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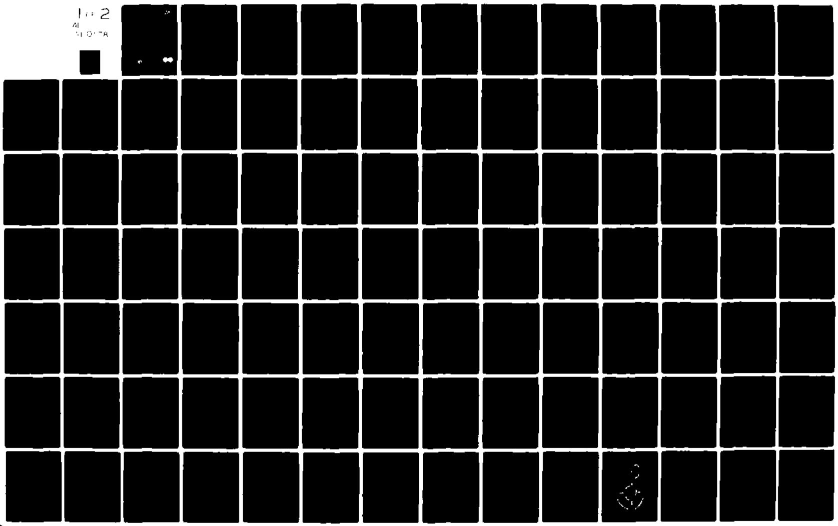

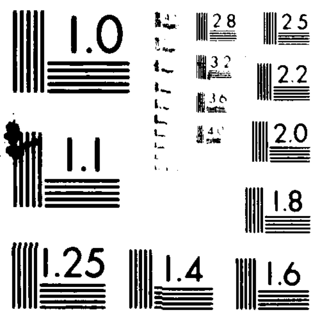


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FINAL TECHNICAL REPORT
GIT/EES PROJECT A–2426





# ADVANCED INFORMATION SYSTEMS RESEARCH PROJECT

By

Edward J. Shanahan, Jr.
Computer Science and Technology Laboratory



Prepared for

DEPARTMENT OF THE ARMY
Army Institute for Research
in Management Information
and Computer Science

through

MERADCOM, Fort Belvoir, Va.

Under

Contract DAAK 70–79–D–0087

June 1980



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20. (continued)

investigated to assist in the fielding of future systems.

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Atlanta, Georgia 30332

# ADVANCED INFORMATION SYSTEMS RESEARCH PROJECT

Phase I

Final Technical Report

by

Edward J. Shanahan, Jr.

of the

Computer Science and Technology Laboratory

GIT/EES Project A-2426

H. Bennett Teates - Project Director

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H. Bennett Teates

Project Director

# ABSTRACT

The Advanced Information System Research Project is a long-term effort to develop a sound technical, economic, and military basis for the support of future (1985+) information systems for the U.S. Army. This study investigated the needs and requirments of U.S. Army information systems; assessed technology in terms of systems, hardware, software, communications and ADP capabilities of Eurasian Communist countries; assess the environment in which the systems would operate; and derived generic requirements for post-1985 information systems and selected technical research issues which must be investigated to assist in the fielding of future systems.

Key Words

Information Systems

Technology Assessment

Information System Environment Assessment

Advanced Prototype Demonstration

Technology Infusion

Life-Cycle Acquisition

## EXECUTIVE SUMMARY

Phase One of The Advanced Information System (AIS) Research Project is the beginning of a long-term effort to develop a sound technical, economic, and military basis for the support of future (1985+) *information systems* (ISs) for the U.S. Army. The objectives of this study were to: assure that the spectrum of Army knowledge and experience in ISs is identified; designate the generic functional requirements for future ISs; identify general areas of research and development required to fulfill future IS expectations; and begin the development of the functional technology base needed to support a Concept Definition for IS engineering developments that might be initiated in the mid-80s.

Research methods used in support of this study include: research of existing literature (periodicals, manuscripts, unpublished reports, and text books); personal interviews with user representatives and system designers; distribution of a questionnaire to major commands and interested agencies; conduct of a three-day workshop to solicit ideas from user representatives and system developers in the combat services support *functional area*; and briefings and presentations from government agencies and industrial firms working at the forefront of IS technology. In the course of conducting the research, a library of periodicals, trir reports, reports and manuscripts, and texts was established.

