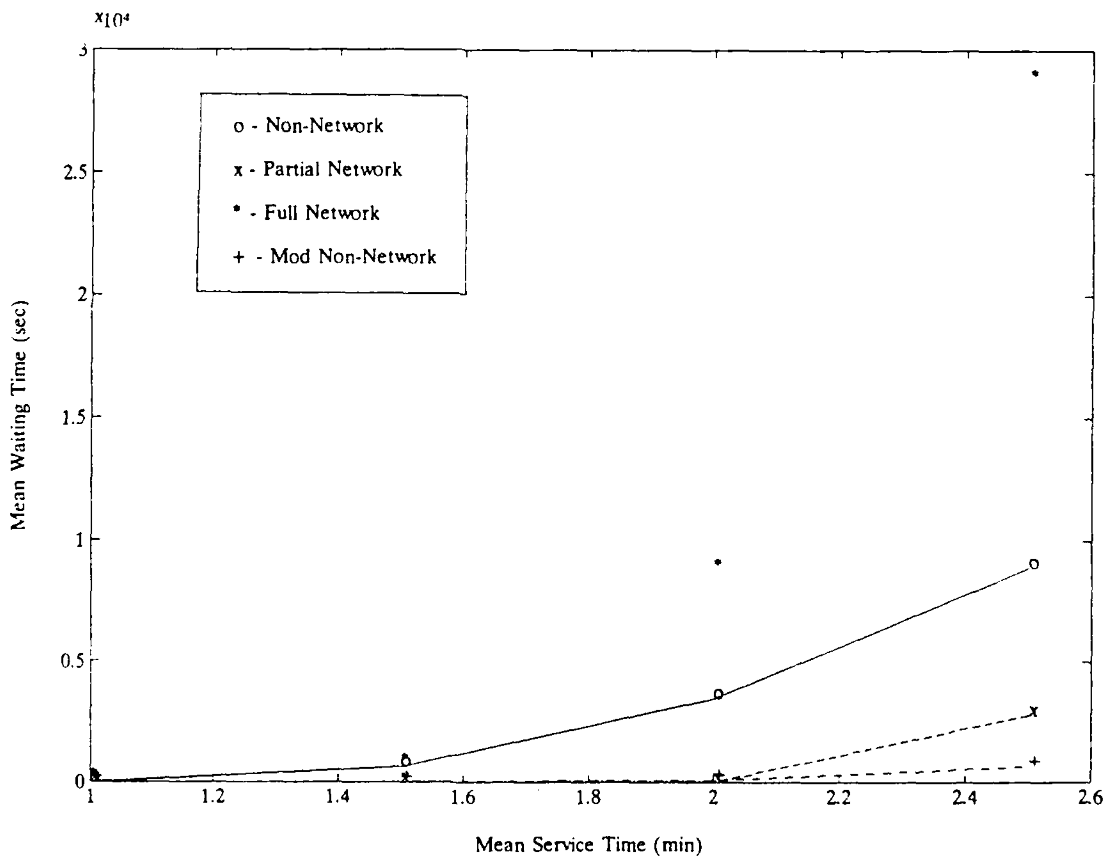

Figure 7. Results with Jamming

Average queue length for a mean serive time of 1.5 minutes are provided in Figures 8 and 9. Figures 10 and 11 provide circuit utilization for the same mean service time.

