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A PLAN FOR CONSOLIDATION AND AUTOMATION
OF MILITARY TELECOMMUNICATIONS ON OAHU

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PREFACE

This report presents an architectural concept of a complete writer to reader, automated message service for all of the Department of Defense units on the Island of Oahu. It is a system plan, not a detailed specification.

For budgetary purposes, the results of a brief study of sizing and costs are included.

The proposed system plan is based upon careful consideration of both the operations on Oahu and the projected requirements. To assure an adequate level of understanding of need, members of the University of Southern California's Information Sciences Institute (ISI) staff visited Hawaii on March 22 through March 29, 1973, and, again, April 24 through April 27, 1973. ISI personnel conducted interviews with staff both in Oahu and in Washington, D.C., and used the results of data obtained from CINCPAC.

This work was supported by the Advanced Research Projects Agency (ARPA) under Contract Number DAHC 15-72-C-0308.

FOREWARD

The current methods of message preparation and handling by the military organizations on the Island of Oahu are largely manual. Though needs of the various organizations and sites on the Island are reasonably common, limitations of the manual system require that message functions frequently be duplicated. Furthermore, within each organization several stages of manual message accounting, copying, and courier forwarding exist between the electronic communications and the action officer. For most action officers there is no secure communication means, other than hand routing, to coordinate messages either for preparation or for action. The manual handling results in high operations costs and often very long delays in message preparation and delivery. For these reasons, the current message service is largely treated as a mail service, rather than a prompt message means.

After observing many action officers and their needs and work styles, we have concluded that a well proven technology and methodology exists which can drastically reduce the operational costs and virtually eliminate the delays characteristic of the current message system.

The particular system architecture which we propose in the body of this report is based on ARPA Network technology which currently brings communication and very flexible message services directly into offices of users whose tasks and office environments are very similar to those of the action officers on Oahu. While the ARPA Network originally served mainly scientific personnel and their computer-based needs, it is also currently used very productively by project administrators, coordinators, technical managers, liaison personnel, and secretaries, for their daily communication needs. The on-line message services provided by the ARPA Network on commonly-shared computers and the ability to quickly coordinate messages with others down the hall, in another building, or thousands of miles away, via computer terminals, have proven to be of immense value to these action level people.

The ARPA Network architecture is suggested here because several hundred man-years of development effort have been invested in its various components, contributing directly to the problem of consolidated telecommunications with writer to reader automation. Very little additional effort would be required to orient this architecture toward the military needs and environment.

We estimate that for an investment of 20 to 40 man-years, approximately \$25 million in capital costs and

\$200,000 per year for leased line costs, the Oahu-wide consolidated, direct writer to reader automation can be installed with large attendant savings, a significant increase in the efficiency of action officers, and a vast improvement in message promptness.

I INTRODUCTION

This study was motivated by the desire to provide an advanced teleprocessing architecture as a means of substantially reducing DoD Oahu message handling costs and delays. After an incisive look at the problem, it was determined that not only a technology, but also a methodology was needed to promote a smooth transition from the present manual arrangement to a largely automated, reliable, and cost effective system. This report suggests a system architecture and a functional methodology; it is emphatically felt that the two are inseparable if an effective, user-oriented system is to be constructed.

In order to inject substance and validity into this study, the system architecture is based on operational, state of the art message-handling system components. These components can be customized to Oahu's needs to dramatically reduce delay times and provide greater interaction than the present manual service. Technically, this entire system could be operational in less than 24 months.

This report is a gross system guideline and should not be misconstrued as a complete system specification. The guideline reflects our experiences in an environment not too

INTRODUCTION (cont.)

unlike that of Oahu. A careful analytic and simulation study should follow this work in order to produce detailed specifications and costs.

Although the principal focus of this study is the solution of the Oahu communications problem, the system should, at the same time, be viewed in larger context. Since the proposed communications architecture is relatively independent of physical area and of number of users served, the Oahu solution might serve as a prototype for other similar sites; it can also serve in expanded form as a worldwide military communications system.

The basic system architecture can accommodate new services and easily expand or contract without disruption of ongoing operations. Thus the Oahu military community will not be constrained by a specific mechanism for their current mode and level of operation.

Military communications on the island of Oahu are currently handled by a sizable collection of communications personnel trained in the handling and distribution of messages. They currently provide the interface between the people who wish to send and to receive messages and the local communications equipment. Approximately two thousand personnel are employed on Oahu to perform this service at a cost of about \$20 million per year.

INTRODUCTION (cont.)

This method of operation has a number of serious drawbacks. For example, because of the large number of personnel required to handle messages for others, the cost of communications is very high. Each message must be handled many times, introducing inconvenience and delay. Of the many possible approaches to solving this problem, all reduce to one: namely, to lower costs, the number of communications personnel must be reduced. However, in order to reduce the number of personnel, their tasks must be taken over by automation of their accounting and routing functions and by providing direct communications capability to the offices of message senders/receivers.

To fully realize the cost and functional benefits of an automated system, it is essential that we bring on-line terminal communication directly to the action officer and/or his secretary. This will not require a terminal for every officer on the Island, since in most cases several officers and support personnel are clustered in a single physical office space. Their traffic levels are such that several officers (average of 3) can share a terminal without conflict. By allowing these people to be directly on-line, the system can provide: complete accountability of messages; preparation aids; scanning aids; interoffice communication; message status reporting; task listing by priority, with audible and visual alarms, and many other personal aids to enhance the effectiveness of action officers.

INTRODUCTION (cont.)

Bringing the communications directly to the user offers a far reaching set of capabilities that extend beyond anything currently available and with more complete security protection. Not only are delay times of seconds attainable, but the possibility for informal inter-terminal communications can improve the operation of a unit and greatly improve security.

In order to achieve these objectives, we propose only that the structure of existing computer and communication systems be adopted and tailored for use by the military. The basic research and development to make this possible is essentially complete. When the existing R&D efforts are used for the foundation of the proposed overall system, investment in modification of existing major system components on the order of a few million dollars can be expected, with an estimated delivery time of about two years after approval. However, if a new system is designed from the beginning, costs in excess of \$50 million can easily be expected, with a final system delivered in three to five years.

Two systems, TENEX [1] and Multics [2], have already been developed and made operational. These systems, in essence, perform this kind of message service today. The TENEX system, based on the the DEC PDP-10, provides a message-handling service on the ARPANET [3]; Multics, based

INTRODUCTION (cont.)

on a Honeywell 6180, provides a capability for handling messages and for multilevel security safeguards. Either of these systems is capable of effectively supporting the communications requirements for Oahu. Software development is needed to tailor the system to the specific requirements of the users of Oahu. However, fundamental changes to the underlying operating system structure are not required.

A reliable communications system is needed to interface the users to these machines. The interconnection should be such that the users are totally unaffected by the failure of an individual computer and its location. The ARPANET packet-switching technology developed by ARPA is extremely well matched to this kind of performance. Although other forms of communications can serve to interconnect the user and computers, we have focused on the packet-switching application in this plan because it is more reliable and more flexible in serving a wide variety of users and user needs. Further, the system is easily scalable in size.

Communication of separate intelligence community traffic through a GENSER network is easily achieved. The network architecture proposed is flexible enough to extend to any capacities that can be reasonably foreseen in the near future. Further, the proposed system permits the interconnection of computers to provide other services. Also, the network can be easily interfaced to other

INTRODUCTION (cont.)

communication systems (i.e., AUTODIN) for worldwide connectivity.

In the remaining sections of this report we develop this plan in greater detail. In SECTION II we describe the communications problem on the Island of Oahu, as we perceive it. In SECTION III we discuss the nature of the user requirements and show how desirable and workable is the objective of placing the user directly on-line. In SECTION IV we propose an overall system and describe its operation. In SECTION V we cover the magnitude of the system required. In SECTION VI and VII we describe detailed cost and implementation considerations.

Briefly, then, in this report we describe a plan for consolidation of communications services on Oahu which relies on placing the users directly in contact with an automated message-handling service. This service would be provided by a set of computer-based message processors configured to provide message handling with security capability and high reliability. These processors would be interconnected with each other and the users via a packet-switch network. The entire system would provide essentially "immediate (seconds) message delivery". The system would be available within two years at a total cost of approximately \$25 million.

INTRODUCTION (cont.)

We believe this approach is an effective, expandable way to proceed in consolidation of the telecommunications services on Oahu.

II PROBLEM DESCRIPTION

INTRODUCTION

There is an acute telecommunications problem confronting the military complex and other Federal governmental agencies on the Island of Oahu. The problem with existing communications methods is one of both high costs and long processing and delivering delays in the Island's message traffic.

