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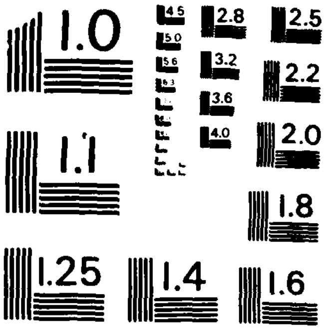

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MILSTAR MODELING SURVEY

FINAL REPORT
26 June 1986

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Arlington, VA 22204

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CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

MILSTAR MODELING SURVEY

FINAL REPORT

26 June 1986

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Executive Summary

Introduction to Task

This task was intended to aid the MILSATCOM Satellite Office (MSO) in its efforts to acquire a capability for computer modeling of the MILSTAR system. The modeling needs of the MSO were examined first, and a survey of existing MILSTAR models was then conducted. Finally, estimates were made on the level-of-effort necessary to develop a new, general-purpose MILSTAR model appropriate for the MSO.

MILSTAR Modeling Needs of the MSO

The MSO is interested primarily in modeling the overall MILSTAR system and in the performance it provides to its end-users in a dynamic environment. An appropriate computer model would, therefore, perform a variety of throughput and response time analyses as functions of system loading and stress. Any model selected should be easily expandable to include new networks, users, and terminal types. Innovative network control techniques [for example, demand assign multiple access (DAMA)] are likely to become increasingly important in MILSTAR and should be modeled. Finally, any model selected should be able to simulate the entire system in different levels of stress (for example, scintillation, jamming, and resource attrition).

A suitable computer model for the MSO would be menu-driven with a large data base of system data; this would allow users with widely varying technical expertise to use the model productively. A well-suited model will be primarily a time simulation of actual message traffic; however, liberal use should be made throughout the program of analytical and statistical approximations to prevent excessive run times for the model. It is assumed that the model would be run on a minicomputer (for example, a VAX 11/780, Data General MV8000, or AT&T 3B20).

Survey of Existing MILSTAR Models

Nine computer-based models of MILSTAR were examined. In this report they have been divided into three categojfkiiqojm
network control. Resource assignment models are concerned primarily with the allocation of physical resources and are primarily system planning tools. These static resource

assignment models provide useful information, but do not demonstrate MILSTAR system performance in a dynamic, operational environment. Resource control models emulate the real-time dynamic allocation of resources on board the spacecraft (for example, antennas, demodulators, and hops). These models perform varying degrees of terminal and spacecraft emulation. The larger, more complex models use extensive time-domain simulation to emulate exactly the actions of the satellite, whereas simpler models make greater use of analytical approximations to model system functions. The network control models are reasonably generic channel simulation models but emulate only a limited portion of the MILSTAR system. The models examined and their approximate capabilities are shown in Figure 1.

Each of the models shown in Figure 1 were designed to study particular aspects of the MILSTAR system; however, no single model suits the MSO's need to assess end-to-end performance in a dynamic traffic and operational environment.

Conclusions and Recommendations

The MSO can acquire an appropriate MILSTAR model by either adding to an existing model or by developing an entirely new model. The current models by Computer Science Corporation (CSC) and Aerospace Corporation are the most likely candidates to be altered to suit the MSO's needs. However, either of these programs would require considerable effort to redesign. A more productive and efficient course of action would be to develop a completely new model.

Figure 2 shows the basic components of a general purpose MILSTAR modeling program. Estimates have been made on the level-of-effort necessary to develop such a program and are shown in Table 1. Approximately 14 staff years would be required to generate such a model. However, a scheme is presented in Figure 3 that allows the complete model to be developed in stages. There are two distinct advantages to a staged development process: first, the cost of the model could be amortized over 2-3 years, and second, a functional model with limited capabilities could be made available after only 3-4 staff years of effort. Successive stages would enhance the modeling capabilities of the earlier stages.

It is clear that a complete, general purpose model could only be procured at a significant cost; however, this cost would still be small compared to the potential performance improvements that could be developed for the much costlier MILSTAR system. Furthermore, it is recognized that a definite need exists in the Defense Department community to model the full MILSTAR system. It is, therefore, highly recommended that the MSO pursue the development of such a model.

MODEL / TYPE OF ANALYSIS	SYSTEM TOPOLOGY		RESOURCE CONTROL MODELS			NETWORK CONTROL MODELS		
	KAMAN	LINCOM	CONTEL	AEROSPACE	MOM CMP	JTPO TRAFFIC LOAD	NOSC	LINKABIT
TERMINAL CONNECTIVITY	✓		✓					
SATELLITE RESOURCE ASSIGNMENT		✓						
SATELLITE RESOURCE CONTROLLER LOADING			✓	✓	✓			✓
NETWORK CONTROL USING C2/C3			✓	✓	✓	✓	✓	✓
NETWORK CONTROL USING C0 AND/OR C1						✓	✓	
NETWORK PERFORMANCE WITH DAMA USING C2/C3 CONTROL			✓	✓	✓	✓	✓	✓
NETWORK PERFORMANCE WITH DAMA USING C0 AND/OR C1 CONTROL						✓	✓	
COMPLETE C0, C1, C2, C3 COMMUNICATIONS ANALYSIS								

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Figure 1. Summary of Existing MILSTAR Computer Models