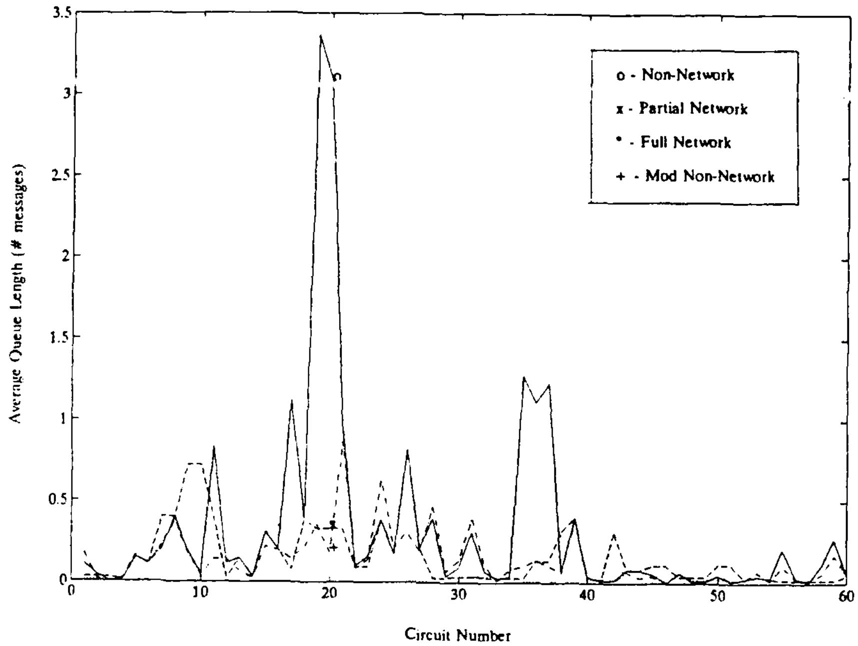

Figure 8. Average Queue Length Ideal Case

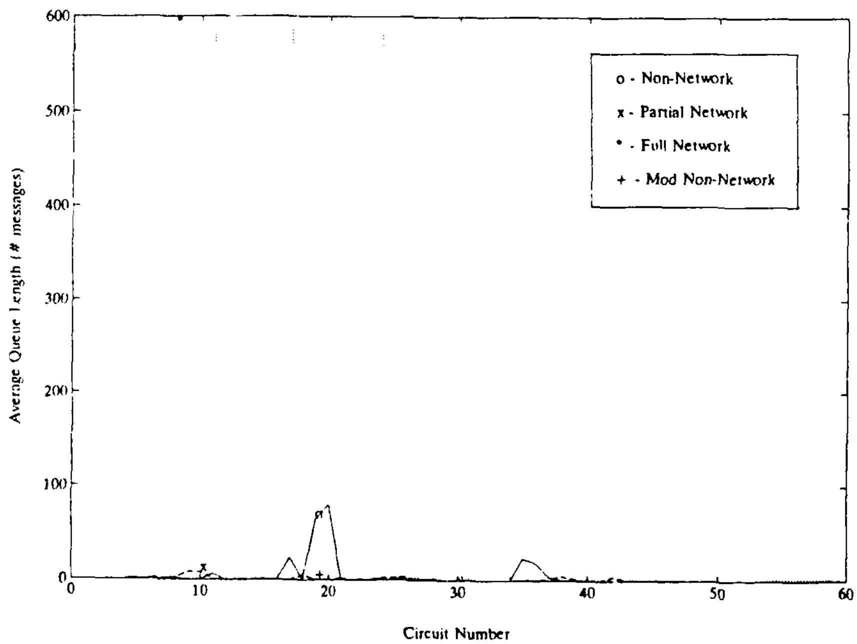

Figure 9. Average Queue Length with Jamming

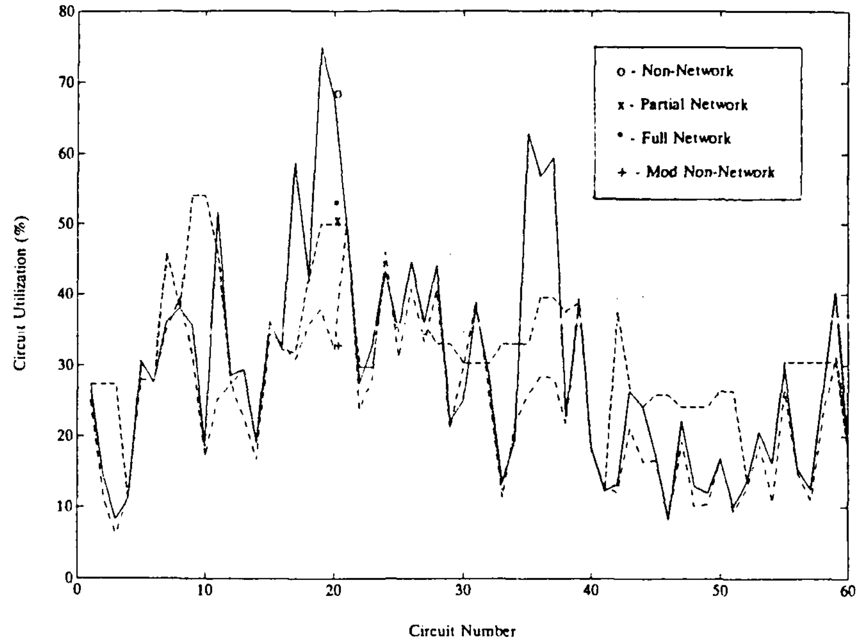

Figure 10. Circuit Utilization Ideal Case

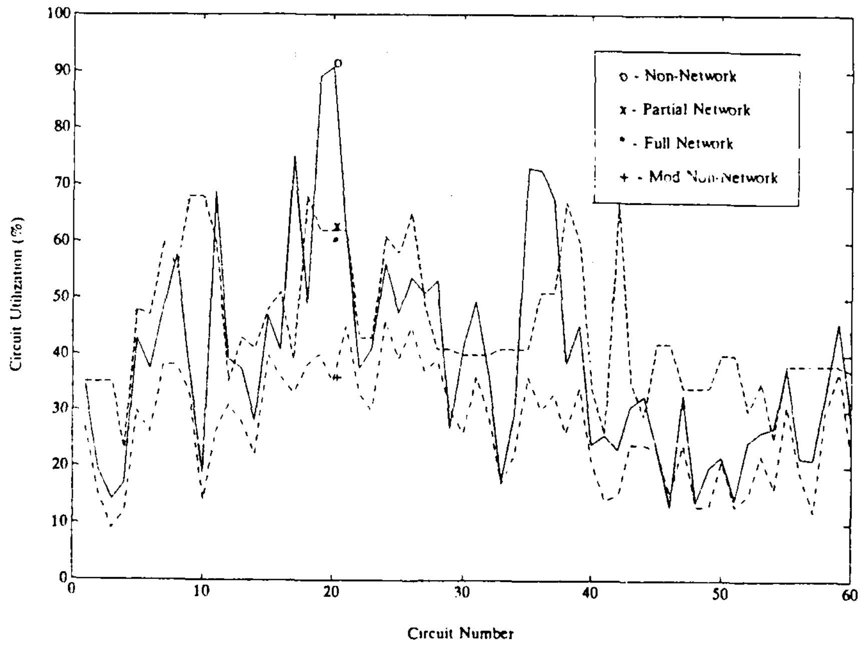

Figure 11. Circuit Utilization with Jamming

V. NETWORK IMPLEMENTATION

A. SYSTEM REQUIREMENTS

Implementation of a switching scheme in the radio system currently utilized by the Marine Corps requires a digital processor located at each unit's MDF and the ability to determine the status of each networked radio circuit. Status implies the information that the circuit is idle or busy and that the circuit is operational. It is very undesirable to have the processor switch an outgoing radio call to a disabled circuit.

Based on the simulation model, the processor is required to determine the originator of the radio call, access an available radio circuit and pass the originator information to the distant MDF processors so that the radio call can be switched to the appropriate remote ensuring radio circuit integrity, i.e., no two stations on the same radio net are allowed to transmit simultaneously on separate radio circuits. As in the current system, collision of two radio transmissions on the same circuit is possible due to the delay of up to 250 milliseconds between push to talk and reception of the signal [Ref. 6:p. 18]. In the case of a collision, the processor would maintain the connection so that the customers can resolve the conflict. The delay could also result in a simultaneous transmission at which time the processor would disconnect the circuits and let the customers retry. For radio circuits with stations that do not have a processor, the receiving MDF processor could be programmed accordingly and keyed from the lack of originator information being passed on that frequency.

A reliable voice radio circuit requires a probability of bit error of only 10^{-2}, i.e., one error in every 100 bits transmitted. VHF radios are capable of transmitting bit rates of 16,000 bits per second [Ref. 6:p. 20] and HF radios are capable of over 300 words per minute [Ref. 7:p. 6]. In order to verify that the circuit is usable for voice traffic would require an electronic radio check of 500 bits to the distant radios and an acknowledgement of acceptable error rates. This could be accomplished in less than 40 milliseconds vice the current radio checks which takes ten seconds when done properly.

B. SYSTEM INTEGRATION

Envision a Communication-Electronic Officer (CEO) workstation located at SYSCON and tied into the processor at the MDF. The workstation would provide the following:

- Status of each radio circuit and the ability to direct corrective action for all inoperative circuits without customer involvement. In most cases, the customer would still have access to an operative radio circuit.
- Statistical information on the availability and utilization of each radio circuit. This would enhance SYSCON's ability to reconfigure the system to support the current tactical situation.

- Enhance Communication Control.
- Generate required reports.

As previously mentioned, the processor can be integrated into the system at the MDF. The MEF, DIV, MAW and FSSG's MDF is the AN/TSQ-84 technical control facility. Size would be a serious design consideration since space is limited, but it is the preferred placement into the system. Subordinate units would require a ruggedized version to be implemented at their MDF's.

VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The thrust of this research is to identify those access or switching systems that will enhance the performance of the Marine Corps VHF and HF voice radio system without requiring modification to the existing radios and cryptographic equipment. A simplified model of the existing system is developed in order to compare its performance with proposed systems under varying message traffic loads and jamming. It is important to note that only 60 out of 145 radio nets were deemed networkable which correlates to the higher echelons of the radio system.

The modification of the existing system into a partial switching system provides a significant improvement in channel capacity. Communication control is enhanced with the additional benefits of tolerance to jamming and the elimination of manual radio checks. Compared to the model of the existing system, the partial network provides over a 47 percent reduction in the mean waiting time that a message is held in queue over all mean service times. This indicates a robust system which corresponds to an increase in the capacity of the system for the same number of radios. The implementation of the switching system can be accomplished at the unit's main distribution frame, thus minimizing modification to existing equipment and procedures.