Results of the research are:

- Current Army information systems were developed to meet peacetime vice wartime roles. As such, they are not responsive to the requirements of the commander and his staff in combat.

- Perceived needs of Army personnel to meet wartime information requirements on the battlefield can be met by interactive, on-line systems. These systems require flexibility, may have distributed processing and storage schemes, and are highly communications dependent.

- Information systems are not a replacement for the individual. Rather, they must be developed to support him by relieving him of tedious repetitive tasks and by providing quick, multi-formatted information to support the decision process.

- Current laws, rules, and regulations are not in themselves barriers to effective IS implementation. However, a process more amenable to the necessary evolution of system requirements may be a coordinated program of research, development, test, and evaluation in a use-learn-develop cycle. This process can best be achieved by the establishment of mini-test beds, termed Advanced Prototype Demonstrations, where design issues can be investigated and results disseminated to appropriate agencies.

- There has been substantial advancement in technology required to meet the needs of future Army information systems. However, numerous issues still must be resolved prior to the fielding of these systems. Such issues are:

  - System interface between command and control and combat service support;

  - Multiple echelon reporting techniques;

- Digital communications requirements;
- Information system network analysis;
- Network security;
- Modern continuity of operations;
- Future data base management systems;
- Decision support system applications; and
- Input/output requirements.

In conclusion, to develop a sound technical, economic, and military basis for future Army ISs, it is recommended that AIRMICS:

- Adopt the Advanced Prototype Demonstration (APD) method for support of technical investigation and to assure that results are available to users, developers, designers, and appropriate agencies in the post-1985 period.

- Study the research issues listed above to determine those with greatest impact on the Army's needs in the post-1985 period.

- Develop a plan to investigate these issues in depth using the vehicle of APDs.

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ADVANCED INFORMATION SYSTEM RESEARCH PROJECT

# 1.0 INTRODUCTION

## 1.1 Background

The Army Institute for Research in Management Information and Computer Science (AIRMICS) is the research arm of the U. S. Army Computer Systems Command. In undertaking research projects, AIRMICS must strive to balance long-term objectives with realistic near-term achievements. The research program objectives are to develop, manage, and coordinate activities relating to the following:

- o Integrated communications planning, hardware, and software programs to satisfy current and future automation needs for both garrison and field operations which will also support the Army's mobilization and wartime missions;

- o Methodologies to assist users to recognize, formulate, and accurately state their requirements;

- o Description and definition of the software development life-cycle and the metrics appropriate for estimating, measuring and controlling resource utilization;

- o Management assistance by publishing significant research which contributes to the understanding and control of software development;

- o Development and demonstration of tools, techniques, procedures, and advanced design concepts applicable to future management information systems; and

- o Development of tools, techniques and procedures to improve the productivity of personnel in the software development process and to increase the reliability of software systems.

The Advanced Information Systems Research Project, the first phase of which is reported in this document, is a long-term effort undertaken by AIRMICS to develop a sound technical, economic, and military basis for the support of future (1985+) information systems (ISs) for the U. S. Army.

## 1.2 Purpose

The objectives of this phase of the project were to: (1) assure that the spectrum of Army knowledge and experience in information systems was identified; (2) designate the generic functional requirements for future ISs; (3) identify general areas of research and development required to fulfill future IS expectations; and (4) begin the development of the functional technology base needed to sustain a Concept Definition for IS engineering developments that might be initiated in the mid-80s.

## 1.3 Methods

The study was divided into four subtasks:

- o Needs and Requirements Assessment;
- o Technology Assessment;
- o Environment Assessment; and
- o Analysis and Report.

Research methods used in support of these four subtasks included:

- o Research of existing literature (periodicals, manuscripts, unpublished reports, and textbooks);

- o Personal interviews with user representatives and system designers;
- o Distribution of a questionnaire to major commands and interested agencies;
- o Preparation and conduct of a three-day workshop to solicit ideas from user representatives and system developers of the combat service support functional area; and
- o Briefings and presentations from government agencies (e.g., DARPA and ARI) and industrial firms working at the forefront of IS technology.