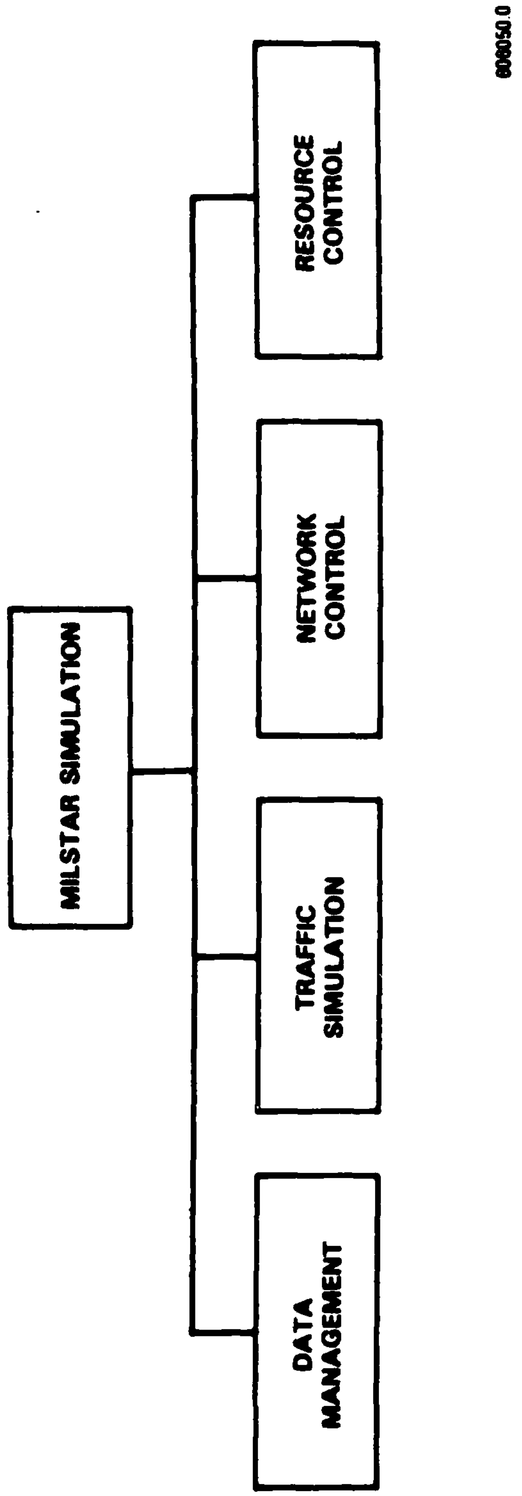

Figure 2. General Structure of MILSTAR Modeling Program

Component	Subsystems	Lines of code	Staff years
General model design and analysis			2
Data management		5000	2
	ground segment		
	space segment		
	comm. channels		
	terminal database		
	user req. database		
	satellite database		
Traffic Simulation			
	C0 messages	1000	.4
	jamming	2500	1
	normal loading	2500	1
	scintillation	2500	1
Network Control			
	C1 messages	1000	.4
	channelization	1200	.5
	throughput/response	2500	1
	loading	2500	1
	protocols	5000	2
Resource Control			
	C2/C3	1000	.4
	resource allocation	1000	.5
	resource attrition	2500	1
		30,200	14.2

Table 1. *Size and Cost Estimates for General Purpose MILSTAR Model*

Build 1	Data management: terminals, user requirements, some networks, geosynchronous satellites; resource control: basic antenna and demodulator assignments.
Build 2	Data management: complete network information, full constellation; resource control: C2/C3 messages; traffic simulation: simple C0 messages, loading model.
Build 3	Network control: complete channelization, throughput and response time analysis, in-band DAMA protocols; complete resource control.
Build 4	Stress: scintillation, jamming, resource attrition; out-of-band DAMA control; further spacecraft modeling: ephemeris data, yaw, pitch, roll.

Figure 3. Possible Program Builds for MILSTAR Modeling Program

1. Introduction

This task was intended to examine the specific MILSTAR computer modeling needs of the MSO and to determine the current availability of computer-based models satisfying these needs. The task was undertaken in two distinct phases: (1) an examination of the MILSTAR computer modeling needs of the MSO, and (2) a survey of the existing MILSTAR computer models. The requirements of a sufficient computer model were determined primarily by the technical needs of the MSO; however, user friendliness was also a necessary feature. The majority of the information available on the specific models was provided by the individual contractors. The final objective of this task was to determine what type of computer model would best suit the needs of the MSO and to recommend either acquiring an existing model or developing a new model.

The remainder of this chapter is an overview of MILSTAR with emphasis on the communications and control portions of the system. Chapter 2 provides a summary of the MILSTAR models surveyed and the criteria used for comparing the models. Chapter 3 presents conclusions on which models are most closely suited to the MSO's needs. The complexities and costs of developing a completely new modeling program are also examined in this chapter. Finally, recommendations are made on an appropriate manner for the MSO to procure a satisfactory model.

1.1 Overview of MILSTAR System

MILSTAR is a large, multi-mission satellite system which is still in development. A comprehensive computer simulation of the entire system is not currently available. Furthermore, the required size and complexity of a full-up simulation of the complete system may limit the usefulness of the model to most users requiring a MILSTAR modeling capability. This implies that an effective computer program will efficiently model only those portions of the MILSTAR system that are of interest to the model's users. It is, therefore, necessary to define the exact needs of a computer model's users. The following is a summary of the MILSTAR system features which should be included in a general-purpose communications computer model of the system.

1.1.1 System Topology

The physical topology of the MILSTAR system may be divided into a space segment and a terminal segment.

1.1.1.1 Space Segment Topology

The space segment is composed of both inclined and equitorial geosynchronous satellites. The orbits of the individual satellites may be assumed to be fixed. Therefore, a sufficient communications model will allow for the entire MILSTAR constellation, but would not be required to analyze system performance with different satellite orbits. A thorough model would, however, allow for the loss of satellites and the possibility of a fragmented constellation.

1.1.1.2 Terminal Segment Topology

MILSTAR is intended to provide global coverage to a wide variety of users and terminal types. The number of users and terminal types are certain to increase during the system's lifetime. It is of paramount importance that a communications model be sufficiently flexible to allow for virtually any combination of users, networks, and terminals. The ability to analyze the loss of important portions of the terminal segment (for example, Constellation Control Stations) should also be available.

1.1.2 Spacecraft Dynamics

The dynamics and control of each satellite are only of indirect concern to the end user of the system. It is assumed that the spacecraft design is fixed, and alternate designs, therefore, need not be modeled. A model requiring extreme fidelity to the actual system could be required to model the effects of imperfect spacecraft control such as yaw, pitch, roll, and drift. However, it is believed that an adequate communications model could be designed without detailed modeling of these effects.

1.1.3 Communications Payload

A prime decision to be made in specifying the requirements of a communication model is the fidelity of payload emulation to be performed by the model. The actions of the resource controller must be modeled in order to analyze the allocation of spacecraft resources such as demodulators, antenna beams, downlink hops, and crosslinks. The contention and associated delays encountered in requesting these resources need to be modeled as a function of system loading. A very precise modeling of these processes would improve the reliability of the overall model; however, the added complexity and increased computational requirements concomitant with modeling these features may offset their usefulness. A more computationally efficient model would use statistical approximations to model most of the queues, buffers, and other delays in the satellite.

1.1.4 Communication System Control

Two levels of communications control are possible in the MILSTAR system: resource control and network control.