B. RECOMMENDATIONS

It is the author's opinion that the results of the simulation model are significant and warrant future study in the following areas:

- Development of an electronic radio check system for voice radios to be utilized at a MDF and incorporated into individual radios.
- Development of a radio circuit exchange for main distribution frames.
- Development of a CEO workstation to take full advantage of a partial network.

For a modest investment, the proposed system can significantly improve our voice radio system. Based on the results of the simulation model, it is recommended that a prototype processor be designed and tested incorporating the proposals presented in this study.

APPENDIX A

COMPUTER PROGRAM

This program simulates the interaction between multiple customers on a radio circuit. [Ref 8] provides detailed instructions on the use of the programing language. [Ref 9] gives a detailed explanation of the code utilized.

```
preamble
        permanent entities
        every RADIO has a MEAN,a ORIGINATOR and owns a QUEUE
        temporary entities
        every MESSAGE has a PRECEDENCE,a DTG,a CHT,
                 and may belong to a QUEUE
        define QUEUE as a set ranked by high PRECEDENCE,
                 then by low DTG
        processes
        every PROCESSOR has a ORIGIN
        every GENERATOR has a MEAN.RADIO and a MSG.ORGIN
        resources include CIRCUIT
        define WAITING.TIME and RUN.TIME as real variables
        accumulate UTILIZATION as the average of N.X.CIRCUIT
        accumulate AVG.QUEUE.LENGTH as the average,
        STD.QUEUE.LENGTH as the std.dev of N.Q.CIRCUIT
        accumulate MEAN.WAITING.TIME as the mean,
        STD.WAITING.TIME as the std.dev of WAITING.TIME
        tally AVG.CHT as the average of CHT
end

main

        let N.RADIO = 348
        create every RADIO
        open 8 for input,file name is "d.in"
        use 8 for input
        for I = 1 to N.RADIO
        do
                let ORIGINATOR(I) = I
        loop
        for I = 1 to N.RADIO,read MEAN(I)
                create every CIRCUIT(60)
        for I = 1 to 60
        do
                let U.CIRCUIT(I)=1
        loop
        for each RADIO
                activate a GENERATOR given MEAN(RADIO),
                 ORIGINATOR(RADIO) now
        start simulation
        open 10 for output,file name is "f.out"
        use 10 for output
```

```
        print 11 lines with  MEAN.WAITING.TIME * 1440.0 * 60.0 ,
        STD.WAITING.TIME * 1440.0 * 60.0 and AVG.CHT thus

        Network Type

        Mean Service Time = 1.0 minutes

        MEAN.WAITING.TIME = ****.***   (SEC)

        STD.WAITING.TIME = ****.***   (SEC)

        AVERAGE CIRCUIT HOLDING TIME = ***.***   (MIN)

        print 5 lines thus

        AVG.QUEUE      STD.DEV.QUEUE        CIRCUIT
         LENGTH            LENGTH         UTILIZATION
         (MSG)             (MSG)              (%)

        for each CIRCUIT
        print 2 lines with AVG.QUEUE.LENGTH,
        STD.QUEUE.LENGTH, UTILIZATION * 100.0 / U.CIRCUIT thus

        ****.***       ****.****             ***.**
end

process GENERATOR

        define X as a real variable
        let RUN.TIME = 1.0
        until time.v >= RUN.TIME
        do
                let X = exponential.f(MEAN.RADIO,1)
                wait X minutes
                activate a PROCESSOR given MSG.ORGIN now
        loop
end

process PROCESSOR

        create a MESSAGE
        define RANDV as a real variable
        let DTG(MESSAGE) = time.v
        RANDV = uniform.f(0,1,1)
        if RANDV >= 0.0 and RANDV < 0.5
                let PRECEDENCE(MESSAGE) = 0
        always
        if RANDV >= 0.5 and RANDV < 0.8
                let PRECEDENCE(MESSAGE) = 1
        always
        if RANDV >= 0.8 and RANDV < 0.95
                let PRECEDENCE(MESSAGE) = 2
        always
        if RANDV >= 0.95
                let PRECEDENCE(MESSAGE) = 3
        always
```

```
let CHT(MESSAGE) = exponential.f(mean service time,1)
let CHT(MESSAGE) = abs.f(CHT(MESSAGE))
let RANDV = uniform.f(0.0,1.0,1)
if RANDV >= 0.0 and RANDV < 0.6
        CHT(MESSAGE)=CHT(MESSAGE)
always
if RANDV >= 0.6 and RANDV < 0.8
        add 0.25 to CHT(MESSAGE)
always
if RANDV >= 0.8 and RANDV < 0.9
        add 0.5 to CHT(MESSAGE)
always
if RANDV >= 0.9
        add 1.0 to CHT(MESSAGE)
always
if ORIGIN >= 1 and ORIGIN <= 4
        go to LABEL.1
always
if ORIGIN >= 5 and Origin <= 8
        go to LABEL.2
always
if ORIGIN >= 9 and Origin <= 12
        go to LABEL.3
always
if ORIGIN >= 13 and Origin <= 15
        go to LABEL.4
always
if ORIGIN >= 16 and Origin <= 21
        go to LABEL.5
always
if ORIGIN >= 22 and Origin <= 26
        go to LABEL.6
always
if ORIGIN >= 27 and Origin <= 30
        go to LABEL.7
always
if ORIGIN >= 31 and Origin <= 35
        go to LABEL.8
always
if ORIGIN >= 36 and Origin <= 38
        go to LABEL.9
always
if ORIGIN >= 39 and Origin <= 41
        go to LABEL.10
always
if ORIGIN >= 42 and Origin <= 45
        go to LABEL.11
always
if ORIGIN >= 46 and Origin <= 49
        go to LABEL.12
always
if ORIGIN >= 50 and Origin <= 56
        go to LABEL.13
always
```

```
if ORIGIN >= 57 and Origin <= 60
        go to LABEL.14
always
if ORIGIN >= 61 and Origin <= 66
        go to LABEL.15
always
if ORIGIN >= 67 and Origin <= 70
        go to LABEL.16
always
if ORIGIN >= 71 and Origin <= 78
        go to LABEL.17
always
if ORIGIN >= 79 and Origin <= 86
        go to LABEL.18
always
if ORIGIN >= 87 and Origin <= 96
        go to LABEL.19
always
if ORIGIN >= 97 and Origin <= 106
        go to LABEL.20
always
if ORIGIN >= 107 and Origin <= 116
        go to LABEL.21
always
if ORIGIN >= 117 and Origin <= 123
        go to LABEL.22
always
if ORIGIN >= 124 and Origin <= 130
        go to LABEL.23
always
if ORIGIN >= 131 and Origin <= 136
        go to LABEL.24
always
if ORIGIN >= 137 and Origin <= 141
        go to LABEL.25
always
if ORIGIN >= 142 and Origin <= 148
        go to LABEL.26
always
if ORIGIN >= 149 and Origin <= 154
        go to LABEL.27
always
if ORIGIN >= 155 and Origin <= 164
        go to LABEL.28
always
if ORIGIN >= 165 and Origin <= 174
        go to LABEL.29
always
if ORIGIN >= 175 and Origin <= 181
        go to LABEL.30
always
if ORIGIN >= 182 and Origin <= 187
        go to LABEL.31
always
```

```
if ORIGIN >= 188 and Origin <= 194
        go to LABEL.32
always
if ORIGIN >= 195 and Origin <= 204
        go to LABEL.33
always
if ORIGIN >= 205 and Origin <= 214
        go to LABEL.34
always
if ORIGIN >= 215 and Origin <= 224
        go to LABEL.35
always
if ORIGIN >= 225 and Origin <= 232
        go to LABEL.36
always
if ORIGIN >= 233 and Origin <= 240
        go to LABEL.37
always
if ORIGIN >= 241 and Origin <= 243
        go to LABEL.38
always
if ORIGIN >= 244 and Origin <= 249
        go to LABEL.39
always
if ORIGIN >= 250 and Origin <= 251
        go to LABEL.40
always
if ORIGIN >= 252 and Origin <= 254
        go to LABEL.41
always
if ORIGIN >= 255 and Origin <= 257
        go to LABEL.42
always
if ORIGIN >= 258 and Origin <= 262
        go to LABEL.43
always
if ORIGIN >= 263 and Origin <= 265
        go to LABEL.44
always
if ORIGIN >= 266 and Origin <= 269
        go to LABEL.45
always
if ORIGIN >= 270 and Origin <= 273
        go to LABEL.46
always
if ORIGIN >= 274 and Origin <= 278
        go to LABEL.47
always
if ORIGIN >= 279 and Origin <= 283
        go to LABEL.48
always
if ORIGIN >= 284 and Origin <= 288
        go to LABEL.49
always
```

```
if ORIGIN >= 289 and Origin <= 290
        go to LABEL.50
always
if ORIGIN >= 291 and Origin <= 292
        go to LABEL.51
always
if ORIGIN >= 293 and Origin <= 294
        go to LABEL.52
always
if ORIGIN >= 295 and Origin <= 297
        go to LABEL.53
always
if ORIGIN >= 298 and Origin <= 300
        go to LABEL.54
always
if ORIGIN >= 301 and Origin <= 309
        go to LABEL.55
always
if ORIGIN >= 310 and Origin <= 318
        go to LABEL.56
always
if ORIGIN >= 319 and Origin <= 327
        go to LABEL.57
always
if ORIGIN >= 328 and Origin <= 336
        go to LABEL.58
always
if ORIGIN >= 337 and Origin <= 345
        go to LABEL.59
always
if ORIGIN >= 346 and Origin <= 348
        go to LABEL.60
always
```