For incoming messages, the problem results from the numerous levels of message handling now prevalent. Each stage in this process usually involves manual logging, copying, pigeon-holing, and a courier schedule in order to reach the next stage. Typically three stages are required to reach the action officer: the individual who will, in fact, take action on the message or require information. Each operation at each stage involves queuing from several minutes to several hours. Outgoing messages are coordinated with several action officers, often requiring several hours or days of an officer's time. Thereafter, the message, when released, must move upward through the same multiple stages. Coordination is another aspect of the communication problem. Essentially all of the delays and the manpower required to support this manual system can be eliminated by discarding

PROBLEM DESCRIPTION (cont.)

the message center concept and bringing electronic communications directly to action officers, along with automated control functions.

The current operations can be characterized as follows (see Table 1). There are currently 24 military and governmental locations housing 96 first-level communications centers which are structured in many different ways.

Each message center has the responsibility of receiving messages from their point of origin via the ASC facility at Wahiawa and disseminating them to approximately 850 next level addressees. The latter, in turn, distribute, control, and receive messages for 6,000 to 7,000 action officers. A significant set of these centers has provided ad hoc separate solutions to message handling. As a result, there is a wide variety of equipment and processes in use on the Island. The heterogeneity of outdated equipment, coupled with local optimization, cause high total system facility, equipment and personnel costs. The local centers have individually improved services, within the scope and budget of their limited charters, to automate message-routing list generation and, in one case, message entry. However, the lack of a consolidated effort has prevented the systematic approach required to obtain the complete and reliable writer-to-reader automation necessary for present and future needs.

Table 1

OAHU COMPLEX

- 24 LOCATIONS WITH 96 CENTERS
- 2147 MESSAGE SUPPORT PERSONNEL
- \$21.5 MILLION ANNUALLY (M & O COSTS)
- ~ 850 PRIMARY ADDRESSEES
- ~ 6000 ACTION OFFICERS

PROBLEM DESCRIPTION (cont.)

HIGH MANPOWER REQUIREMENTS

Supporting the communications system are 2,147 message personnel that have responsibility only for trafficking messages around the Island. They are not message senders; they are not message receivers; they are message support personnel.

Many message centers, critical centers among them (e.g., Kunia), anticipate a 30% reduction in manpower over the next 12 months. These sites are currently operating at full capacity in terms of message-handling capabilities. They cannot sustain current traffic levels within the present operating environment with reduced manpower.

The 2,147 message support personnel presently consume \$21.5 million annually in O&M costs, plus communications costs, in meeting the Island's communication needs. Concomitant with manpower reductions, the telecommunications systems must necessarily reflect a significant decrease in operating and maintenance costs while providing improved performance.

USER INACCESSIBILITY

The AUTODIN system and existing automated message-routing determination processors (LDMX, ACAMPS, et. al.) have demonstrated the practical ability of moving messages several thousand miles on a priority basis in

PROBLEM DESCRIPTION (cont.)

minutes or even seconds. However, in the current Oahu complex the first and last 1,000 feet between reader/writer and communications system typically add several hours to message delivery time. In addition to these delays incurred, a high dollar cost is required to maintain control, audit capability, and mobility of the messages in the manual environment.

III FUNCTIONAL REQUIREMENTS OF AN AUTOMATED SYSTEM

CONSOLIDATED AND AUTOMATED SERVICES

An overall goal of a future Oahu telecommunications system is to significantly reduce costs of operations, of maintenance, and of manpower. This objective is realized by automation of the message services, a consolidation of the facilities, and an integration of the multi-service user community with respect to the message services offered. Furthermore, these objectives can be realized promptly.

The proposed automated system allows a small number of identical, distributed telecommunications centers to serve all subscribers independent of service affiliation, and independent of the subscribers' geographical location on the Island.

IMPROVED SERVICES

An equally important goal is to improve the effectiveness of the telecommunications functions by providing new communications methods that closely couple the action officers (who generate and respond to messages) in a man-machine environment that will literally bring the message service to the office of the action officer. Such a communications system should provide the action officer with

FUNCTIONAL REQUIREMENTS (cont.)

powerful but natural aids to deal with message activities directly, rather than through intermediate message processing centers. Effectively, the system should be: 1) easy to use; 2) responsive; and 3) complete as an electronic message service.

EXTENSION OF SERVICES

These design objectives encompass all on-Island message needs, both general services traffic (GENSER) and intelligence traffic (Intelligence). The system should mediate off-Island communications through the ASC facility in such a way that the discourse between the action officer and the system appear to be the same as for on-Island correspondence.

Such a communications can be extended to carry mixed mode (messages and data processing) traffic, so that WWMCCS and other virtual networks may be integrated at a small additional cost. Thus, any terminal can access all available services.

SYSTEM PERFORMANCE REQUIREMENTS

The proposed architecture is described in Section IV of this report. Performance requirements for the system are briefly listed here.

Reliability, Maintainability, and Survivability -- A

FUNCTIONAL REQUIREMENTS (cont.)

proposed system should be redundantly constructed and connected to provide high reliability. Components should be modular in design and function. The connectivity and modularity result in a system with immunity to conventional hardware failure and survivability from attack or sabotage; stations surviving attack or failure can operate together as a coherent entity.

Responsiveness -- The system must support users in an interactive mode and must comply with message delivery time standards established by the JCS.

Security -- The system must satisfy security criteria similar to those within AUTODIN.

Accountability -- Data and message accountability must be available within all levels of the proposed system.

Variable Capacity -- The system architecture must possess the ability to be expanded or contracted an order of magnitude in capacity without causing disruption or degradation of performance.

MESSAGE SERVICE REQUIREMENTS

As mentioned above, it is the intent of this report to specify a system which brings direct access to message service into the office of the action officer. Two forms of message service are recommended: 1) to perform those

FUNCTIONAL REQUIREMENTS (cont.)

functions of the current formal message service, and 2) a new, informal message service.

Informal Message Service

The informal message service does not exist presently, except by telephone which in most cases is not secure. Recommended is a mechanism to allow two or more people to securely link together to discuss a problem before that problem becomes a matter of record. A very serious potential drawback to the current, nonautomated system is that an action officer may delay communicating about a problem until he is certain that he is willing to allow the communication to become a matter of record.

The informal message service should be provided both by an "electronic mailbox" and by direct, terminal-to-terminal linking. This service should exist at all priority and security levels, corresponding to the formal service, and there should be a guarantee that these communications will not be recorded or archived.

Formal Message Service

The formal message service is expected to be completely automated from writer to reader and to provide all of the services of the current, nonautomated message service.

For both the formal and informal service, the system is

FUNCTIONAL REQUIREMENTS (cont.)

designed to maintain continuity of service and extreme reliability. No message, whether formal or informal, should ever be lost or misrouted.

MESSAGE CREATION AND TRANSMISSION

With respect to outbound messages, the action officer or his designee require a number of capabilities. They are:

Text Creation -- An editing mechanism which will provide the user with a set of easy to learn and easy to use commands for creating, inserting, deleting, and modifying text which will become the body of a message.

Coordination -- Automated aids to facilitate the "hand carry" phase of message preparation during which the text content is cleared with interested and/or responsible parties.

Routing -- A normal part of the message preparation facility which queries the writer to obtain the correct and appropriate set of on and off-Island addressees for a message. This phase requires that valid routing be supplied. Errors are detected and interactively corrected.

Release -- A mechanism for releasing a message after it has been created and coordinated. This is controlled by the responsible action officer. At the instant of release, the message is internally queued for distribution.

FUNCTIONAL REQUIREMENTS (cont.)

Distribution -- A mechanism internal to the message facility which insures the transmission of off-Island messages via ASC and the delivery of on-Island messages via the facility itself. The system guarantees that the distribution addressee is a valid entry in the routing guide.

Status Query -- A facility by which the originator or addressees of messages may query the message system to ascertain the general status of the distributed message. Examples of queries are: "Has it been read?", "By whom?", "Is action pending?", "By whom?".

MESSAGE RECEPTION

Each action officer must have a complete set of capabilities for managing his received messages. They are:

Alerts -- An audio and/or visual alarm to alert him to the arrival of a message or coordination request.

Hierarchy -- Messages and requests must be maintained in a hierarchical fashion reflecting the priority of the messages.

Scanning, Viewing, and Browsing -- The ability to scan the hierarchy of messages awaiting action by criteria such as precedence and age. Items for action require full viewing. Browse mode should be available for information

FUNCTIONAL REQUIREMENTS (cont.)

items or for large volume reception. Aids for increasing efficiency in scanning large numbers of messages should be provided.

Fanout and Redirection -- A limited capability to forward received messages to other action officers and redirect messages within addressee boundaries.

Action Indication -- For on-Island originated traffic received on-Island, a method whereby recipients can provide feedback to the sender concerning the state of the received message. Examples are message not read, read but no action, action pending, etc.

MESSAGE SERVICE SUPPORT

Additional supporting facilities should be available to both senders and receivers to aid message-related tasks. Included here are access to printed copy and archives for referencing previous messages.