1.1.4.1 Resource Control

The resource controller on board the satellite dynamically allocates the satellite resources to the various networks using the satellite. Terminals request either initial access to the satellite resources or reconfiguration of previously allocated resources by sending C2 messages to the satellite. The resource controller responds (either confirming or denying the request) by transmitting a C3 message on the downlink. A network cannot be established without proper resource allocation being performed initially.

1.1.4.2 Network Control

This secondary level of control can be performed only after the resource controller has allocated the proper system resources to the network. Network control is considered herein as a means of arbitrating the shared use of channel resources that have previously been allocated by the resource controller. Network control can, therefore, be performed by user ground control independently of the satellite resource control if the network has been allocated sufficient resources. This control would include a method (for example, DAMA) of assigning the C0 and C1 slots assigned to the network. A small part of the network's overall channel allocations would be needed as overhead communication for the network control algorithm. This low volume, orderwire-type communication could be conducted by user ground terminals in a portion of the C1 slots or possibly as transparent messages (that is, messages that are not interpreted by the resource controller but are passed on to the downlink) in the C2/C3 slots.

It is also possible to perform network control via satellite resource control. This single-level control is possible by using the satellite resource controller to assign satellite resources on a per-user basis rather than on a more flexible per-network basis. During periods when individual networks with certain users need to operate, each user within the network can be assigned his own subset of the network resources. In this manner network control is achieved by allocating the satellite resources to only one user at a time per-network.

1.1.4.3 Control Modeling Needs

Since resource control arbitrates the shared use of the satellite by various networks and users, the resource controller must be modeled to analyze overall system loading. The resource control model would likely remain constant for all analyses because it would model the actions of an invariant component on the spacecraft.

An effective MILSTAR communications model would accommodate easily a wide range of network control techniques. During its lifetime the size and number of MILSTAR user networks are likely to grow significantly; however, the available resource control on board the spacecraft will remain essentially constant. Innovative network control will, therefore, play a major role in expanding the capacity of the system. Any communications model selected must be able to analyze the performance of individual networks and the entire system as different network control techniques are investigated.

1.2 Performance Under Stress

Since MILSTAR is intended to provide critical communications throughout any level of military conflict, it is necessary to analyze system performance under different levels of stress. This would include the effects of jamming, scintillation, and physical attacks on the satellite.

1.3 Summary of Modeling Needs of MSO

The MSO is concerned primarily with the overall performance of the MILSTAR system to its end-user community. This type of model would entail analysis of system parameters such as throughput and response time as a function of loading and stress on the system. The MSO is also interested in ensuring the effectiveness of the MILSTAR system in the future. Any computer model chosen should, therefore, be easily expanded to analyze new networks, network control techniques, and terminal types.

A variety of users with widely varied experience with computer programming and the MILSTAR system are likely to use this model; therefore, it is recommended that a user-oriented, user-friendly model be chosen. Furthermore, a model would be desirable that is able to produce accurate results without protracted set-up and run times. For such a model to be useful on a day-to-day basis, limited software support from the developers should be needed after installation.

A well-suited model for the MSO would be primarily menu-driven and would require a large data base of system and user parameters. The full constellation as well as worldwide (including airborne) user locations would need to be modeled.

An efficient computer model satisfying these needs would likely employ both analytical approximations and time-domain simulation techniques. While a model using complete time simulation of the entire system might yield the most accurate results, it would be computationally slow with precision greater than that required for the analysis being performed. Many system parameters such as queuing delays, transmission delays, and message arrival times could be modeled sufficiently with statistical techniques. However, the model would be required to model actual C0, C1, C2, and C3 messages in order to study various network control techniques.

2. MILSTAR Computer Models Examined

Nine different computer models[1] are examined in this report. Each of which is intended to model or to analyze some aspect of the MILSTAR system. The models may be coarsely divided into three groups: (1) Resource Assignment, (2) Resource Control, and (3) Network Control. Although some of the models can perform analysis in more more than one of these areas, the groupings still apply since each model is intended to analyze primarily one of these subjects.

Section 2.1 describes the general criteria used to compare the models. Sections 2.2 through 2.4 then present each model with a description of its purpose, a general description, and pertinent implementation details.

2.1 Criteria for Examining Models

Each of the models was examined based on the presentations and literature available on the models from their respective authors. These models vary enormously in their size, complexity, and purpose. Therefore, a set of common criteria was used to evaluate each model. Sections 2.1.1 through 2.1.3 describe the model evaluation criteria.

2.1.1 Purpose of the Model

The initial decision, which needs to be made on any model, is the purpose for which it was written. In some instances the purpose of the model was quite different from the general communications analysis being assumed for the MSO.

2.1.2 General Description of the Model

A brief synopsis of each model is given, which describes some of the more salient features of the model. The extent to which analytical approximations are used in place of actual time-domain simulation is estimated. Many of the models were written to study specific areas of the MILSTAR system and, therefore, contain unique features which are

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[1] All of the following models, with the exception of the CSC and Linkabit models, were presented by their respective developers at a session of the Air Force sponsored MILSTAR Modeling Working Group, February 25-26, 1986. Information on CSC's MOMCMP was obtained through the program's functional description manual (under Air Force contract F11628-83-G-0001). Information on the Linkabit EAM model was obtained directly from its authors.

not of particular interest for general purpose analysis. An estimate is also given of the relative complexity of each model compared to the other models. Finally, an estimate is given on the overall usefulness of this model as an analysis tool for MSO personnel.

2.1.3 Implementation of the Model

Important implementation considerations include the type of computer and amount of storage required, the extent and amount of available documentation, and the amount of software support from the authors necessary to operate the model.

2.2 Resource Assignment Models

The three models assembled under this heading are intended to be used as tools in the overall assignment of resources in both the terminal and space segments. The first two models are useful for planning terminal ground locations. The third model attempts to optimize the assignment of resources on board the spacecraft; its output would be useful in programming the resource controller on board the satellite.

2.2.1 Kaman Sciences Platform Analysis

2.2.1.1 Purpose

To calculate Constellation Control Station (CCS) survivabilities during various levels of military conflict.

2.2.1.2 General Description

This is a simple program that performs probability calculations based on user-specified input parameters. The program must be provided with a data base of survival probabilities for CCSs at various locations. Appropriate satellite footprints are used to calculate the survivability, endurability, and availability statistics for each CCS.

This is a highly specialized program which is useful in strategic planning of the locations of CCSs. It is not likely to be of significant use to MSO for its modeling needs.

2.2.1.3 Implementation

This program was written for a microcomputer (for example, a personnal computer) but requires downloading of satellite footprints from a minicomputer. The software and accompanying documentation have been delivered to Air Force Space Command.