The specific customer using each radio circuit is anotated after the comment section (''). See glossary for associated terms.

```
'LABEL.1'       ''LF Command Net 1
        request 1 CIRCUIT(1) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        '' MEF G3
        '' DIV G3
        '' FSSG HQ
        '' MAW CC
        relinquish 1 CIRCUIT(1)
        go to STOP
```

```
'LABEL.2'        ''LF Command Net 2
        request 1 CIRCUIT(2) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G3
        ''DIV G3
        ''FSSG HQ
        ''MAW CC
        relinquish 1 CIRCUIT(2)
        go to STOP

'LABEL.3'        ''LF Alert/Broadcast Net
        request 1 CIRCUIT(3) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G3
        ''DIV G3
        ''FSSG HQ
        ''MAW CC
        relinquish 1 CIRCUIT(3)
        go to STOP

'LABEL.4'        ''LF Reconnaissance
        request 1 CIRCUIT(4) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G2
        ''DIV G2
        ''Force Recon
        relinquish 1 CIRCUIT(4)
        go to STOP

'LABEL.5'        ''LF Combat Service Support Net
        request 1 CIRCUIT(5) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G4
        ''DIV G4
        ''TACLOG
        ''TACC
        ''MWSG
        ''DASC
        relinquish 1 CIRCUIT(5)
        go to STOP

'LABEL.6'        ''LF Intelligence Net
        request 1 CIRCUIT(6) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G2
        ''DIV G2
        ''FSSG HQ
        ''MAW CC
        ''Force Recon
        relinquish 1 CIRCUIT(6)
        go to STOP
```

```
'LABEL.7'         ''LF Artillery Command/Fire Direction Net
        request 1 CIRCUIT(7) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF ARTY O
        ''DIV ARTY O
        ''ARTY FDC
        ''SACC
        relinquish 1 CIRCUIT(7)
        go to STOP

'LABEL.8'         ''LF NGF Support Net
        request 1 CIRCUIT(8) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF NGF O
        ''DIV NGF O
        ''GS Ship
        ''SACC
        ''ANGLICO
        relinquish 1 CIRCUIT(8)
        go to STOP

'LABEL.9'         ''LF Tactical Net 1
        request 1 CIRCUIT(9) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G3
        ''DIV G3
        ''MAW CC
        relinquish 1 CIRCUIT(9)
        go to STOP

'LABEL.10'        ''LF Tactical Net 2
        request 1 CIRCUIT(10) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G3
        ''DIV G3
        ''MAW CC
        relinquish 1 CIRCUIT(10)
        go to STOP

'LABEL.11'        ''LF Fire Support Coordination Net
        request 1 CIRCUIT(11) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF FSCC
        ''DIV FSCC
        ''SACC
        ''ARTY FDC
        relinquish 1 CIRCUIT(11)
        go to STOP
```

```
'LABEL.12'      ''LF Communication Coordination Net
        request 1 CIRCUIT(12) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF SYSCON
        ''DIV SYSCON
        ''FSSG SYSCON
        ''MAW SYSCON
        relinquish 1 CIRCUIT(12)
        go to STOP

'LABEL.13'      ''LF Damage Control Net
        request 1 CIRCUIT(13) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G3
        ''DIV G3
        ''MAW CC
        ''FSSG HQ
        ''MAG VF
        ''MAG VA
        ''MAG VH
        relinquish 1 CIRCUIT(13)
        go to STOP

'LABEL.14'      ''LF Medical Regulating Net
        request 1 CIRCUIT(14) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF C4
        ''FSSG HQ
        ''MED BN
        ''Hospital Ship
        relinquish 1 CIRCUIT(14)
        go to STOP

'LABEL.15'      ''LF Helicopter Support Team Control Net
        request 1 CIRCUIT(15) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MEF G4
        ''DIV G4
        ''TACLOG
        ''TACC
        ''DASC
        ''LSB BN
        relinquish 1 CIRCUIT(15)
        go to STOP
```

```
'LABEL.16'      '' LF NGF GROUND SPOT
        request 1 CIRCUIT(16) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''NGF SPOT TEAMS
        ''LF NGF O
        ''DS SHIP
        ''GS SHIP
        relinquish 1 CIRCUIT(16)
        go to STOP

'LABEL.17'      ''DIV NGF GROUND SPOT
        request 1 CIRCUIT(17) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        ''DIV MAIN FSCC
        ''NGF SPOT TEAM
        ''DS SHIP
        ''GS SHIP
        ''ANGLICO
        relinquish 1 CIRCUIT(17)
        go to STOP

'LABEL.18'      ''TACTICAL AIR REQUEST NET (MAW NET)
        request 1 CIRCUIT(18) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN FSCC
        ''DIV ALT FSCC
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        ''FAC
        ''DASC
        ''ANGLICO
        relinquish 1 CIRCUIT(18)
        go to STOP
```

```
'LABEL.19'      ''ARTILLERY REG FIRE DIRECTION NET
        request 1 CIRCUIT(19) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''ART REG FDC
        ''DIV MAIN FSCC
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        ''GS BN A
        ''GS BN B
        ''DS BN A
        ''DS BN B
        ''DS BN C
        relinquish 1 CIRCUIT(19)
        go to STOP

'LABEL.20'      ''ARTILLERY REG AIR SPOT NET
        request 1 CIRCUIT(20) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''ART REG FDC
        ''DIV MAIN FSCC
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        ''GS BN A
        ''GS BN B
        ''DS BN A
        ''DS BN B
        ''DS BN C
        relinquish 1 CIRCUIT(20)
        go to STOP

'LABEL.21'      ''ARTILLERY REG TACTICAL NET
        request 1 CIRCUIT(21) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''ART REG COC
        ''DIV MAIN FSCC
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        ''GS BN A
        ''GS BN B
        ''DS BN A
        ''DS BN B
        ''DS BN C
        relinquish 1 CIRCUIT(21)
        go to STOP
```

```
'LABEL.22'      ''ARTILLERY REG COMMAND NET
        request 1 CIRCUIT(22) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''ART REG COC
        ''DIV MAIN FSCC
        ''GS BN A
        ''GS BN B
        ''DS BN A
        ''DS BN B
        ''DS BN C
        relinquish 1 CIRCUIT(22)
        go to STOP

'LABEL.23'      ''ARTY REG METRO NET
        request 1 CIRCUIT(23) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''ART REG FDC
        ''DIV MAIN FSCC
        ''GS BN A
        ''GS BN B
        ''DS BN A
        ''DS BN B
        ''DS BN C
        relinquish 1 CIRCUIT(23)
        go to STOP

'LABEL.24'      ''DIV NGF SUPPORT NET
        request 1 CIRCUIT(24) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN FSCC
        ''GS SHIP
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        relinquish 1 CIRCUIT(24)
        go to STOP

'LABEL.25'      ''DIV FIRE SUPPORT COORDINATION NET
        request 1 CIRCUIT(25) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN FSCC
        ''ARTY REG FDC
        ''REG A FSCC
        ''REG B FSCC
        ''REG C FSCC
        relinquish 1 CIRCUIT(25)
        go to STOP
```

```
'LABEL.26'     ''DIV TACTICAL NET 1
        request 1 CIRCUIT(26) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''DIV COP
        ''TANK BN
        relinquish 1 CIRCUIT(26)
        go to STOP

'LABEL.27'     ''DIV TACTICAL NET 2
        request 1 CIRCUIT(27) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''AAV BN
        ''ENG BN
        ''RECON BN
        relinquish 1 CIRCUIT(27)
        go to STOP

'LABEL.28'     ''DIV COMMAND NET 1
        request 1 CIRCUIT(28) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''TANK BN
        ''AAV BN
        ''ENG BN
        ''RECON BN
        relinquish 1 CIRCUIT(28)
        go to STOP
```

```
'LABEL.29'      ''DIV COMMAND NET 2
        request 1 CIRCUIT(29) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''TANK BN
        ''AAV BN
        ''ENG BN