The bibliography lists the literature used in this study. These documents are organized to provide the nucleus of an IS library. The following visits or interviews were made to obtain an insight into future requirements of the Army:

| Date | Unit/Agency | Activity |
|---|---|---|
| 23 Aug 79 | Combined Arms Center Development Activity | Visit |
| 24 Aug 79 | Defense Advanced Research Projects Agency | Visit |
| 24 Aug 79 | Defense Intelligence Agency | Visit |
| 5 Sep 79 | US Army Force Command | Visit |
| 19 Sep 79 | US Army Signal Center | Visit |

| | | |
|---|---|---|
| 19 Sep 79 | National Bureau of Standards | Telephone Interview |
| 20 Sep 79 | US Army Computer System Command (USACSC) | Visit |
| 24 - 27 Sep 79 | US Army Europe (USAREUR)<br>USACSC Support Group, Europe<br>21st Support Command<br>V Corps Automation Management Office<br>3rd Armor Division<br>USAREUR Office, World-Wide Military Command and Control System<br>25th Data Processing Unit | Visit |
| 1 Nov 79 | USACSC Support Group Fort Lee, VA | Visit |
| 2 Nov 79 | US Army Military Personnel Center | Visit |
| 8 Nov 79 | US Army Electronics Laboratory | Visit |

Additionally, a three-day workshop attended by representatives of the combat service support community and system developers was conducted in Atlanta, Georgia, in December 1979. Proceedings from that workshop are documented under separate cover (Advanced Information Systems Concepts Research Workshop, 12-24 Dec 79).

## 1.4 Organization of the Report

The organization of the remainder of this report is divided into six sections:

- o Needs and requirements assessment;
- o Technology assessment;
- o Environment assessment and implementation of advanced information systems;
- o Generic requirements and technical research issues
- o Results/conclusions; and
- o Recommendations.

Section 2 addresses current Army ISs, the requirement for future systems, and develops potential research areas required to support future Army ISs. The Technology Assessment, Section 3, provides a perspective on the technology base that will be available to support ISs in the post-1985 period. It includes an examination of current, emerging, and projected computer hardware, software, development technology, and telecommunications networks and provides an unclassified summary of Eurasian communist countries' automation capabilities. Section 4 identifies and evaluates factors which affect the implementation and operations of ISs. Included in this section is an analysis of government policies and regulations and their impact on ISs. Section 5 summarizes the generic requirements and presents research issues requiring future investigation. Sections 6 and 7 address results/conclusions and recommendations, respectively.

# 2.0 NEEDS AND REQUIREMENTS ASSESSMENT

## 2.1 Background

The purpose of this assessment was to generate requirements for the 1985-95 time period to support the identification of a generic IS. Using these requirements, coupled with a survey of existing and planned technology, a forecast of areas needing research to support a generic system could be identified. This forecast will be used by AIRMICS as a guide for future planning and budget development efforts.

The functional area of combat service support (CSS) at division level was selected as the focus of the requirement effort. The primary reason for using CSS as the vehicle for deriving requirements is that USACSC, the parent organization of AIRMICS, concentrates its work in this area. In addition, the area of automated support of command and control ($C^2$) within the Army is under continued investigation.

Specific CSS areas investigated were logistics and personnel, both in their present and future forms. The basis for the development and operation of these systems is addressed in Section 4, the environmental assessment. However, for clarity, some conclusions developed in that section are presented below when discussing the rationale for the current systems.

## 2.2 Present Systems

As stated, the current combat service support system is divided into two functional areas: logistics and personnel. Logistics is further partitioned into the Division Logistic System (DLOGS) and the Maintenance Reporting and Management (MRM) System. The personnel system is the Standard

Installation/Division Personnel System (SIDPERS).

The CSS system equipment consisting of two vans, three M109 shop vans, and a power source is organic to the Division Data Center (DDC). Computer hardware consists of an IBM 360/30 with expanded memory and associated mass memory devices. This equipment is housed in the two 35-foot mobile vans. The three M109 shop vans are provided as part of the DDC; one is designed to accomplish a maintenance/parts load list mission, another is used to store paper, and the third van is designed to house automatic data processing (ADP) support equipment. Two of the shop vans tow the 100KW generators.

By its size, the signature that this configuration presents on the battlefield is noteworthy. Also, while the DDC is mobile, the nature of the operational requirements (i.e., vans must be leveled and air conditioned prior to operations) dictates that the DDC not be moved frequently. Thus, the size and nature of the operations of the ADP equipment is considered by many to be a hindrance to battlefield operations.

Details concerning the logistic and personnel systems follow.

2.2.1 Logistics System. The present automated logistics system addresses supply and maintenance at division level and supply at non-division and corps levels. Specifically, at division, the following functions are automated.