As additional aids are implemented -- abstracting service, personal keyword searching, etc. -- they should immediately become available to the entire Oahu community.

IV SYSTEM ARCHITECTURE

COMMUNICATIONS NETWORK

Figure 1 illustrates the proposed basic consolidated user-service network. It is composed of an Island-wide communications system called a "subnet" which provides connectivity between users, services, and external communication systems such as AUTODIN. The properties of this network are such that it creates a common community of users and services. User connectivity is homogeneous over the entire subnet, independent of physical location. All terminals are multi-homed via redundant, dynamically-switched communications paths to all available services. Terminals in geographically adjacent locations can be connected to the subnet at logically and electrically isolated points, thus insulating a given user from local failures. Information transition times across the subnet will be on the order of 100 milliseconds, providing immediate and interactive user service uniformly throughout the common environment of Oahu.

Figure 2 is a more detailed abstract of the system architecture proposed for the Island. It illustrates a network composed of action officers' terminals at geographically separated sites. The terminals are connected

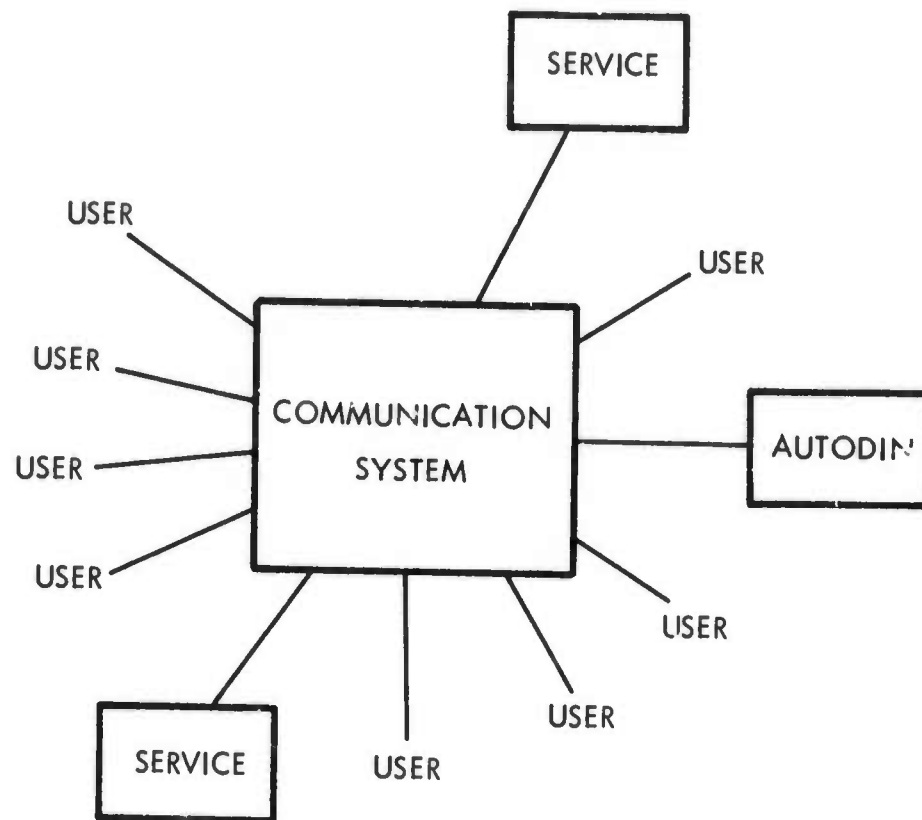


Figure 1. Common communication community

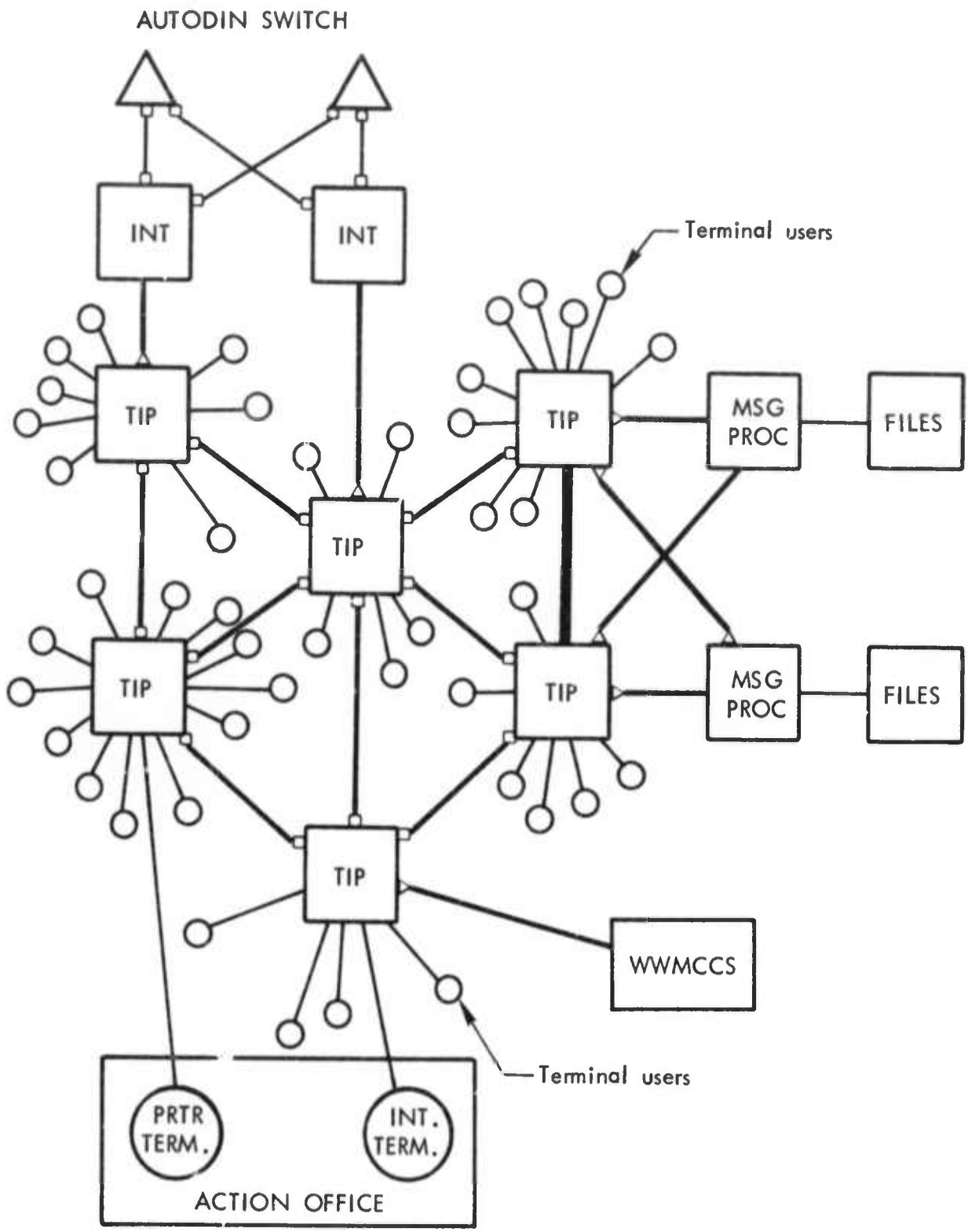


Figure 2. Abbreviated communication system architecture

SYSTEM ARCHITECTURE (cont.)

by voice grade lines to Terminal Interface Message Processors (TIPs) [4], like those of the ARPANET, or similar small, standardized minicomputers; the latter, in turn, are interconnected through high-speed lines leased from HAWTEL and/or other communications media (such as the military microwave now used on the Island). Several larger processors are also connected to the TIPs to supply the message-service functions. The communications medium is a distributed, packet-switched, store-and-forward network. Traffic routing is governed adaptively by the TIPs over redundant network paths. Via this network, each action officer can reliably access the various message functions as well as other remote action officers. The TIPs are located about the Island where action officers reside, as well as where the several message processors will be located. The TIPs act both as a multiplexer, concentrating many terminal lines, and as a routing processor, dynamically optimizing message traffic routes within the network.

Within the communications subnetwork, error rates and down-time can be made to conform to virtually any desired specification. Off-the-shelf equipment provides the following features: 1) at least two transmission paths between nodes; 2) cyclic checksums incorporated and designed to detect transmission errors. The error detection is accompanied by re-transmission rather than error correction. Experience with the ARPANET has shown that the undetected

SYSTEM ARCHITECTURE (cont.)

error rate is better than one bit in a trillion; and 3) TIPs ruggedized against external environmental conditions and whose operation is independent of any electromechanical devices (except fans).

MESSAGE PROCESSORS

The message processor does not support user jobs. Rather, it executes special system processes which implement the message service. Two off-the-shelf, commercially-available candidates for message system processors are TENEX and Multics, either of which can be stripped of their general-purpose capabilities and optimized for message service for the Island environment. There are no user terminals directly connected to the message processor; all access to the service is through the network.