2.2.2 Kaman Sciences LOS Connectivity Model

2.2.2.1 Purpose

This program is intended to indicate connectivity between the space and terminal segments of the MILSTAR system.

2.2.2.2 General Description

This program is used as an aid in determining locations for earth stations in mountainous locations. The user inputs the latitude, longitude, and altitude of a possible terminal location. The user may also specify the presence of certain large obstructions (for example, mountains) in the terminal's horizon. The full MILSTAR constellation is modeled and simple line-of-sight (LOS) calculations are made to determine the amount of time a terminal in the specified location can communicate with certain satellites.

This is a relatively simple program; however, it does allow for obstructions near the terminals. It is principally a planning tool and is not likely to be useful as a system model.

2.2.2.3 Implementaion

This program was written for a minicomputer and is owned by the Government. The software and accompanying documentation have been delivered to Air Force Space Command.

2.2.3 Lincom System Loading Model

2.2.3.1 Purpose

This program is being developed to provide a computer-based capability for planning satellite resource assignment for different system network loadings.

2.2.3.2 General Description

This is a static loading model that attempts to optimize resource allocation based on the satellite loading. This program is intended to provided a deterministic method of deciding how to allocate the spacecraft's resources between the various networks sharing the satellite. The information provided as output from this program could be used to program the resource controller.

If successful this model could significantly improve the speed and accuracy with which spacecraft resource allocations must be readjusted as new networks and users are added to the system. This model could, therefore, be used to provide optimized programming to a resource controller model at the front end of a more general purpose model.

2.2.3.3 Implementation

This program is still being developed and will be owned by Air Force Space Division. The program is being written as an expert system (that is, with the use of artificial intelligence) and operates on a microcomputer.

2.3 Resource Control Models

These models tend to be the largest and most sophisticated of the MILSTAR models. They are simulation-type programs, which model various loadings on the satellite resource controller. These models vary in the amount of fidelity and degree of sophistication with which they model both the terminal and space segments.

2.3.1 Contel Throughput and Response Time Model

2.3.1.1 Purpose

This program is intended to evaluate spacecraft design trade-offs in throughput and response time performance of the resource controller.

2.3.1.2 General Description

The Contel model is certainly the most comprehensive and sophisticated of the MILSTAR models examined. The program is intended to emulate exactly the actions of the satellite resource controller. The physical spacecraft is also modeled extensively with effects such as spacecraft position and stability being modeled. Propagation losses due to rain are also modeled. The model is driven by a large data base of all current Block I networks and users. An initial program is run that generates a C2/C3 traffic scenario file. This traffic file is then loaded into the main program that simulates all C2/C3 message activity corresponding to the traffic file input. The resource controller is modeled extensively with queues and buffers being modeled individually. The model includes the full MILSTAR constellation and performs complete resource allocation (for example, hand-over, and terminal acqusition) during the simulation. All C2/C3 messages are recorded as well as the activity of most queues.

This model appears to emulate the actions of the resource controller with excellent fidelity. The program should be useful for benchmarking accurately the performance of the resource controller. Its use as a general purpose model is limited by its excruciatingly exact modeling of the resource control traffic (C2/C3 messages) and processing, but its lack of modeling any terminal-to-terminal (C0 and C1) messages.

2.3.1.3 Implementation

This is an extremely large program that requires approximately 9 hours of VAX 11/785 CPU time to simulate 6 hours of real-time communications. The program generates a large (approximately 200 MB) log file, which needs to be maintained in disk storage. The size and complexity of this model tend to indicate a large amount of software support would be necessary to use this model.

2.3.2 Aerospace Traffic and Payload Model

2.3.2.1 Purpose

This model is intended to simulate resource allocation message traffic for various network configurations.

2.3.2.2 General Description

This is a fairly extensive modeling program that provides statistics on the amount of C2/C3 message traffic resulting from various network loadings. Only the equatorial satellites are modeled; satellite yaw is also modeled. Terminal acquisitions are modeled in a separate program, and the resulting traffic scenario is then loaded into a system simulation program. Only the resource control traffic (C2/C3 messages) is modeled. Message lengths and arrivals are modeled statistically.

This is the type of simulation that needs to be used for general purpose modeling. It is predominantly a time-domain simulation; yet, it uses reasonable analytical techniques to model non-critical portions of the overall system. Inclined satellites, C0 and C1 messages, and real-time terminal acquisition are among the needed features for this model to be useful as a general analysis model.

2.3.2.3 Implementation

The terminal acquisition portion of this model is currently run on a minicomputer with the real-time traffic modeling program then being run on a mainframe computer. Simulations run at approximately real time on the mainframe, but would be slowed considerably if the entire model were run on a minicomputer. The program is designed with menus for interactive use by operators with knowledge of the MILSTAR system but without programming expertise. A limited amount of documentation is available and the program is owned by the Air Force.

2.3.3 CSC MOMCMP

2.3.3.1 Purpose

This is an early MILSTAR model developed to simulate overall system operational management.

2.3.3.2 General Description

This is a reasonably general-purpose model of an example three-satellite MILSTAR system. As with the other resource control models, system performance is analyzed by modeling the C2/C3 message traffic for various system loadings. The model is run with essentially static networks; however, networks may be preempted. The model does not bring up preempted networks or new networks during a run. Most communications traffic parameters (for example, queuing delays and message lengths) are modeled statistically. The model performs complete resource allocation of downlink hops, crosslinks, agile beams, and other system resources.

MOMCMP is, in general, the type of computer model that would be most useful to MSO for its general modeling needs. It appears to be a reasonably flexible program, which models the necessary resource control processes with reasonable fidelity. Necessary improvements to make the model more useful for the MSO would be the modeling of the inclined satellites and the ability to input the various networks through a data base interface rather than through a keyboard. The modeling of C0 and C1 messages would also need to be added.

2.3.3.3 Implementation

MOMCMP has been developed for interactive use and has accompanying documentation. The program currently runs on a HP-9836 microcomputer but would likely have to be transported to a minicomputer if it were expanded as suggested above.

2.4 Network Control Models

The three models in this category examined are all general-purpose, generic channel model simulators. The models assume that sufficient resources have been previously allocated to each network; static networks are assumed. These programs principally model the channels allocated to the networks and, therefore, perform little or no emulation of the spacecraft.

2.4.1 Booz-Allen Traffic Loading Model

2.4.1.1 Purpose

This model was developed to study interoperable protocol performance on the MILSTAR system.