- Supply: Three separate subsystems perform supply functions.

  (a) DLOGS - This subsystem performs the functions of stock control and inventory management of repair parts. Requisitions are processed along with transactions that change quantity, conditions, locations, and other identification of items. History transaction information is maintained. Inventory count cards and related reports, supply management data, and performance statistics are produced.

(b) Property Book - All management is consolidated under the Division Property Book Officer. Property book accountability is maintained under the provisions of AR 735-35, and necessary information is maintained on ADP listings. The property book management system provides for maintaining a due-in file of all expendable requirements and provides elements for unit readiness reporting.

(c) Army Equipment Status Reporting System (AESRS) - This subsystem extracts asset data from the ADP records and produces necessary reports for AESRS.

o Maintenance: The CSS Maintenance Reporting and Management (MRM) system consists of two subsystems.

(a) Maintenance Control System (MCS) - This subsystem is a workload accounting system for use in the direct support/general support (DS/GS) production control office at the shop level and in the Maintenance Battalion Materiel Office or Division Materiel Management Center (DMMC), depending upon TOE series. MCS has been designed to assist the maintenance manager by recording and accounting for data on maintenance requests.

(b) Modification Work Order (MWO) - This is an accounting subsystem that serves all levels of management in the division by providing an accurate and efficient method for the storage and display of the large volume of MWO data. The subsystem is designed to assist MWO management by insuring that MWO's are applied in a timely manner. To assist in the MWO management function, the system maintains a current master index of MWO requirements, a file of MWO assets, and the status of each requirement.

At non-divisional level, the Direct Support Unit Standard Supply System (DS4) provides automated services. DS4 provides automated processes which accomplish inventory record and management information support for repair parts supply (Class IX), general supplies (Classes II & IV), and packaged petroleum products (Class III). Included within DS4 is the capability to fully automate prescribed load list support, the direct support supply system, and the quick supply store.

At installation and corps level (where CSS must interface), supply (and often financial management) are automated in the Standard Army Intermediate

Level Supply System (SAILS). This system is designed to accomplish all stock control and supply management between the wholesale level in CONUS and the direct support system. The hub of the current SAILS system consists of the basic supply cycle steps: input preparation, stock location, and pre-edit steps; document history validation; catalog validation; consumer fund certification; supply main balance; document history update; basic finance; daily supply control study; output processing for AUTODIN transmission; and medical quality control.

In sum, all of the currently automated logistic systems are transaction oriented, using card input and employing batch processing. The key to initiation of activity is the punched card which indicates the item desired by organization. These are entered into the system at division or non-division level during periodic cycles, normally daily. Limited user interaction, such as querying the data base, is permitted. The logistic system is "stovepipe" in nature with few interfaces with other systems (e.g., personnel) at the same organizational level. Large communications systems (AUTODIN) and hand-carried pouches move data from information node to information node. A typical transaction from an overseas user to the wholesale service center takes about six days. The system accesses extremely large data bases with an average of 77,000 transactions per day. Information is provided in bulk record (132-column) printout. Therefore, to determine a specific item of information, a great deal of manual search, extraction, and accumulation is required.

2.2.2 Personnel System. The automated personnel system is the Standard Installation/Division Personnel System (SIDPERS), which provides for personnel management and administration functions of the division and installation.

SIDPERS has been designed to perform the major functions of strength accounting, organization and personnel record keeping, interface system reporting, and management reporting. It serves all permanent party personnel at the installation as well as personnel assigned to units in the same geographical area. For each SIDPERS installation, maximum capacity of one data base is 1,000 organizations and 50,000 personnel records.

SIDPERS is designed to interface with the Joint Uniform Military Pay System (JUMPS), the Trainee Accounting and Management System (TAMS), and the Centralized Assignment Procedure III (CAP-III). It reports directly to Headquarters Department of the Army (HQDA) without the intervening processing performed by the Continental Army and Major Overseas Command System (CARMOCS). All activities currently use this capability with the exception of USAREUR. The Vertical Army Authorization Document System (VTAADS) provides authorization and organization structure data which are used to make personnel requisitions and assignments and to validate authorized strength.