The message processor is backed with very large files to keep the current traffic (say the previous 30 days) on-line and accessible by authorized action officers.

Message processors are redundantly connected to the TIPs, which are in turn redundantly interconnected such that when a temporary outage occurs, a second TIP can serve the message-processor host.

One function of the message processor is to keep another message processor up-to-date with respect to file changes. Any time the status of a message changes, a

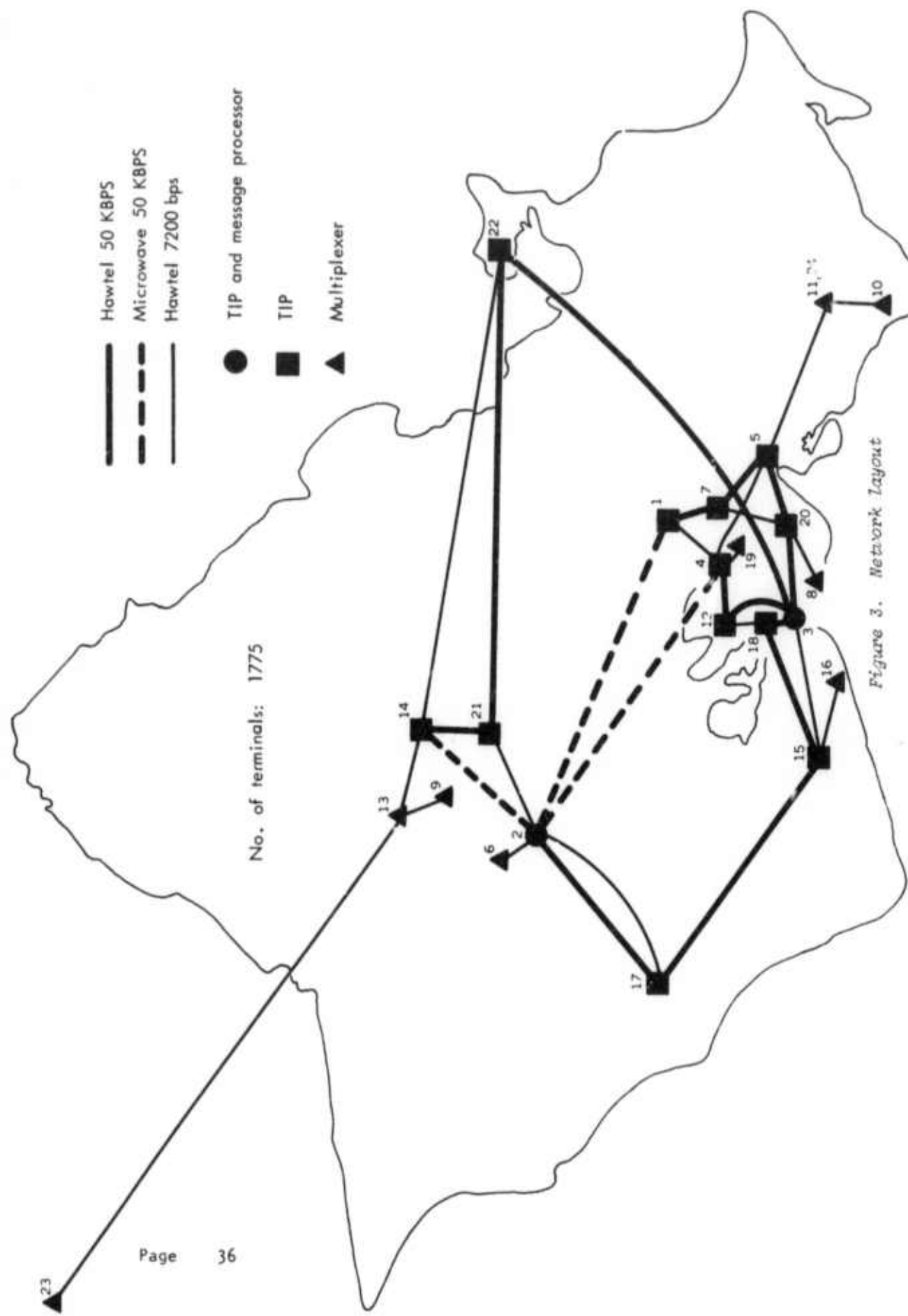
SYSTEM ARCHITECTURE (cont.)

message processor relays updating information to a second processor. Thus, should a message processor cease functioning, a second processor can immediately assume the tasks ongoing of the first machine. In most cases, the TIP serving a particular message processor will be able to perform the switchover function in a manner which is invisible to the user at the terminal. After sensing the lack of immediate acknowledgement from a processor, the TIP will dynamically redirect its user traffic to the designated backup processor.

OFF-ISLAND CONNECTIVITY

In addition to the message processors, the Inter-Network Translator (INT) in Figure 2 connects the AUTODIN switch for off-Island communications systems. The INT is a mini computer intended to be kept very simple, straight-forward, and reliable. Its primary function is to accept, reformat, and transmit messages between the AUTODIN switch and the message processors. It will also have the capability of directing AUTODIN computer traffic to and from general service hosts on the network, such as WWMCCS. Reconfiguration processors of this nature have been built frequently for the ARPANET.

Figure 3, a map of the Island of Oahu, shows probable TIP placement, and Table 2 lists the number of types and terminals for each location. These data were derived from



- Howtel 50 KBPS
- - - Microwave 50 KBPS
- Howtel 7200 bps
- TIP and message processor
- TIP
- ▲ Multiplexer

No. of terminals: 1775

Figure 3. Network layout

23

Table 2

DISTRIBUTION OF HARDWARE

| <u>Locations</u> | <u>No. of Act. Officers</u> | <u>No. of Terminals</u> | <u>No. of TIPS</u> | <u>No. of Multiplexers</u> |
|------------------|---------------------------------|-----------------------------|------------------------|--------------------------------|
| 1) CP SMITH (3) | 900 | 270 | 6 | 4 |
| 2) KUNIA (3) | 30(2) | 10 | 2 | 0 |
| 3) HICKAM (3) | 900 | 310 | 6 | 10 |
| 4) MAKALAPA | 610 | 230 | 5 | 10 |
| 5) FT SHAFTER | 470 | 140 | 3 | 30 |
| 6) SCHOFIELD | 580 | 140 | 3 | 30 |
| 7) ALIAMANU | 60 | 15 | 1 | 2 |
| 8) KAMEHAMEHA | ? | 15 | - | 2 |
| 9) POAMOHO | ? | 2 | - | |
| 10) FT RUGER | ? | 2 | - | |
| 11) ARMSTRONG | 20 | 6 | - | 1 |
| 12) FORD IS | 180 | 60 | 1 | 10 |
| 13) HELEMANO | 150 | 5 | | 2 |
| 14) WAHIAWA | 150 | 50 | 1 | 0 |
| 15) BARBERS PT | 450 | 150 | 3 | 10 |
| 16) EWA BFACH | ? | 5 | | 5 |
| 17) LUALUALEI | 240 | 30 | 1 | 0 |
| 18) PEARL HARB | 500 | 170 | 4 | 30 |
| 19) MOANAIUA | 100 | 20 | - | 2 |
| 20) DAMON TRAC | 20 | 5 | 1 | 2 |
| 21) WHEELER | 200 | 70 | 2 | 10 |
| 22) KANEOHE MC | 200 | 40 | 1 | 3 |
| 23) BARKING SN | 60 | 15 | - | 2 |
| 24) HONOLULU | 60 | 15 | - | 2 |
| TOTAL | <u>5880</u> | <u>1775</u> | <u>39</u> | <u>167</u> |

NOTE:

- (1) Numbers of Action Officers estimated from Joint Military Telephone Book of Hawaii, 10/72, and Organization Directories.
- (2) Kunia requires special consideration
- (3) Message Processors Locations

SYSTEM ARCHITECTURE (cont.)

several sources, discussed in Section V. The map and table are keyed through the site numbers shown on the map.

TERMINALS

The action office is typically manned by one to six action officers and one or more secretaries or clerk typists. We can expect that the immediate evolutionary step into an automated system, though enhancing their actions, would not radically change the style of the action officers' work habits. Thus, we have assumed a soft (CRT) terminal and a hardcopy (printing) terminal available to the secretary and sometimes one or two additional soft terminals for the office, depending upon numbers of officers, traffic levels, and mission. There are no bothersome system limitations to these assignments, and they can grow and shrink on demand during operation.

Both the hard and soft terminal commercial markets in the United States are highly competitive and functional designs are well established. Soft terminals for the commercial market are not ordinarily designed with security considerations in mind (mainly due to RFI problems). However, we believe the technology exists to immediately and economically produce the appropriate terminals given the impetus of the number of terminals required for the Oahu complex.