        ''RECON BN
        relinquish 1 CIRCUIT(29)
        go to STOP

'LABEL.30'      ''DIV RECONNAISSANCE NET
        request 1 CIRCUIT(30) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        relinquish 1 CIRCUIT(30)
        go to STOP

'LABEL.31'      ''DIV AIR OBSERVATION NET
        request 1 CIRCUIT(31) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        relinquish 1 CIRCUIT(31)
        go to STOP
```

```
'LABEL.32'      ''DIV INTELLIGENCE NET
        request 1 CIRCUIT(32) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        relinquish 1 CIRCUIT(32)
        go to STOP

'LABEL.33'      ''DIV ALERT/BROADCAST NET
        request 1 CIRCUIT(33) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        ''AAV BN
        ''TANK BN
        ''ENG BN
        relinquish 1 CIRCUIT(33)
        go to STOP

'LABEL.34'      ''DIV DAMAGE CONTROL NET
        request 1 CIRCUIT(34) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        ''AAV BN
        ''TANK BN
        ''ENG BN
        relinquish 1 CIRCUIT(34)
        go to STOP
```

```
'LABEL.35'      ''DIV COMMUNICATION COORDINATION NET
        request 1 CIRCUIT(35) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN COC
        ''DIV ALT COC
        ''ARTY REG COC
        ''REG A COC
        ''REG B COC
        ''REG C COC
        ''RECON BN
        ''AAV BN
        ''TANK BN
        ''ENG BN
        relinquish 1 CIRCUIT(35)
        go to STOP

'LABEL.36'      ''MAW TACTICAL AIR COMMAND NET
        request 1 CIRCUIT(36) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''MWSG
        ''MAG VF
        ''MAG VA
        ''MAG VH
        ''MACS
        ''AAOC
        ''DASC
        relinquish 1 CIRCUIT(36)
        go to STOP

'LABEL.37'      ''MAW TACTICAL ALERT NET
        request 1 CIRCUIT(37) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''MWSG
        ''MAG VF
        ''MAG VA
        ''MAG VH
        ''MACS
        ''AAOC
        ''DASC
        relinquish 1 CIRCUIT(37)
        go to STOP

'LABEL.38'      ''MAW A R OPERATION CONTROL NET
        request 1 CIRC  T(38) with priority PRECEDENCE(MESSAGE)
        let WAITING.TI   = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''AAOC
        ''EW
        relinquish 1 CIRCUIT(38)
        go to STOP
```

```
'LABEL.39'      ''MAW COMBAT INFORMATION/DETECTION NET
        request 1 CIRCUIT(39) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''BCC/PCP
        ''AAOC
        ''EW
        ''DASC
        ''MACS
        relinquish 1 CIRCUIT(39)
        go to STOP

'LABEL.40'      ''MAW HANDOVER/CROSS TELL NET
        request 1 CIRCUIT(40) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MACS
        ''EW
        relinquish 1 CIRCUIT(40)
        go to STOP

'LABEL.41'      ''MAW ANTIAIRCRAFT CONTROL NET
        request 1 CIRCUIT(41) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''BCC/PCP
        ''AAOC
        ''EW
        relinquish 1 CIRCUIT(41)
        go to STOP

'LABEL.42'      ''MAW COMMAND ACTION NET
        request 1 CIRCUIT(42) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''AAOC
        ''EW
        relinquish 1 CIRCUIT(42)
        go to STOP

'LABEL.43'      ''MAW ANTIAIRCRAFT INTELLIGENCE NET
        request 1 CIRCUIT(43) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''AAOC
        ''BCC/PCP
        ''MACS
        ''DASC
        relinquish 1 CIRCUIT(43)
        go to STOP
```

```
'LABEL.44'      ''MAW HELICOPTER REQUEST NET
        request 1 CIRCUIT(44) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''DIV MAIN FSCC
        ''DASC
        relinquish 1 CIRCUIT(44)
        go to STOP

'LABEL.45'      ''MAW GUARD NET
        request 1 CIRCUIT(45) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''AAOC
        ''DASC
        ''MACS
        relinquish 1 CIRCUIT(45)
        go to STOP

'LABEL.46'      ''MAW SEARCH AND RESCUE 2 NET
        request 1 CIRCUIT(46) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''TACC
        ''AAOC
        ''DASC
        ''MACS
        relinquish 1 CIRCUIT(46)
        go to STOP

'LABEL.47'      ''MAW COMMAND NET 1
        request 1 CIRCUIT(47) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MWSG
        ''WING CC
        ''MAG VF
        ''MAG VA
        ''MAG VH
        relinquish 1 CIRCUIT(47)
        go to STOP

'LABEL.48'      ''MAW COMMAND NET 2
        request 1 CIRCUIT(48) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MWSG
        ''WING CC
        ''MAG VF
        ''MAG VA
        ''MAG VH
        relinquish 1 CIRCUIT(48)
        go to STOP
```

```
'LABEL.49'      ''MAW AIRBASE SECURITY NET
        request 1 CIRCUIT(49) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MWSG
        ''WING CC
        ''MAG VF
        ''MAG VA
        ''MAG VH
        relinquish 1 CIRCUIT(49)
        go to STOP

'LABEL.50'      ''MAW TACTICAL AIR DIRECTION NET
        request 1 CIRCUIT(50) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DASC
        ''ASRT
        relinquish 1 CIRCUIT(50)
        go to STOP

'LABEL.51'      ''MAW ASRT CONTROL NET
        request 1 CIRCUIT(51) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DASC
        ''ASRT
        relinquish 1 CIRCUIT(51)
        go to STOP

'LABEL.52'      ''MAW FSS NET
        request 1 CIRCUIT(52) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DASC
        ''AAOC
        relinquish 1 CIRCUIT(52)
        go to STOP

'LABEL.53'      ''MAW TAOC/ASRT HANDOVER
        request 1 CIRCUIT(53) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MACS
        ''ASRT
        ''EW
        relinquish 1 CIRCUIT(53)
        go to STOP
```

```
'LABEL.54'      ''MAW GCI/GCA HANDOVER
        request 1 CIRCUIT(54) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''MACS
        ''TACC
        ''EW
        relinquish 1 CIRCUIT(54)
        go to STOP

'LABEL.55'      ''FSSG COMMAND NET 1
        request 1 CIRCUIT(55) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''FSSG HQ
        ''CSSA HQ
        ''LF SP HQ
        ''LSB BN
        ''ENG SPT BN
        ''MT BN
        ''MED BN
        ''SUPPY BN
        ''MAIN BN
        relinquish 1 CIRCUIT(55)
        go to STOP

'LABEL.56'      ''FSSG COMMAND NET 2
        request 1 CIRCUIT(56) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''FSSG HQ
        ''CSSA HQ
        ''LF SP HQ
        ''LSB BN
        ''ENG SPT BN
        ''MT BN
        ''MED BN
        ''SUPPY BN
        ''MAIN BN
        relinquish 1 CIRCUIT(56)
        go to STOP
```

```
'LABEL.57'      ''FSSG ALERT/BROADCAST NET
        request 1 CIRCUIT(57) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''FSSG HQ
        ''CSSA HQ
        ''LF SP HQ
        ''LSB BN
        ''ENG SPT BN
        ''MT BN
        ''MED BN
        ''SUPFY BN
        ''MAIN BN
        relinquish 1 CIRCUIT(57)
        go to STOP

'LABEL.58'      ''FSSG DAMAGE CONTROL NET
        request 1 CIRCUIT(58) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''FSSG HQ
        ''CSSA HQ
        ''LF SP HQ
        ''LSB BN
        ''ENG SPT BN
        ''MT BN
        ''MED BN
        ''SUPPY BN
        ''MAIN BN
        relinquish 1 CIRCUIT(58)
        go to STOP

'LABEL.59'      ''FSSG COMMUNICATION COORDINATION NET
        request 1 CIRCUIT(59) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''FSSG HQ
        ''CSSA HQ
        ''LF SP HQ
        ''LSB BN
        ''ENG SPT BN
        ''MT BN
        ''MED BN
        ''SUPPY BN
        ''MAIN BN
        relinquish 1 CIRCUIT(56)
        go to STOP
```

```
'LABEL.60'       ''DIV RADAR BEACON NET
        request 1 CIRCUIT(60) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        ''DIV MAIN FSCC
        ''BEACON TEAM
        ''ANGLICO
        relinquish 1 CIRCUIT(60)
        go to STOP

'STOP'

end
```