There is a high degree of similarity between the personnel and the logistics systems. SIDPERS is a card input, batch processing system with cycle reporting (normally one per working day.) There is little direct user query interaction with the system. SIDPERS is a large system in many ways: 24 volumes of functional specifications; 200 program modules; 9,000 input transactions; 11 data files; 355 options on 135 reports; 600,000 lines of code; handles 1,000 unit and 50,000 personnel per site; and accommodates 15,000 Army registered units. Records are large and there are approximately 250,000 transactions weekly. There is little interface between SIDPERS and other systems with the exceptions noted above.

There have been recent efforts of the personnel community to modify SIDPERS to improve the support provided in terms of war (SIDPER-WT). The objectives of this conversion are to provide only essential information to commanders, to provide only essential personnel data to HQDA, to handle force expansion, and to reduce runtime.

There are numerous systems which should and in the future will interface with CSS. The command and control system has the need for information (in summary format) which is developed in detail within CSS. This interface in terms of information content and method of transmission has yet to be defined. However, documents such as the Army Command and Control Master Plan, the draft Tactical Interface Concept (TIC) and the Automated Battlefield Interface Concept (ABIC) recognize in general terms the requirement for the interface. Further work in this interface definition is suggested.

## 2.3 Basis for Present Systems

The ISs described above are products of the environment in which they were developed. The CSS system concept stems from Army-initiated studies beginning in 1956. In May 1965, Department of the Army approved an implementation plan for the development of the Automatic Data Systems within the Army in the Field (ADSAF). This plan identified three ADSAF systems: Tactical Fire Control System (TACFIRE), Tactical Operations System (TOS), and CSS.

CSS systems were developed in a time period dominated by large-size computers generating 132-column reports produced in a cyclic basis. Input media for the time was generally punch cards, a modernization of Hollerith's technique developed to count the population during the 1880 census. Thus, the initial and continuing concept of providing combat service support has been card input, large size, van-mounted computers producing periodic reports on bulk record (132-column) format.

Legislation and internal studies provided added impact on the systems of the period. Primary importance can be given to Public Law 89-306 (Brooks Bill) and the Army's Study of Management Information System Support. The Brooks Bill established a management "chain of command" to insure better utilization of ADP resources. The General Services Administration (GSA) has overall control, acting as the central agency for all ADP purchases, leases, and maintenance contracts. The Office of Management and Budget (OMB) assists GSA within the executive branch. The Assistant Secretary of Defense, Comptroller is responsible to the Secretary of Defense for administration and management of Defense ADP activities. The Assistant Secretary of the Army for Installation, Logistics, and Financial Management is responsible to the Secretary of the Army for the management of Army ADP activities.

While the impacts of the Brooks Bill were still being felt, President Johnson and Secretary of Defense McNamara directed, during June and July 1966, that emphasis be placed on the standardization of ADP systems for multi-installation use and that these standard systems be designed by centralized agencies. As a result of these directives, the Chief of Staff of the Army (then General Harold K. Johnson) initiated a Study of Management Information Systems Support (SOMISS) to determine appropriate changes needed in policies, procedures, and organization in order to make the best use of the Army's automatic data processing capability. The study was completed in six months and received input from 24 HQDA staff agencies and major commands. The general conclusions of the study were as follows:

> The Army does not possess, nor can it acquire, sufficient technical expertise in ADP systems to continue the current practice of developing many systems on a fragmented, nonstandard basis. It must exploit every opportunity for development of ADP systems which can have multiple-command, multi-organizational/echelon use. To do this, it must move

> steadily to further consolidate and centralize planning, management, systems design, and technical support for information systems. Responsibility for the formulation of information requirements must also be consolidated so that for Army standard/centralized design efforts, the systems designers have only one source for functional guidance. This source should be the HQDA Staff.

There were 20 approved recommendations in the SOMISS. The recommendations required changes in ADP development thinking from Department of the Army down through the major commands to the individual user. The study called for drastic changes in organization.

The major impacts of the SOMISS were centralized Army IS development as much as possible, standardized documentation of applications, the creation of two new terms - multicommand systems and command unique systems, and the major DA staff agencies and selected special staff agencies were provided Class II activities to provide ADP support facilities or computer centers.

SOMISS guidance is still being followed today with the result that system design philosophy is toward systems developed and operating along functional (stovepipe) lines rather than integrated at command echelons. The goals of these systems are more oriented towards the problems and requirements of HQDA rather than field units.