SYSTEM ARCHITECTURE (cont.)

The hardcopy terminals should be assigned at various printing rates, depending upon traffic demands of the particular office. Care should be taken, however, in selecting relatively quiet printers in order to maintain a productive office environment.

SECURE NETWORK

There are two levels of security problems as indicated in Table 3. One is within the general service traffic where messages range from unclassified to top secret. Another dimension of classification within the general service traffic involves "eyes only", "specat", etc. To provide message security, all links between TIPs must be encrypted. Furthermore, TIPs must be placed in physically secure locations.

Separation of terminals on the basis of their physical point of connection provides the necessary security at the user-level, since there is no way for the user to modify the behavior of the processes within the TIPs. This philosophy is extant in AUTODIN. Terminals should then be placed in physical environments appropriate to use and security considerations.

Table 3

SECURITY CONSIDERATIONS

- ENCRYPTED LINKS BETWEEN TIPS AND SECURE TIP LOCATIONS
- TIP SEPARATION VIA SYSTEM PROCESSES ONLY
- MESSAGE PROCESSOR SEPARATION VIA SYSTEM PROCESSES ONLY

INTELLIGENCE-GENSER CONSIDERATIONS

- SEPARATE MESSAGE PROCESSOR AND TERMINALS WITH PRE AND POST-ENCRYPTION ACROSS THE NET
- SMALL SEPARATE SYSTEM

SYSTEM ARCHITECTURE (cont.)

The same design philosophy applies to the message processors, since there is no way for a user to modify the actions of the message processors. That is, the message processors execute only system processes and terminal devices are connected to the processors only through system processes in the TIPs.

INTELLIGENCE - GENSER CONSIDERATIONS

Intelligence information is a completely separate category of traffic which probably accounts for about 15% of all Island message traffic. Either of two solutions are recommended to handle the intelligence service. The preferred solution is to use a separate message processor and separate terminals but the same subnet for communications. The intelligence messages are pre-encrypted prior to entering the subnet and are de-encrypted after leaving. These external encryption devices would be provided only at IMP and terminal locations, combined within this framework, both intelligence and GENSER traffic can be combined within one common communication medium and yet fully separated in a security sense.

The alternative is a similar but smaller separate total system for intelligence traffic. The system would consist of independent connections to the ASC facility, and separate independent message processors, subnet, and terminals.

SYSTEM ARCHITECTURE (cont.)

SUMMARY

In summary, the proposed system architecture is based on the ARPANET, which has proven in three years of continuous service. It has demonstrated an ability to insulate itself from local outages, large growth, and the addition of many new service machines and users. It is employed by hundreds of simultaneous, interactive users throughout the United States, including Hawaii via a satellite link. The message processor candidates are based on operating systems which have been used on the ARPANET for services similar to those required by the proposed system. In short, the utility, performance capacities, development requirements, and costs of the proposed system are well established. A design based upon the ARPANET approach is implementable within two years, will meet requirements, and will provide an economic solution to the Oahu telecommunications problem.

V SYSTEM SIZING

INTRODUCTION

In order to accurately estimate the size requirements for the proposed architecture, the following sources were consulted: the 21 day COTCO study [5], Oahu military organization charts, staff directories, and maps of the physical area to be covered by telecommunications. Additionally, several man-weeks were spent in observing a wide variety of message system users. Distribution and quantity of message traffic, location of action officers, action officer functions, staff locations, and the availability of office support personnel were all factors used to determine the size requirements for the proposed system.

TERMINAL PLACEMENT

The goal of writer-to-reader automation through elimination of manned message centers requires that terminals be located within easy access of the user. The placement of terminals in this analysis is based on the number of action officers, how they are clustered, on office locations, and on the distribution of message traffic for the primary addressees.

SYSTEM SIZING (cont.)

An on-site inspection of many of the action offices revealed that from one to six officers occupy a single office, and that these officers are supported by one to three secretaries or clerk typists. It is recognized that few action officers type or care to type. Hence, terminal locations provide the option of either dealing directly on-line with the message-service or through a secretary, according to individual work styles. Personal observations were consistent with the subsequent analysis of the COTCO study data, showing mean physical clustering of action officers to be about four to six.

In an effort to size the problem, to estimate the number of terminals, and to estimate the complexity of wiring them into the network, four commands in four different locations were examined in detail. This analysis shows uniformity, which allows scaling upward to cover the entire Island with an accuracy appropriate to the limitations of the scope of this report. The commands examined were CINPAC at Camp Smith, PACAF at Hickam Field, CINCPACFLT at Makalapa, and USARPAC at Fort Shafter. Among the sites for which detailed information was available, USARPAC was selected for a detailed network terminal analysis. Due to the large number of buildings involved, this selection represents a "worst case" condition.

SYSTEM SIZING (cont.)

For this analysis, an Interactive terminal has been assigned to each office with four or fewer action officers handling more than 100 messages per week. An additional printing terminal (hardcopy) is assigned to be shared by two adjacent offices. This results in approximately one and one-half terminals per office. More extensive sharing of terminals is proposed for offices with less than 100 messages per week; which results in about one-half of a terminal per office, including the hardcopy terminals. For offices with five or more action officers, three terminals, including hardcopy, are assigned for those with high traffic volume, and one and one-half per office for low volume stations. Terminal placement should be reexamined with regard to the sensitivity of the mission of the station in order to determine those offices with requirements that deviate from the norm.

The results of the analysis are summarized in Table 2, including the scaling of terminal requirements for the entire Island based on the number of action officers determined to be at each location. The number of action officers was obtained from the Joint Military Telephone Directory of Hawaii. The analysis reveals a fairly consistent distribution of action officers over all bases considered and suggests that an extrapolation to the entire Island can be made at an average of three action officers per terminal (including both hardcopy and Interactive

SYSTEM SIZING (cont.)

terminals). It is estimated that 95% of the action officers have been accounted for in this analysis.

The TIPs are distributed over the Island according to the number of terminals required at a site, plus a few TIPs added to provide appropriate connectivity for reliability and for "soft failure" capability. The TIP distribution is shown in Table 2 and on the map of Figure 3. TIP siting is also based on the message processor locations (Kunila and Hickam), and on maximizing the reliability of operation for Hickam, Makalapa, Fort Shafter, Camp Smith, and Kunila. Where possible, multiplexers to nearby TIPs are used for locations with fewer than 20 terminals; they are also used within a base to reduce crypto requirements. A TIP can support 63 terminals and a multiplexer can support 16 terminals.

BASE COMMUNICATION

The detailed layout of ARPAC at Fort Shafter (Figure 4), illustrates the use of multiplexers to implement the connectivity of a base, as well as the connectivity of remote users around the Island. The multiplexer minimizes the number of TIPs required and reduces the number of crypto devices. The number of multiplexers required throughout the Island was calculated by scaling up from the Fort Shafter layout and is dependent on the number of buildings,