2.4.1.2 General Description

This is a generic model that simulates various network control protocols using C2/C3 messages. The program generates channel usage statistics for each protocol. Message lengths and arrivals are modeled statistically. Simulations are performed on individual static networks.

This model does not actually simulate the MILSTAR system, but rather simply assumes a predetermined amount of C2/C3 messages have been allocated for network control. This model is quite useful for studying protocol performance; yet, its utility for studying the overall MILSTAR system is quite limited. Some of the protocols and the methods implemented to model them could, however, be used to study network control in a larger, more complete MILSTAR model.

2.4.1.3 Implementation

This is a reasonably simple model designed for use on a minicomputer. The software was not a deliverable and does not have formal documentation.

2.4.2 NOSC MILSTAR Model NASTEE

2.4.2.1 Purpose

This model is intended to analyze the throughput and response time of messages in established networks of the MILSTAR system.

2.4.2.2 General Description

NASTEE is a general-purpose channel modeling program. It currently models message traffic by assuming a predetermined amount of C0 message slots have been assigned to a particular network. Traffic parameters, such as message lengths and queuing delays, are all modeled statistically. This model only simulates network performance and does not model resource control functions.

NASTEE is best described as a generic channel simulator which could easily be adapted to any channel type; C1, C2/C3, or non-MILSTAR channel types could be analyzed. It is likely too simple (for example, it does not directly model the satellites or terminals) a model to be useful for analysis of the complete MILSTAR system.

2.4.2.3 Implementation

This program was developed for in-house use and is not formally documented.

2.4.3 Linkabit EAM/RB Model

2.4.3.1 Purpose

This model was developed specifically to study the impact of an emergency action message (EAM) and its associated report backs (RBs) on the MILSTAR system.

2.4.3.2 General Description

This model is intended to study the cycle time (the time required for a specific number or percentage of network members to report back after an EAM has been received) statistics for different loadings on the MILSTAR system. Contention for the short report back (SRB) and long report back (LRB) slots is modeled. Static European and CONUS networks are assumed. Message lengths and delays are modeled statistically.

This is also a fairly generic channel simulator model, which could be adapted to study channel usage statistics for a wide variety of channels. This model's usefulness in an overall MILSTAR model is likely to be limited. The methods used for modeling contention are unique to this model and could be incorporated into a larger system model.

2.4.3.3 Implementation

This program was developed for a microcomputer and has limited documentation; the software was not a deliverable.

3. Conclusions and Recommendations

It is clear from the descriptions of each of the models presented above that no single model exactly fits the computer modeling needs of the MSO. Most of these models have been written to analyze certain aspects of the MILSTAR system. Figure 3-1 is a summary of the models examined and their basic capabilities. This figure further demonstrates that no single model is appropriate for modeling the entire MILSTAR system. The three resource control simulation models discussed are reasonably general modeling programs that could possibly be adapted into general-purpose simulation programs. However, the Contel model is too complex due to its extensive resource controller modeling and would, therefore, not be easily adapted to a general purpose simulation. The CSC and Aerospace models are better candidates if an existing model is to be adapted to the needs of the MSO.

3.1 Possible Changes to an Existing MILSTAR Model

As discussed above the CSC and Aerospace models are the best candidate models to be adapted into general-purpose communication user models of the MILSTAR system. However, the software development cost necessary to adapt either of these models would be on the order of man-years of effort. A significant portion of this effort would be devoted to analyzing the software already written and devising methods of adding modules to the existing software. A decision by the MSO to revise an existing model could restrict the model's utility since the final software would be limited by assumptions and approximations made in the original software.

3.2 Development of a New Model

It appears that developing a new MILSTAR model would be a more productive, cost-efficient course of action than modifying an existing model. Furthermore, a more efficient, customized model would be possible since it would be designed specifically as a communication users modeling program. An appropriate model for MSO would emphasize communications analysis for the end-users of the system. A successfully developed model of this nature would be useful not only to the MSO, but also to a wide range of users in the DCA and DoD communities. Some use could be made of the existing models; however, the unique purpose of a new model as a general purpose communications model would necessitate mostly new software development. The

MODEL / TYPE OF ANALYSIS	SYSTEM TOPOLOGY		RESOURCE CONTROL MODELS			NETWORK CONTROL MODELS		
	KAMAN	LINCOM	CONTEL	AEROSPACE	MOM CMP	JTPO TRAFFIC LOAD	NOSC	LINKABIT
TERMINAL CONNECTIVITY	✓		✓					
SATELLITE RESOURCE ASSIGNMENT		✓						
SATELLITE RESOURCE CONTROLLER LOADING			✓	✓	✓			✓
NETWORK CONTROL USING C2/C3			✓	✓	✓	✓	✓	✓
NETWORK CONTROL USING C0 AND/OR C1						✓	✓	
NETWORK PERFORMANCE WITH DAMA USING C2/C3 CONTROL			✓	✓	✓	✓	✓	✓
NETWORK PERFORMANCE WITH DAMA USING C0 AND/OR C1 CONTROL						✓	✓	
COMPLETE C0, C1, C2, C3 COMMUNICATIONS ANALYSIS								

005878.0

Figure 3-1. Summary of Existing MILSTAR Computer Models computer data bases currently maintained for the MILSTAR system would likely be sufficient and would be used extensively in a new model.

3.2.1 Software Development Philosophy

It has been emphasized throughout this report that flexibility should be a primary design driver in a general modeling program of the MILSTAR system. A program should, therefore, be developed in a highly modular structure to allow for simple changes and additions to the program. This further suggests the use of a high-level computer programming language (for example, Fortran or Pascal) that would facilitate software changes to the model by persons other than the authors.

3.2.2 Components of Model

Figure 3-2 shows the main MILSTAR model and four major components of a model. Most of the models examined previously are concerned primarily with data management (that is, data base control) and resource control. The proposed model would also require an extensive data base; however, traffic simulation and network control modeling would be simulated more extensively than would resource control.

3.2.2.1 Data Management Component

Figure 3-3 shows the data management component and its various subsystems. This component would be reasonably simple to implement because it involves mostly interfacing existing data bases with a new program. Included in the space segment data would be a program to position and to fly the satellites as a function of the simulation time.

3.2.2.2 Traffic Simulation Component

Figure 3-4 depicts the message traffic simulation component and its associated subsystems. Terminal-to-terminal message traffic would be simulated here and could be used to analyze throughput and response time characteristics or in-band control techniques for various loadings. The jamming and scintillation subsystems shown would provide output suitable for modeling these effects on the traffic simulation component as well as the other components.