This section provides the modifications that were incorporated into the original program for the Partial Network. The circuits that are using multiple access are anotated by ('').

Main Modification

```
        create every CIRCUUIT(36)
        let U.CIRCUIT(1)=4
                ''LF Command Net 1
                ''LF Command Net 2
                ''LF Alert/Broadcast Net
                ''LF Communication Coordination Net
        let U.CIRCUIT(2)=1
                ''LF Reconnaissance
        let U.CIRCUIT(3)=1
                ''LF Combat Service Support Net
        let U.CIRCUIT(4)=1
                ''LF Intelligence Net
        let U.CIRCUIT(5)=2
                ''LF Artillery Command/Fire Direction Net
                ''LF Fire Support Coordination Net
        let U.CIRCUIT(6)=1
                ''LF NGF Support Net
        let U.CIRCUIT(7)=2
                ''LF Tactical Net 1
                ''LF Tactical Net 2
        let U.CIRCUIT(8)=1
                ''LF Damage Control Net
        let U.CIRCUIT(9)=1
                ''LF Medical Regulating Net
        let U.CIRCUIT(10)=1
                ''LF Helicopter Support Team Control Net
        let U.CIRCUIT(11)=1
                '' LF NGF GROUND SPOT
        let U.CIRCUIT(12)=1
                ''DIV NGF GROUND SPOT
        let U.CIRCUIT(13)=1
                ''TACTICAL AIR REQUEST NET (MAW NET)
```

```
let U.CIRCUIT(14)=3
        ''ARTILLERY REG FIRE DIRECTION NET
        ''ARTILLERY REG AIR SPOT NET
        ''ARTILLERY REG TACTICAL NET
let U.CIRCUIT(15)=2
        ''ARTILLERY REG COMMAND NET
        ''ARTY REG METRO NET
let U.CIRCUIT(16)=1
        ''DIV NGF SUPPORT NET
let U.CIRCUIT(17)=1
        ''DIV FIRE SUPPORT COORDINATION NET
let U.CIRCUIT(18)=1
        ''DIV TACTICAL NET 1
let U.CIRCUIT(19)=1
        ''DIV TACTICAL NET 2
let U.CIRCUIT(20)=5
        ''DIV COMMAND NET 1
        ''DIV COMMAND NET 2
        ''DIV ALERT/BROADCAST NET
        ''DIV DAMAGE CONTROL NET
        ''DIV COMMUNICATION COORDINATION NET
let U.CIRCUIT(21)=3
        ''DIV RECONNAISSANCE NET
        ''DIV AIR OBSERVATION NET
        ''DIV INTELLIGENCE NET
let U.CIRCUIT(22)=2
        ''MAW TACTICAL AIR COMMAND NET
        ''MAW TACTICAL ALERT NET
let U.CIRCUIT(23)=2
        ''MAW AIR OPERATION CONTROL NET
        ''MAW COMMAND ACTION NET
let U.CIRCUIT(24)=1
                ''MAW COMBAT INFORMATION/DETECTION NET
let U.CIRCUIT(25)=1
        ''MAW HANDOVER/CROSS TELL NET
let U.CIRCUIT(26)=1
        ''MAW ANTIAIRCRAFT CONTROL NET
let U.CIRCUIT(27)=1
        ''MAW ANTIAIRCRAFT INTELLIGENCE NET
let U.CIRCUIT(28)=1
        ''MAW HELICOPTER REQUEST NET
let U.CIRCUIT(29)=2
        ''MAW GUARD NET
        ''MAW SEARCH AND RESCUE 2 NET
let U.CIRCUIT(30)=3
        ''MAW COMMAND NET 1
        ''MAW COMMAND NET 2
        ''MAW AIRBASE SECURITY NET
let U.CIRCUIT(31)=2
        ''MAW TACTICAL AIR DIRECTION NET
        ''MAW ASRT CONTROL NET
let U.CIRCUIT(32)=1
        ''MAW FSS NET
let U.CIRCUIT(33)=1
        ''MAW TAOC/ASRT HANDOVER
```

```
let U.CIRCUIT(34)=1
        ''MAW GCI/GCA HANDOVER
let U.CIRCUIT(35)=5
        ''FSSG COMMAND NET 1
        ''FSSG COMMAND NET 2
        ''FSSG ALERT/BROADCAST NET
        ''FSSG DAMAGE CONTROL NET
        ''FSSG COMMUNICATION COORDINATION NET
let U.CIRCUIT(36)=1
        ''DIV RADAR BEACON NET

process PROCESSOR Modification

if ORIGIN >= 1 and ORIGIN <= 12 or
   ORIGIN >= 46 and ORIGIN <= 49
        go to LABEL.1
always
if ORIGIN >= 13 and Origin <= 15
        go to LABEL.2
always
if ORIGIN >= 16 and Origin <= 21
        go to LABEL.3
always
if ORIGIN >= 22 and Origin <= 26
        go to LABEL.4
always
if ORIGIN >= 27 and Origin <= 30 or
   ORIGIN >= 42 and Origin <= 45
        go to LABEL.5
        always
if ORIGIN >= 31 and Origin <= 35
        go to LABEL.6
always
if ORIGIN >= 36 and Origin <= 41
        go to LABEL.7
always
if ORIGIN >= 50 and Origin <= 56
        go to LABEL.8
always
if ORIGIN >= 57 and Origin <= 60
        go to LABEL.9
always
if ORIGIN >= 61 and Origin <= 66
        go to LABEL.10
always

if ORIGIN >= 67 and Origin <= 70
        go to LABEL.11
always
if ORIGIN >= 71 and Origin <= 78
        go to LABEL.12
always
if ORIGIN >= 79 and Origin <= 86
        go to LABEL.13
always
```

```
if ORIGIN >= 87 and Origin <= 116
        go to LABEL.14
always
if ORIGIN >= 117 and Origin <= 130
        go to LABEL.15
always
if ORIGIN >= 131 and Origin <= 136
        go to LABEL.16
always
if ORIGIN >= 137 and Origin <= 141
        go to LABEL.17
always
if ORIGIN >= 142 and Origin <= 148
        go to LABEL.18
always
if ORIGIN >= 149 and Origin <= 154
        go to LABEL.19
always
if ORIGIN >= 155 and Origin <= 174 or
   ORIGIN >= 195 and Origin <= 224
        go to LABEL.20
always
if ORIGIN >= 175 and Origin <= 194
        go to LABEL.21
always
if ORIGIN >= 225 and Origin <= 240
        go to LABEL.22
always
if ORIGIN >= 241 and Origin <= 243 or
   ORIGIN >= 255 and Origin <= 257
        go to LABEL.23
always
if ORIGIN >= 244 and Origin <= 249
        go to LABEL.24
always
if ORIGIN >= 250 and Origin <= 251
        go to LABEL.25
always
if ORIGIN >= 252 and Origin <= 254
        go to LABEL.26