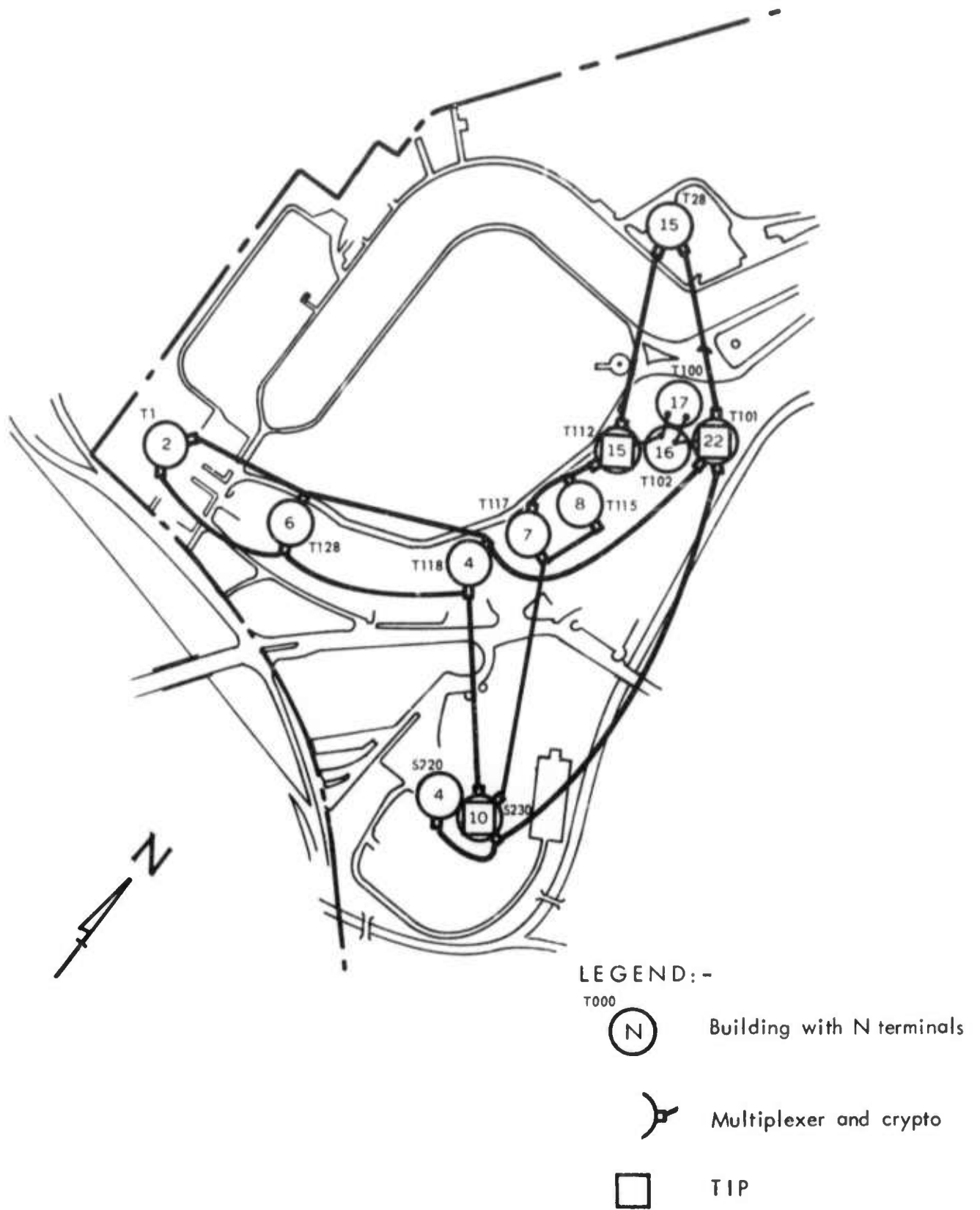


Figure 4. Example of intra site communications at Fort Shafter

SYSTEM SIZING (cont.)

clustering of users, and security restrictions within that location.

The connectivity of terminals to TIPs is accomplished so that each office or cluster of offices is doubly connected. That is, half of each of the clustered terminals are connected to one TIP and the remainder to a second TIP. In the event of a TIP or line failure, the office or building, remains connected to the network. It is assumed that most of the wiring is accomplished without the use of crypto devices (i.e. armored cable and properly identified conduit). The connectivity of the YIPs and TIPs to the network is part of the final overall network design and shown in Figure 2 for reference only.

TERMINAL CAPABILITIES

Interfacing the action officer to the network, message processor, and other data processing services necessitates a closely coupled man-machine system. The selection and specifications of terminals is critical with respect to the sensitivity, skills, and work habits of the user. Two types of inexpensive (about \$3,000 purchase price) terminals can satisfy the identified needs of the users of the message services: an interactive, soft copy terminal (CRT) with high speed electronic viewing surface, and a printing device (hardcopy).

SYSTEM SIZING (cont.)

The soft copy terminal is desirable for message creating and scanning functions, including message-delivery alarms and interrogating. When hardcopy is needed for presentation, draft copy, etc., output can be directed to a printer.

The speed of the terminal (and of the system) must be carefully matched for user response time expectations. A high speed display of at least 2400 baud and preferably 4800 baud is anticipated. Line buffering at the terminal on input is suggested in order to enhance system performance by reducing effective bandwidth requirements.

The hardcopy terminal will provide the printed page, which must be suitable for duplicating (Xerox, etc.), and also an additional keyboard for redundant terminal access. The printing mechanisms must be reliable and print at a variety of speeds to meet the variable traffic loads of the different offices. A "silent printer" is required so that it can be located within office spaces.

SUBNET CONSIDERATIONS

Network Analysis Corporation (NAC), Glen Cove, New York, through a contract with ARPA, has been responsible for the ARPANET topological design since 1969. To provide the most cost-effective designs subject to system constraints, NAC has developed a large body of analytical techniques that

SYSTEM SIZING (cont.)

have been implemented in computer programs for analysis and design of distributed packet-switched networks. These programs were used to provide the network cost and performance data in this report. The technique used employs a complex network analysis program that utilizes heuristic routing, time-delay and reliability analyses, and optimization algorithms to generate low-cost designs.

Under subcontract, NAC provided an analysis of network connectivity for estimates generated early in our study of traffic and terminal requirements. The breadth of their analysis has allowed us to supply reasonably accurate subnet costs, a configuration, and reliability estimates. The primary emphasis centers on cost, although other areas such as network reliability and response time are considered. The constraints on the topological design are the available common carrier circuits, the target costs and throughput, and the desired reliability.

As noted above, the network can be configured to obtain essentially any reliability figure desired. However, for reference purposes, the connectivity represented in Figure 3 will result in greater than 99.9% reliability for 97% of the terminal locations, and greater than 90% reliability for the remaining 3%, the noncritical locations.

Each TIP port interfaces one terminal to the network. TIPs are located at most of the 24 sites listed in Table 2.

SYSTEM SIZING (cont.)

Two TIPs are assigned to several locations even though the number of terminals at the location is far below the 63 ports a TIP can provide. A second TIP is assigned to improve reliability. No TIP is assigned to locations with very few terminals; rather, the terminals at these sites are multiplexed into a single line and demultiplexed at the TIP. Each demultiplexed channel is connected to one TIP port.

Numbers of terminals, TIPs, and multiplexers are listed in Table 2.

MESSAGE PROCESSOR TRAFFIC

Table 4 summarizes traffic levels in and out of the collective message processors. File access is also listed as an important determinant in system component selection. These data and access rates are peaked by 3 which is an upper bound on today's loading, and are based on the assumptions summarized in Table 5.

Some assumptions of the current traffic on the Island are summarized in Table 5. The certainty of each of these numbers varies; thus, they are worthy of a few brief comments. In general, the numbers reflect an upper bound where data were gathered at different times or estimates were made by different sources.

Table 4

PEAKTIME MESSAGE TRAFFIC FOR THE COLLECTIVE
MESSAGE PROCESSORS (MP)

| | <u>MP-TIP</u> <u>BITS/SEC</u> | | <u>MP</u> <u>FILE ACCESS</u> |
|---------------------|----------------------------------|------------|---------------------------------|
| | <u>IN</u> | <u>OUT</u> | |
| EDITING INPUT | 12K | | 30/SEC |
| COORDINATING OUTPUT | | 110K | 22/SEC |
| AUTODIN INPUT | 16K | | .3/SEC |
| AUTODIN OUTPUT | | 3K | .2/SEC |
| DISTRIBUTION OUTPUT | | 228K | 45/SEC |
| FILE UPDATES | <u>7K</u> | <u>7K</u> | <u>1/SEC</u> |
| TOTALS | 35K | 348K | 100/SEC |

Table 5

MESSAGE TRAFFIC

ASSUMPTIONS:

NO. MSGS./DAY GENERATED = 6000
ON OAHU

NO. CHARS./MSG. = 2.5K

EFFECTIVE HRS./DAY = 10

PEAK FACTOR = 3

AVG. NO. CHAR./LINE = 40

MSGS. FROM OFF-ISLAND = 15,000/24 HR. DAY

MSGS. TO OFF-ISLAND = 5,000/24 HR. DAY

SYSTEM SIZING (cont.)

Six thousand messages per day are generated on the Island. The average number of characters per message is 2,500, with a very wide dispersion from about half a paragraph to more than 25 pages. However, the average appears to hold over many sample days. A 10-hour work day is assumed since most personnel work an 8-hour day, although some duty watch level of activity continues 24 hours and weekends. Within the day there are several hours where the traffic is higher by a factor of 3 over the average. An average of 40 characters per line is assumed since the proposed system would involve line buffering by the terminal. The number of messages arriving from off-Island through AUTODIN is assumed to be 15,000 per 24-hour day. The estimate of messages generated on the Island destined for off-Island is 5,000 per 24-hour day.

Message creating and editing of 6,000 messages will generate about 12,000 bits per second at the peak hour of the day across the interface between TIPs and the sum of all message processors. Coordinating output is related to the number of messages generated, and is based on the assumption that during coordination a message will be examined 11 times on the average. Message processor interfaces to off-Island traffic are shown in Table 5, along with distribution output (which involves the message alert functions) and file updates (to keep the message processors in one-to-one correspondence).

SYSTEM SIZING (cont.)

Figure 5 is a summary, in abstract form, of the data flow through the collective message processors at peak periods. The archive file update rate is not peaked; it is averaged over 24 hours rather than 10.

The archive is not pictured in Figure 5 since it is unclear exactly where it should reside. It could, in fact, reside outside the network, say in Washington, D.C.