3.2.2.3 Network Control Component

Figure 3-5 shows the network control component and its associated subsystems. The models developed for this component would be used primarily to investigate system performance improvements made possible through the use of DAMA network control techniques.

3.2.2.4 Resource Control Component

Figure 3-6 illustrates the resource control component and some of the subystems needed to model the resource controller.

3.2.3 Level-of-Effort Estimates to Develop Proposed Model

Table 3-1 shows estimates on the number of lines of code and staff years necessary to design, write, debug, and document each of the components described in the previous sections. These estimates were derived by using general software estimation techniques as well as by examining the the sizes of existing MILSTAR model programs. The estimate on total level-of-effort -- 14.2 staff years -- required to complete the model indicates this would be a large-scale software development effort as was originally expected.

The estimates provided in Table 3-1 should also be applicable if the proposed model were to be built in stages, rather than a single large effort. The considerable cost of developing this model could, therefore, be amortized over a few years. A gradually developed model could also be designed so that a useful model, with limited capabilities, would be available after only 3-4 staff years effort. Program builds in successive years would add to the model until the full program (described in Figures 3-2 through 3-6) is complete. A possible series of four program builds is given in Figure 3-7. This methodology would allow for a simple model to be available after Build 1, which could be used to examine network requirements. The second build would allow simple loading analysis and point-to-point C0 messages. The non-stressed model would be essentially complete after the third build with complete network and resource control possible. The fourth build would allow for complete system analysis under jamming and scintillation as well as completing the detailed model of the spacecraft dynamics.