A third factor which influenced the present systems was the manner by which they were developed. User representatives defined in general terms the need that the system was to meet. These needs were then expressed in more granular terms by a user proponent and passed to the system designer, who translated them into system specifications. A development process followed with the aim of meeting the stated specifications. During the course of the development cycle, user requirements changed and often there was a substantial change in the technology base potentially available to the developer. Since the design was essentially "frozen" in the form of system specifications, the developer community could not adjust to meet the new situation; new user requirements were not accommodated and systems were developed with old technology. This process resulted in systems being fielded (or often delayed for lengthy periods if there was a strong functional proponent) that did not meet users needs and were technologically dated. The basic cause of this phenomenon does not appear to be poor user representatives or system developers. Rather, it is the failure to understand that requirements will always change during system development and to accommodate this fact into the system acquisition process.

## 2.4 Future Systems

Review of available automated battlefield planning documents (e.g., ABIC, AC2MP, BAMP, and BAA III AND IV), interviews with both user representatives and system developers, and responses to the questionnaire indicate that the current systems will not meet current or future battlefield requirements. This conclusion is based on the nature of the systems themselves: card-input, daily cyclic reporting, bulk report output, and limited user interface. In addition, system users have witnessed the technological development of the mini/micro-computers and heard the praises of advocates (such as Captain Grace Harper, USN) of networks supporting these computers to provide real-time processing. Thus, a combination of disillusionment with the status quo and a need for current technology to support the battlefield have caused both users and developers to consider systems other than those employing batch processing.

2.4.1 Future Trends in Requirements. Through research, discussions with users and developers, and participation in the workshop, trends in future system requirements were noted. Many user representatives were able to verbalize these requirements in part. The proponents of personnel systems have made some strides in documenting their future systems needs which are representative of other developers presented at the AIS workshop, December 1979. The personnel community is attempting to meet future needs by looking at systems which embrace:

- The flexibility, modularity, and lower cost inherent in the micro-mini computer technology.
- The emerging realization that the Army functional communities on and off the battlefield need, and can now afford, their own stand-alone systems.
- The use of state-of-the-art hardware and modern system design techniques.
- The realization that a family of standardized hardware subsystems could and should be developed for the TOE and TDA Army similar to the family of tactical radios.

This approach allows for interchangeability, hence automation redundancy, reduction of computer vulnerability and increases computer availability and system reliability.

This design philosophy attempts to meet the following generic needs:

- Modularity. The Army personnel system must be capable of meeting the needs of the Army in several environments, i.e. combat, mobilization, and peacetime. Each of these environments utilizes various common functions as well as exclusive functions. Each of these functions would be designed into a module. The system must be adaptable by adding to the common modules those exclusive modules required by a particular operating environment, thereby optimizing the system for that environment. By exercising the common modules daily, user skills and familiarity will be enhanced, adequate system support will be insured, and transition of the system between environments will be eased.
- Functional Ownership of ADP Resources. The functional manager at every command level needs to control his system resources to insure responsive support. All functional areas have a bona fide need for their own system, to eliminate the contention for computer run time of present day "shared" support operations and to reduce the load otherwise placed upon communications channels. In time of mobilization and wartime, this contention and communication loading could prevent a commander or staff officer from getting timely and critically needed information. This would be a valid first step

toward giving the commanders and functional staffs a tool to help manage their people and other resources.

- o Discretionary Access. The system should be primed, waiting to be used. It must be the means with which we function, rather than the end for which we function. There are functions that could be supported which would capitalize on the variety of information already in digital form but which must be manually prepared on documents later used as sources to be data reduced and data processed. When an action needs reporting, the system should be available. When information is desired, the system should be available.

- o Responsiveness. Experience shows that everyone cannot be satisfied with a standard product. Standard reports perform an important task, but additional system flexibility must be available to allow the user to define his informational needs in his own way, and to rapidly receive a useful response on which to base a decision.

- o Improved Data Reduction. Data capture as close to the source as practical is needed to insure timeliness and accuracy. Provisions must be made for: using data already recorded; performing extensive editing; visual (and in some cases audio) feedback; use of clear, understandable, helpful instruction; simplified operating procedures; automatic data communications access; alternative or backup data transmission method; and user confidence through instantaneous information feedback.

- o Reduction of Paper. By providing users direct access to data and by interconnecting system components, useful information can be visually displayed to enable the "operator" to be selective. This is contrasted with today's system which produces hardcopy of virtually everything in hopes that the information wanted/needed is printed out. A printing capability must be available since it may be necessary to transmit report/record data from one system component to another and, after viewing, have it printed on demand.