MESSAGE PROCESSOR REQUIREMENTS

The sizing of the Central Processor Unit (CPU) to perform the tasks outlined in Table 4 requires detailed analysis which is beyond the scope of this study. However, preliminary estimates based on the bandwidth requirements from TIP to message processor, the number of files accessed, the number of expected simultaneous users, and experience with TENEX providing similar services for the ARPANET indicate that five machines should be sufficient, including essential backup capability. Two of the message processors are used exclusively for intelligence traffic.

As suggested earlier, the use of Multics systems is an option. Based on other experiences, two Multics systems should have sufficient power to perform the GENSER message processing tasks. A WWMCCS is desirable as backup; otherwise a third MULTICS would perhaps be required.

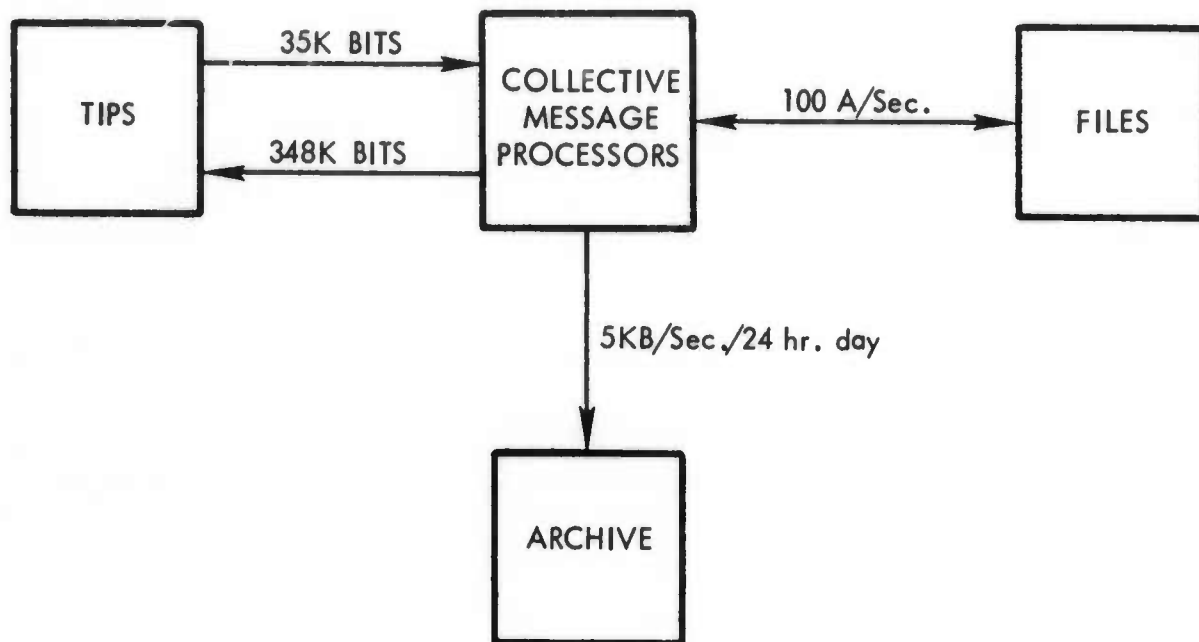


Figure 5. Message processors interface traffic (peaked)

SYSTEM SIZING (cont.)

INTELLIGENCE TRAFFIC TERMINAL CONSIDERATIONS

The terminal count for the Island is based on the organization directories and it must be assumed that the intelligence community has been taken into account since it is apparently a subset of the action people already considered. However, where both intelligence and GENSER traffic are made available to the same office, a separate terminal is required.

The special encryption device for intelligence traffic (Figure 6) must also be considered in the sizing of the system. These special encryption devices (we are told) are minicomputers and are attached to the TIP as a host capable of servicing several terminals. The data is asynchronous and requires a minimal amount of overhead traffic at the beginning and end of each transmission.

Therefore, if the system is sufficiently protected so that certain designated terminals can support Intelligence and GENSER traffic, the majority of terminals for this community have been considered. The option of implementing a separate Intelligence network would require additional terminals for the action officers.

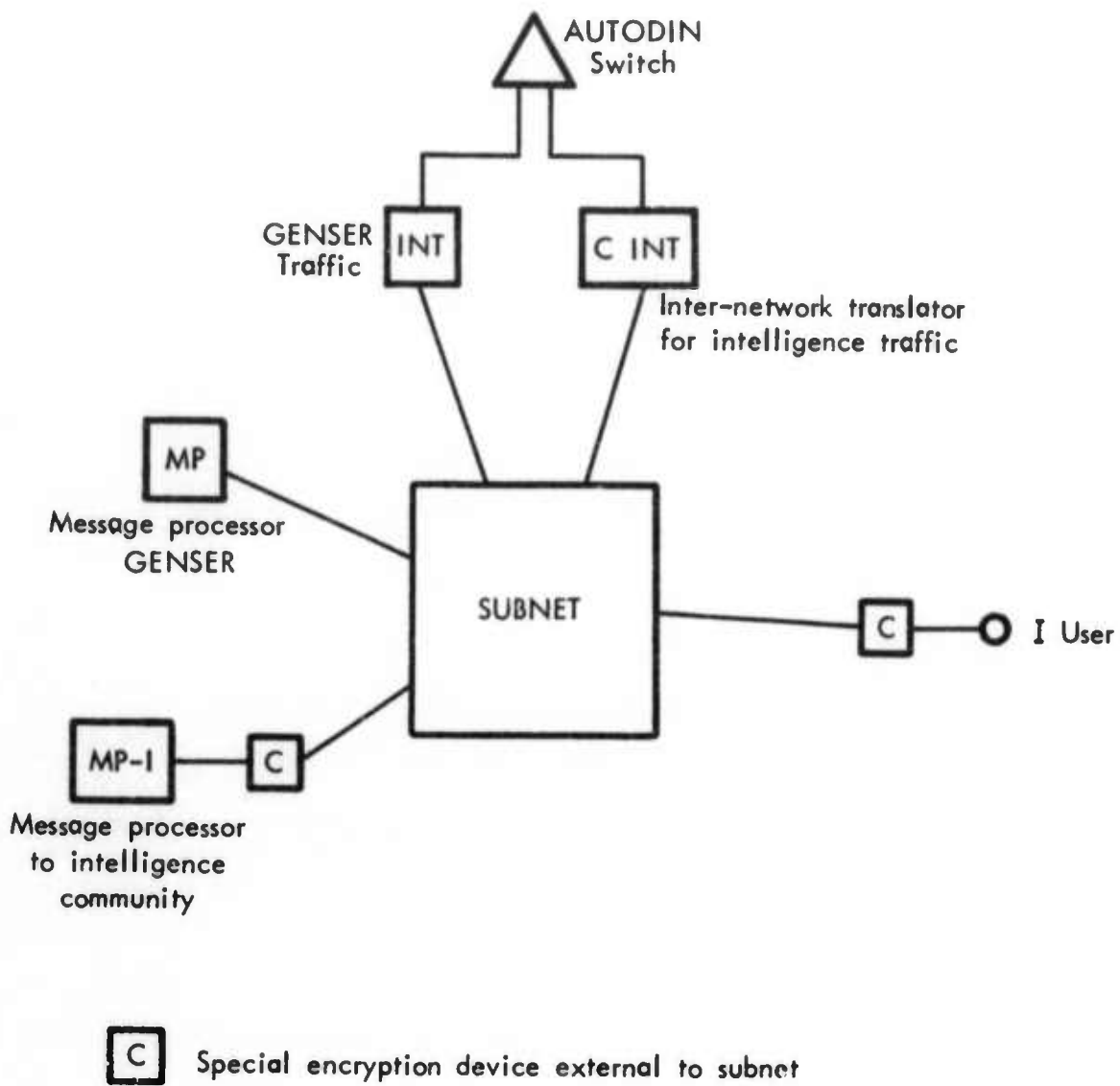


Figure 6. Accommodation of intelligence traffic over subnet by super-encryption

VI COST CONSIDERATIONS

INTRODUCTION

Budgetary estimates for the system as described in the previous section are summarized in Table 6. Implementation costs are shown for the TENEX plan. Commercial retail prices are used rather than GSA schedules. The Multics version would vary significantly upward only in processor costs. Software development estimates are also included in Table 6.

HARDWARE COSTS

The proposed architecture suggests a long system life expectancy. Thus, a reasonably safe amortization period of five years was chosen for the calculations appearing in Table 6, which yield an annual expenditure of \$4.72 million. The hardware line items of Table 6 are self-evident with the exception of communication links. The TIP-to-TIP link costs are based on an analysis of network topology provided by the Network Analysis Corporation.

COST CONSIDERATIONS (cont.)

SOFTWARE DEVELOPMENT COSTS

The labor charges of Table 6 (\$1.6 million) are based on an estimate of the number of man-years of development required by personnel currently engaged in similar ARPA-sponsored activities. These designers and programmers are experienced in interactive, resource-sharing systems and networks. In particular, they have been responsible for developing the major components of the recommended architecture, i.e. TENEX or Multics and the ARPANET.