always
if ORIGIN >= 258 and Origin <= 262
        go to LABEL.27
always
if ORIGIN >= 263 and Origin <= 265
        go to LABEL.28
always
if ORIGIN >= 267 and Origin <= 273
        go to LABEL.29
always
if ORIGIN >= 274 and Origin <= 288
        go to LABEL.30
always
if ORIGIN >= 289 and Origin <= 292
        go to LABEL.31
always
```

```
        if ORIGIN >= 293 and Origin <= 294
                go to LABEL.32
        always
        if ORIGIN >= 295 and Origin <= 297
                go to LABEL.33
        always
        if ORIGIN >= 298 and Origin <= 300
                go to LABEL.34
        always
        if ORIGIN >= 301 and Origin <= 345
                go to LABEL.35
        always
        if ORIGIN >= 346 and Origin <= 348
                go to LABEL.36
        always


'LABEL.1'
        request 1 CIRCUIT(1) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(1)
        go to STOP

'LABEL.2'
        request 1 CIRCUIT(2) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(2)
        go to STOP

'LABEL.3'
        request 1 CIRCUIT(3) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(3)
        go to STOP

'LABEL.4'
        request 1 CIRCUIT(4) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(4)
        go to STOP

'LABEL.5'
        request 1 CIRCUIT(5) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(5)
        go to STOP
```

```
'LABEL.6'
        request 1 CIRCUIT(6) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(6)
        go to STOP

'LABEL.7'
        request 1 CIRCUIT(7) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(7)
        go to STOP

'LABEL.8'
        request 1 CIRCUIT(8) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(8)
        go to STOP

'LABEL.9'
        request 1 CIRCUIT(9) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(9)
        go to STOP

'LABEL.10'
        request 1 CIRCUIT(10) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(10)
        go to STOP

'LABEL.11'
        request 1 CIRCUIT(11) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(11)
        go to STOP

'LABEL.12'
        request 1 CIRCUIT(12) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(12)
        go to STOP

'LABEL.13'
        request 1 CIRCUIT(13) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(13)
        go to STOP
```

```
'LABEL.14'
        request 1 CIRCUIT(14) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(14)
        go to STOP

'LABEL.15'
        request 1 CIRCUIT(15) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(15)
        go to STOP

'LABEL.16'
        request 1 CIRCUIT(16) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(16)
        go to STOP

'LABEL.17'
        request 1 CIRCUIT(17) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(17)
        go to STOP

'LABEL.18'
        request 1 CIRCUIT(18) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(18)
        go to STOP

'LABEL.19'
        request 1 CIRCUIT(19) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(19)
        go to STOP

'LABEL.20'
        request 1 CIRCUIT(20) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(20)
        go to STOP

'LABEL.21'
        request 1 CIRCUIT(21) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(21)
        go to STOP
```

```
'LABEL.22'
        request 1 CIRCUIT(22) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(22)
        go to STOP

'LABEL.23'
        request 1 CIRCUIT(23) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(23)
        go to STOP

'LABEL.24'
        request 1 CIRCUIT(24) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(24)
        go to STOP

'LABEL.25'
        request 1 CIRCUIT(25) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(25)
        go to STOP

'LABEL.26'
        request 1 CIRCUIT(26) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(26)
        go to STOP

'LABEL.27'
        request 1 CIRCUIT(27) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(27)
        go to STOP

'LABEL.28'
        request 1 CIRCUIT(28) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(28)
        go to STOP

'LABEL.29'
        request 1 CIRCUIT(29) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(29)
        go to STOP
```

```
'LABEL.30'
        request 1 CIRCUIT(30) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(30)
        go to STOP

'LABEL.31'
        request 1 CIRCUIT(31) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(31)
        go to STOP

'LABEL.32'
        request 1 CIRCUIT(32) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(32)
        go to STOP

'LABEL.33'
        request 1 CIRCUIT(33) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(33)
        go to STOP

'LABEL.34'
        request 1 CIRCUIT(34) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(34)
        go to STOP

'LABEL.35'
        request 1 CIRCUIT(35) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(35)
        go to STOP

'LABEL.36'
        request 1 CIRCUIT(36) with priority PRECEDENCE(MESSAGE)
        let WAITING.TIME = time.v - DTG(MESSAGE)
        work CHT(MESSAGE) minutes
        relinquish 1 CIRCUIT(36)
        go to STOP
```