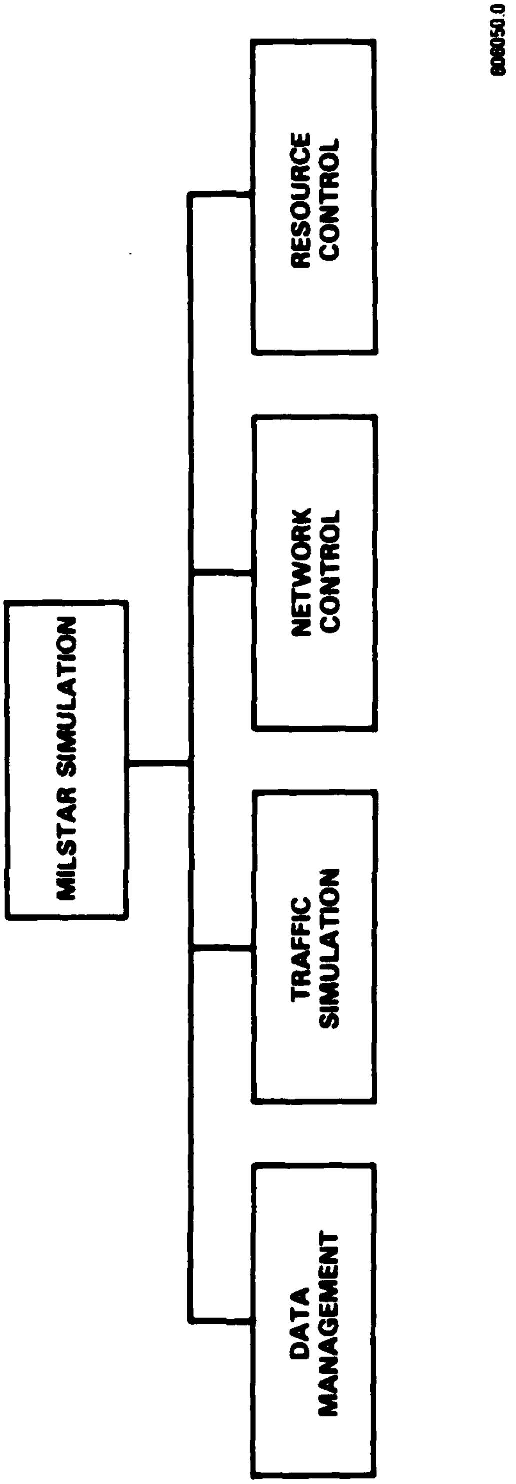

Figure 3-2. MILSTAR Computer Model and Components

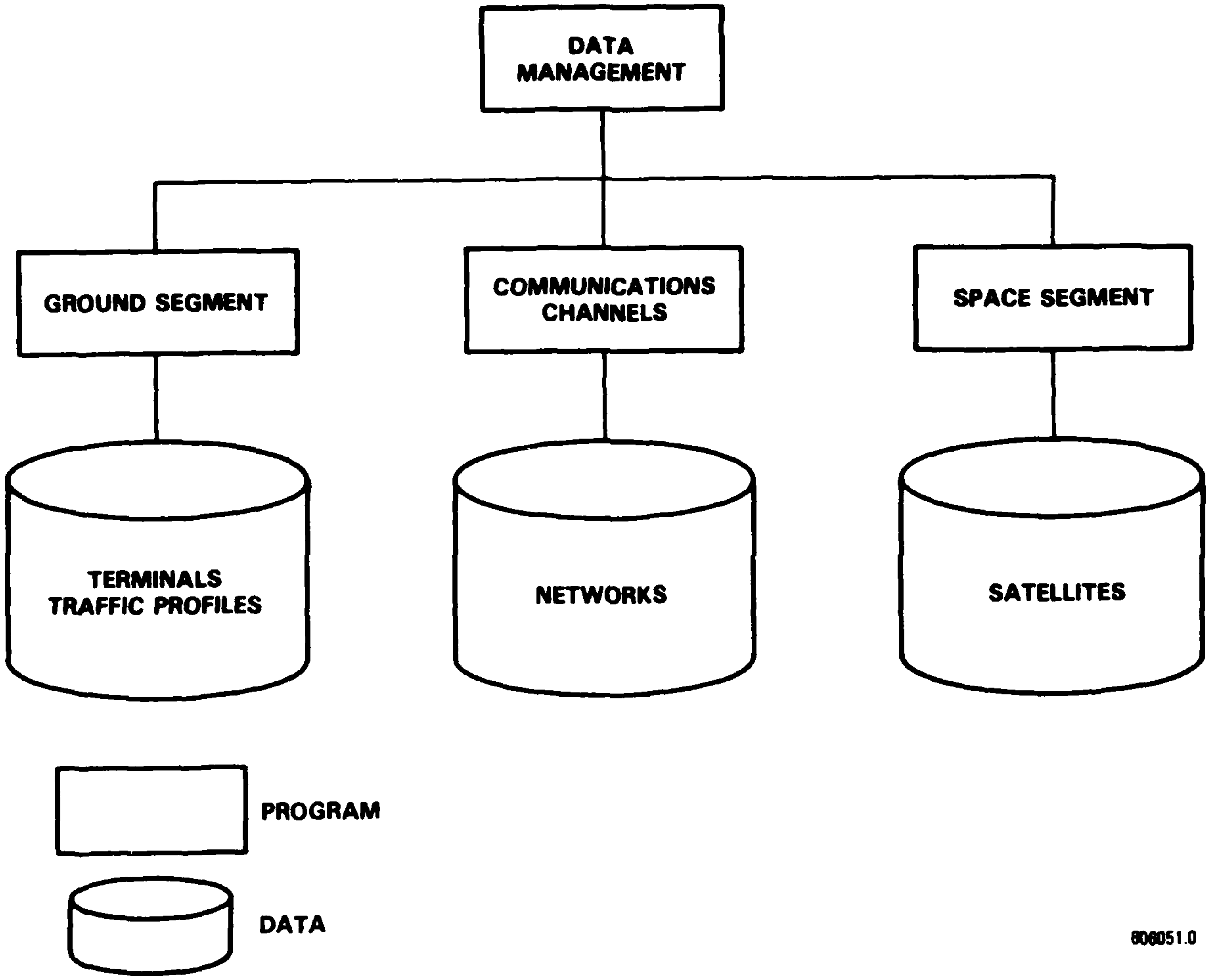

Figure 3-3. Data Management Component

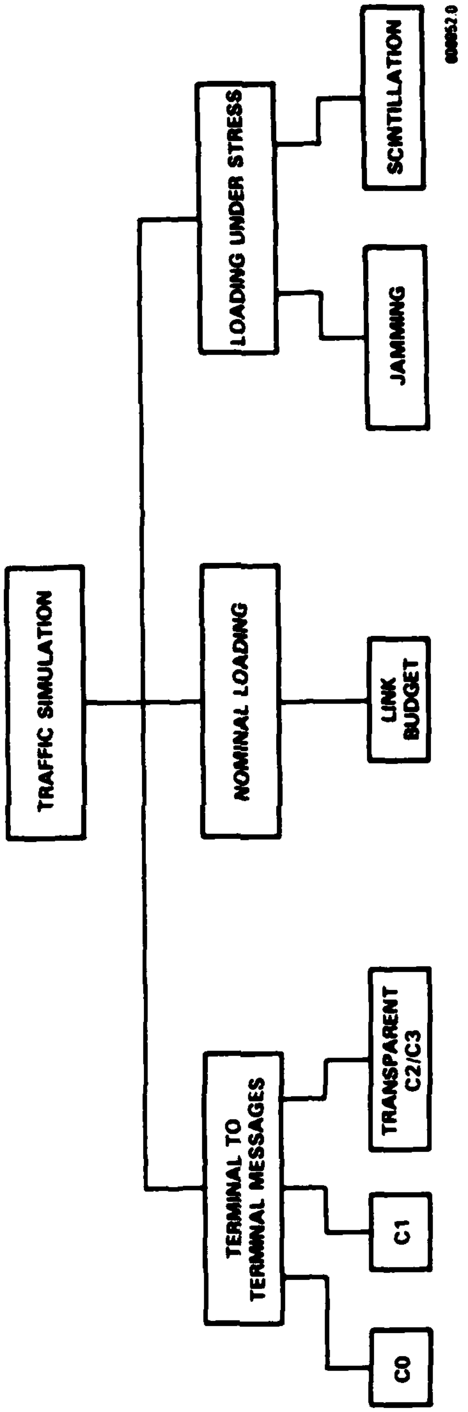

Figure 3-4. Message Traffic Component

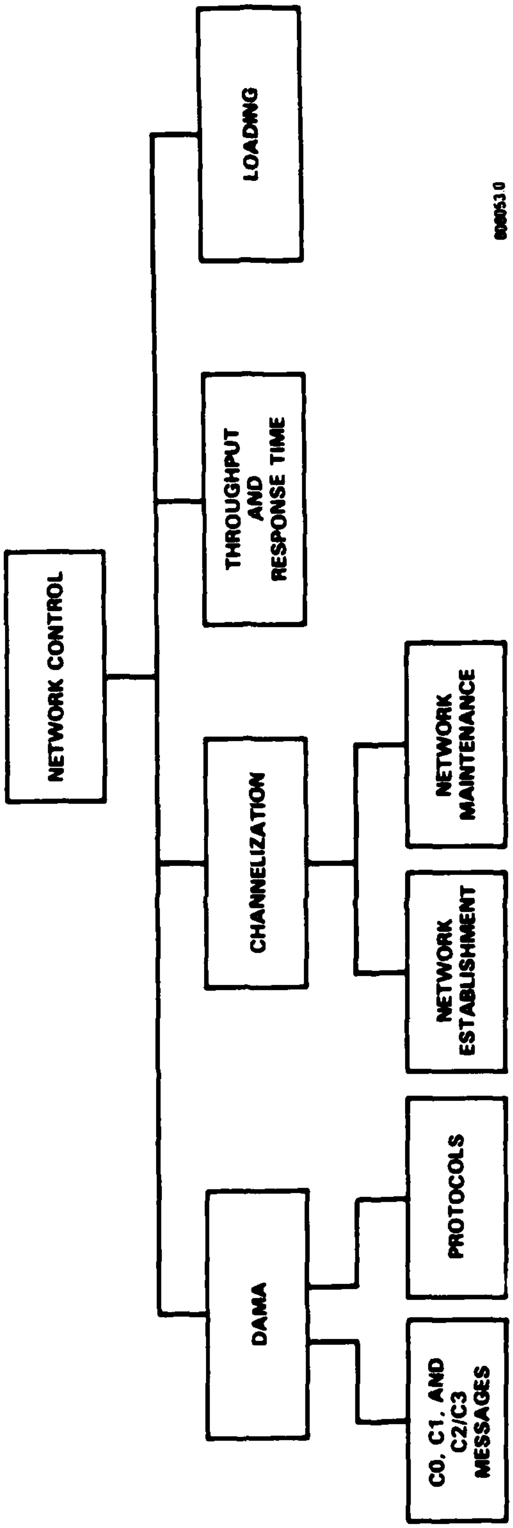

Figure 3-5. Network Control Component

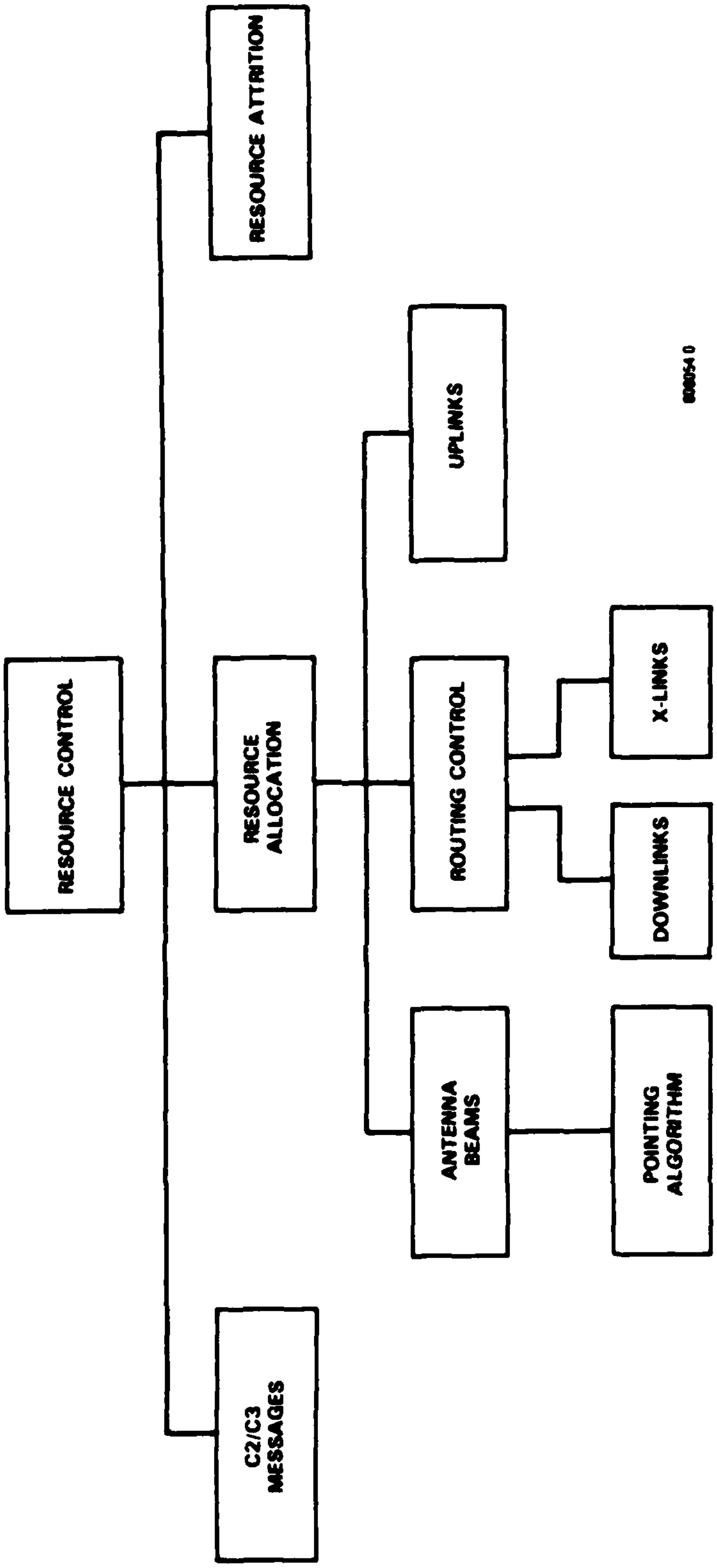

Figure 3-6. Resource Control Component

Component	Subsystems	Lines of code	Staff years
General model design and analysis			2
Data management		5000	2
	ground segment		
	space segment		
	comm. channels		
	terminal database		
	user req. database		
	satellite database		
Traffic Simulation			
	C0 messages	1000	.4
	jamming	2500	1
	normal loading	2500	1
	scintillation	2500	1
Network Control			
	C1 messages	1000	.4
	channelization	1200	.5
	throughput/response	2500	1
	loading	2500	1
	protocols	5000	2
Resource Control			
	C2/C3	1000	.4
	resource allocation	1000	.5
	resource attrition	2500	1
		30,200	14.2

Table 3-1. Size and Cost Estimates for General Purpose MILSTAR Model

Build 1	Data management: terminals, user requirements, some networks, geosynchronous satellites; resource control: basic antenna and demodulator assignments.
Build 2	Data management: complete network information, full constellation; resource control: C2/C3 messages; traffic simulation: simple C0 messages, loading model.
Build 3	Network control: complete channelization, throughput and response time analysis, in-band DAMA protocols; complete resource control.
Build 4	Stress: scintillation, jamming, resource attrition; out-of-band DAMA control; further spacecraft modeling: ephemeris data, yaw, pitch, roll.

Figure 3-7. Possible Program Builds for MILSTAR Modeling Program

3.3 Summary and Conclusions