A significant amount of money has been invested in the development of each of these systems (\$20 million for TENEX and \$40 million for Multics). Since each was designed with extensibility in mind, the low cost of Table 6 reflects the ability to capitalize on ongoing and prior developments. This architecture and these systems have been designed specifically as a solution to large-scale communications problems, and can therefore be economically adapted to Oahu.

OPERATION AND MAINTENANCE COSTS

Operation and maintenance personnel requirements are based on the five shift multiplier currently used on Oahu to account for sick leave, transfer, etc.

Table 6

MESSAGE SERVICE IMPLEMENTATION COST (TENEX PLAN)

| <u>HARDWARE</u> | | | |
|---------------------|-----------------|--------------------|----------------------------------|
| <u>ITEM</u> | <u>QUANTITY</u> | <u>TOTAL PRICE</u> | <u>FIVE-YEAR AMMORTIZED COST</u> |
| MSG. PROC. | 5 | 7.5M | 1500K/YR. |
| TIP | 37 | 3.7M | 740K/YR. |
| SUBNET CRYPTO | 164 | 1.6M | 320K/YR. |
| SUBNET MODEMS | 164 | .5M | 100K/YR. |
| TERMINAL | 2000 | 7.0M | 1400K/YR. |
| TERMINAL MUX | 167 | .5M | 100K/YR. |
| TERMINAL CRYPTOS | 167 | 1.7M | 340K/YR. |
| INT. NET. TRANS. | 2 | .2M | 40K/YR. |
| COMMUNICATION LINKS | 82 LINKS | | 180K/YR. |
| | | <u>22.7M</u> | <u>4720K/YR.</u> |

DIRECT LABORMAN-YEARS

SOFTWARE

| | |
|-------------------|----|
| TENEX | 15 |
| INT | 4 |
| TIP | 3 |
| FIELD ENGINEERING | 6 |
| DOCUMENTATION | 4 |

32 @ \$50K EACH = \$1600K

MAINTENANCE & OPERATIONSPEOPLE/SHIFT

MSG. PROC. PEOPLE

| | |
|-------------------------------------|----|
| HARDWARE MAINT. | 6 |
| SOFTWARE MAINT. & UPDATE | 6 |
| OPERATORS | 6 |
| SUPERVISORS | 3 |
| TIP MAINT. & FIELD SERVICE | 2 |
| TERMINAL MAINT./PERSONNEL EDUCATION | 12 |

35 x 5 SHIFTS = 175

MISC.

10

TOTAL 185

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VII IMPLEMENTATION CONSIDERATIONS

MESSAGE PROCESSORS

The preceding sections have presented a telecommunications system implementation which is an adaptation of an existing communications network -- the ARPANET. Candidate message processors were chosen from two systems currently in operation on the ARPANET: TENEX and Multics.

Neither of the candidate systems currently functions solely as a message processor. However, both of their operating systems lend themselves to modification in support of the message processing function. Necessary changes, and estimates of their complexity, are reflected in Tables 7-9.

The changes to either system are confined to those areas which address specific aspects of the message-processing function -- routing, releasing, distributing, etc. User-system interaction, such as text editing, is a capability that is available on both systems and would remain almost intact during the conversion of the system to a dedicated message processor. Similarly, the general resource-scheduling and resource-sharing mechanisms would be transferred intact to the message-processing role.

Table 7

MESSAGE PROCESSOR CHANGES

- SIMPLE EDITOR/FILE ACCESS
- TICKLER FILE/COORDINATION MODULE
- ROUTING FUNCTIONS
- RECEIPT OF MESSAGE POSITIVE ACKNOWLEDGEMENT
- AUTO DUAL FILE MAINTENANCE
- UPDATE DISK FROM CORE/DRUM
- REDUNDANT TIP INTERFACE
- ACCOUNTING, AUDIT TRAILS

IMPLEMENTATION CONSIDERATIONS (cont.)

MESSAGE PROCESSOR - NETWORK CONNECTION

The redundant TIP interface does not exist, nor are the existing accounting and audit trails adequate for the military environment. Functionally, these items are straightforward but they are not presently available on the ARPANET and would require a modest amount of development and implementation.

TIP CHANGES

The TIP improvements listed in Table 8 are self-explanatory.

INT SOFTWARE

The Inter-Network Translator software does not exist although the system functions and protocols are quite similar to those of other hosts on the ARPANET. Table 9 lists the basic function that must be programmed for this mini-computer.

WWMCCS INTEGRATION ADVANTAGES

Five WWMCCS machines, based on the Honeywell 6050 and GECOS3, are planned for Island data processing services. Table 10 lists some advantages of integrating these machines into the proposed communications network for message services.

Table 8

TIP CHANGES

- CRYPTO SYNCH FAILURE RECOVERY
- SECURITY LEVEL SEPARATION
- REDUNDANT HOST INTERFACE

Table 9

INT SOFTWARE FUNCTIONS

- ROUTING TO/FROM AUTODIN
- ROUTING TO/FROM MESSAGE PROCESSORS
- ROUTING TO/FROM OTHER HOSTS (WWMCCS)
- ALTERNATE ROUTING TO TIP STATIONS
- BI-DIRECTIONAL REFORMATTING
- ACCOUNTING AND AUDIT TRAILS

WWMCCS INTEGRATION ADVANTAGES

1. RESOURCE AND DATA SHARING VIA ESTABLISHED NET AT ESSENTIALLY NO ADDITIONAL COST.
2. COMMON TERMINALS-
REDUCE: COST, TRAINING, MAINTENANCE, ETC.
3. REDUNDANT FACILITIES PER USER EXTENDED TO USER LOCATION.
4. SOFTWARE COMMONALITY ENCOURAGED.
5. PROVIDES SIMULTANEOUS OAHU CONSOLIDATION AND WORLD-WIDE CONNECTIVITY.
6. POSSIBLE FUTURE COMMON WWMCCS HARDWARE FOR MP FUNCTION WILL PROVIDE FURTHER BACKUP.

IMPLEMENTATION CONSIDERATIONS (cont.)

The WWMCCS machines are not currently netted, but they can be connected to the proposed communication network at essentially no additional cost; assuming the operating systems on the machines provide the services, data sharing is instantly established to the then existent network of interactive terminals. Software commonality would be encouraged, which aids in consolidation of services and service centers, not only on the Island of Oahu but worldwide.

If Multics were chosen as the message processor, then there is the future possibility of common WWMCCS hardware [*], allowing emergency backup for the message-processing service and more flexibility in expansion and contraction, plus all the advantages of common hardware for maintenance, personnel, management, etc.

IMPLEMENTATION MILESTONES

It is necessary to bring up a new system in parallel to the existing centers so as not to disrupt message service for the action officer. Further, to establish confidence in system operation, implementation should be staged so that it can be provided in parallel at one major command within the Oahu complex. Camp Smith is felt to be a good choice since

* The Honeywell 6050 is field-upgradable to the Multics

IMPLEMENTATION CONSIDERATIONS (cont.)

It is the site of the CINCPAC communications group. As shown in Table 11, this milestone would involve several hundred terminals so as to completely service that command. Also because of the compactness of this site it can be implemented with minimal line and equipment installation. Figure 7 indicates the probable distribution of equipment and conduit requirements for Camp Smith. A parallel connection to AUTODIN and a second message processor (for continuous service) would be established to provide a complete parallel message service for that major location. At this point, the system would serve the command completely while backed up by the old system. The end goal of this phase would be to establish user confidence to support the next phase.

The second major phase would be the extension of the service to all sites and replacement of their present systems as user confidence is instilled. Lastly, other services, such as WWMCCS, would be incorporated.

IMPLEMENTATION MILESTONES

I. ESTABLISH SYSTEMS CONFIDENCE

- SMALL NETWORK TO PARALLEL EXISTING ON-ISLAND MESSAGE SERVICE AT ONE MAJOR SITE
 - 1 MESSAGE PROCESSOR
 - 4 TIPS
 - 200 TERMINALS

- PARALLEL CONNECTION TO AUTODIN SWITCH
 - 1 INT
 - 1 TIP

- 2ND. MESSAGE PROCESSOR FOR CONTINUOUS SERVICE

II. ESTABLISH USERS CONFIDENCE

- PROVIDE FULL MESSAGE SERVICE
 - 1) ASSUME PRIMARY SERVICE FOR CURRENT SUBSCRIBERS
 - 2) EXTEND SERVICE TO ALL SUBSCRIBERS FOR TOTAL OF:
 - 4 MESSAGE PROCESSORS
 - 37 TIPS
 - 2000 TERMINALS

 - 3) INTEGRATE WWMCCS

- INTERCONNECT AND INTEGRATE OTHER SYSTEMS

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