APPENDIX B

JAMMING CODE

This code was utilized to modify each model to simulate the effects of heavy jamming.

Add the following line to the preamble after 'processes' on line eight:

```
processes include JAMMER
```

Add the following line to the main after line 14 and above the line 'for each radio' :

```
for I = 1 to 6, activate a JAMMER now
```

Add the following section to the program. It's location can be anywhere after main, but for presenting a logical order this section was placed after 'process GENERATOR' and before 'process PROCESSOR' :

```
process JAMMER

        define Y as an integer variable
        until time.v >= 1.0
        do
                let Y = randi.f(1,60,1)
                request 1 CIRCUIT(Y) with priority 4
                work 20.0 minutes
                relinquish 1 CIRCUIT(Y)
                wait 10.0 minutes
        loop
end
```

APPENDIX C

INPUT DATA FILE

This file corresponds to the mean interarrival times (in minutes) that the individual customers generate message traffic for their assigned circuit. Reading left to right, the first number is the mean interarrival time for the MEF G3 on the LF Command Net 1 where as the first 40.0 on the second line corresponds to the DIV G3 on the LF Command Net 2 as specified in appendix A on page 7.

20.0	20.0	30.0	20.0	40.0
40.0	60.0	40.0	60.0	120.0
120.0	120.0	30.0	30.0	60.0
40.0	30.0	15.0	30.0	30.0
30.0	20.0	20.0	30.0	20.0
60.0	15.0	15.0	15.0	15.0
15.0	15.0	30.0	15.0	15.0
10.0	15.0	15.0	20.0	30.0
30.0	10.0	10.0	10.0	10.0
15.0	20.0	20.0	20.0	30.0
30.0	30.0	30.0	50.0	50.0
50.0	30.0	30.0	30.0	30.0
60.0	20.0	20.0	20.0	20.0
20.0	15.0	20.0	15.0	15.0
20.0	20.0	20.0	20.0	15.0
15.0	15.0	20.0	20.0	40.0
30.0	30.0	30.0	30.0	20.0
30.0	15.0	30.0	30.0	30.0
30.0	15.0	15.0	15.0	15.0
15.0	15.0	30.0	30.0	30.0
30.0	15.0	15.0	15.0	15.0
15.0	20.0	60.0	60.0	60.0
60.0	20.0	20.0	20.0	20.0
20.0	30.0	60.0	30.0	30.0
30.0	30.0	30.0	30.0	60.0
30.0	30.0	30.0	30.0	30.0
15.0	15.0	20.0	20.0	20.0
20.0	15.0	15.0	20.0	20.0
20.0	15.0	30.0	20.0	20.0
20.0	60.0	20.0	15.0	30.0
20.0	20.0	30.0	30.0	20.0
30.0	30.0	30.0	30.0	30.0
40.0	40.0	40.0	60.0	40.0
60.0	60.0	60.0	60.0	60.0
80.0	80.0	80.0	120.0	20.0
40.0	40.0	40.0	40.0	40.0

60.0	20.0	20.0	20.0	20.0
20.0	40.0	20.0	40.0	30.0
40.0	40.0	40.0	40.0	60.0
120.0	120.0	120.0	120.0	120.0
180.0	180.0	180.0	180.0	30.0
60.0	60.0	60.0	60.0	60.0
90.0	90.0	90.0	90.0	15.0
20.0	20.0	20.0	20.0	20.0
30.0	30.0	30.0	30.0	15.0
20.0	20.0	20.0	20.0	20.0
20.0	15.0	15.0	20.0	20.0
20.0	20.0	20.0	20.0	15.0
15.0	20.0	15.0	20.0	30.0
20.0	20.0	20.0	30.0	15.0
15.0	30.0	30.0	30.0	30.0
30.0	30.0	30.0	30.0	30.0
30.0	30.0	20.0	20.0	20.0
30.0	30.0	30.0	30.0	60.0
60.0	60.0	60.0	30.0	30.0
30.0	30.0	30.0	60.0	60.0
60.0	60.0	60.0	60.0	60.0
60.0	60.0	60.0	15.0	15.0
30.0	30.0	20.0	20.0	20.0
20.0	20.0	30.0	30.0	30.0
30.0	30.0	30.0	30.0	60.0
60.0	60.0	60.0	60.0	60.0
60.0	60.0	60.0	120.0	120.0
120.0	120.0	120.0	60.0	120.0
120.0	120.0	120.0	120.0	120.0
120.0	120.0	30.0	60.0	60.0
60.0	60.0	60.0	60.0	60.0
60.0	20.0	40.0	40.0	40.0
40.0	40.0	40.0	40.0	40.0
20.0	20.0	20.0		

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