This report has examined the MILSTAR modeling needs of the MSO and determined that a general-purpose, end-user communications model would be the most useful to the MSO. Before a model is either acquired or developed, the exact requirements of the MSO would need to be more fully detailed.

Nine currently available MILSTAR computer modeling programs have been examined. It was concluded that each of these models was written to model specific portions of the overall MILSTAR system and that none of these models is completely appropriate for the MSO. The possibility of acquiring one of these models and altering it appropriately has been considered; however, this option is considered less attractive than developing a new model for several reasons. In general it was concluded that developing a new, general purpose communications model of MILSTAR would be the most productive and efficient course of action.

Estimates have been made on the number of staff years required to produce a general purpose model. The large number of staff years -- 14.2 -- indicates that the value of the final model to MSO should be carefully weighed against the considerable development cost. However, this cost is quite small in comparison to the overall MILSTAR system development cost and the potential benefits in system performance that would potentially accrue through examination of new network control and resource control algorithms. Thus, MSO development of a new MILSTAR model is highly recommended.

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The MILSTAR modeling needs of the MSO are analyzed. It is determined that the MSO is concerned primarily with end-user-type analysis of the system, and that a good general purpose MILSTAR communications analysis model is needed.

A survey of nine (9) existing MILSTAR modeling programs is presented; no one of these programs fits the needs of the MSO.

Finally, level-of-effort estimates on the development of a new model are made.

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