- o Data Integrity. When a data base contains data that is maintained at numerous locations, and the primary data base is updated, all data stored at other locations should be changed automatically without human intervention or special cyclic processing.

- o Quality of Data. The level of criticality of data elements must be determined in conjunction with the specific information that is supported by the data element. The criticality of a data element may vary depending upon the information that it is supporting. The criticality will be determined based upon the perishability, compatability requirements, and accuracy probability of data elements.

2.4.2 Information Networks. To be successful, the designer of an IS must meet the needs of the battlefield user. While these needs may not now be clearly defined by doctrine, the developer of systems of the post-1985 time period should anticipate requirements and design systems with sufficient flexibility to accommodate subsequent changes. The personnel systems proponent has stated requirements for peacetime, mobilization, and wartime. Analysis of these statements indicates that the modularity, responsiveness, functional ownership, and other attributes described by the personnel community can best be met by mini/micro-computers linked together via information networks. A brief description of information networks follows.

Becker describes all systems as having the basic functional sets of information processing, network processing, and data base processing. He defines information processing as the manipulation (by application programs) of information to produce the desired results. Network processing is the control of information movement between the various locations (nodes) of the network. Data base processing is the storage of quantities of information in one or more forms available to the network and its users.

In the 1960s (and in current Army ISs computer installations) all three functions were (and are) contained and executed in essentially a single computer per installation (See Figure 2-1); thus the requirements of economy of scale were met with responsiveness being sacrificed. As overhead on the computer grew and attempts were made to obtain more efficiency within the central processing unit of the computer, the mid-60s saw the initial separation of functions that produced the front-end processor (Figure 2-2). This approach, however, still retained all functions at the same location. With the trend towards on-line data bases, there was a higher level of interference between the information processing and data base processing functions as they competed for common resources. This confrontation resulted in solutions such as those presented in Figure 2-3.

Figures 2-1 through 2-3 are considered central processing as all of the functions reside at a single location. Figures 2-4 through 2-6 are examples of partially to fully distributed systems.

No one system can be considered the best; rather, the candidate that best meets the users' needs with economies can meet that claim. The problem arises when the program manager attempts to select that candidate that best meets his needs. In the current environment, he is left to his own resources to make that decision in the face of rapidly approaching deadlines and without rules by which to guide his judgment.

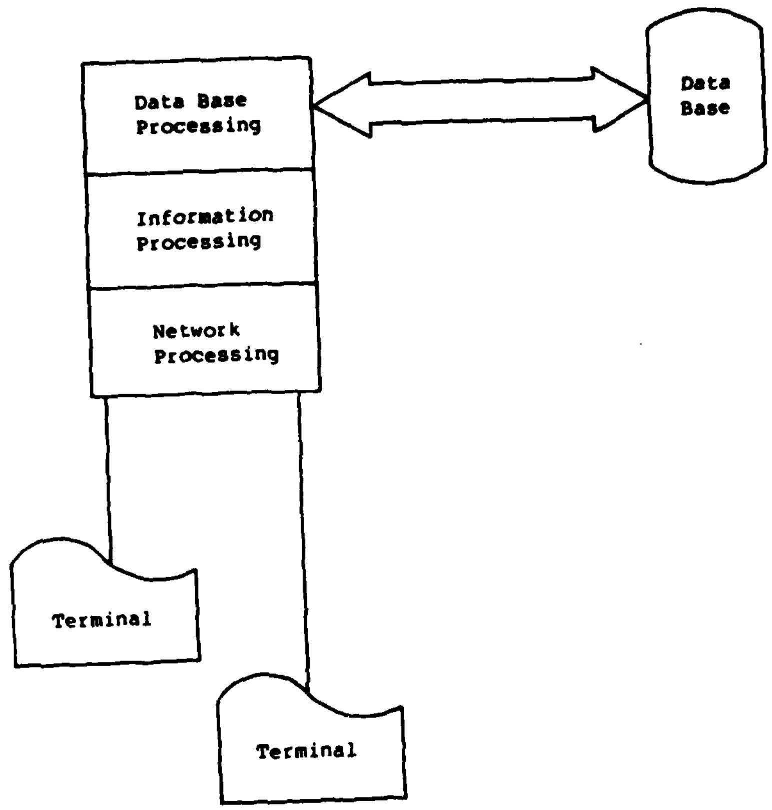
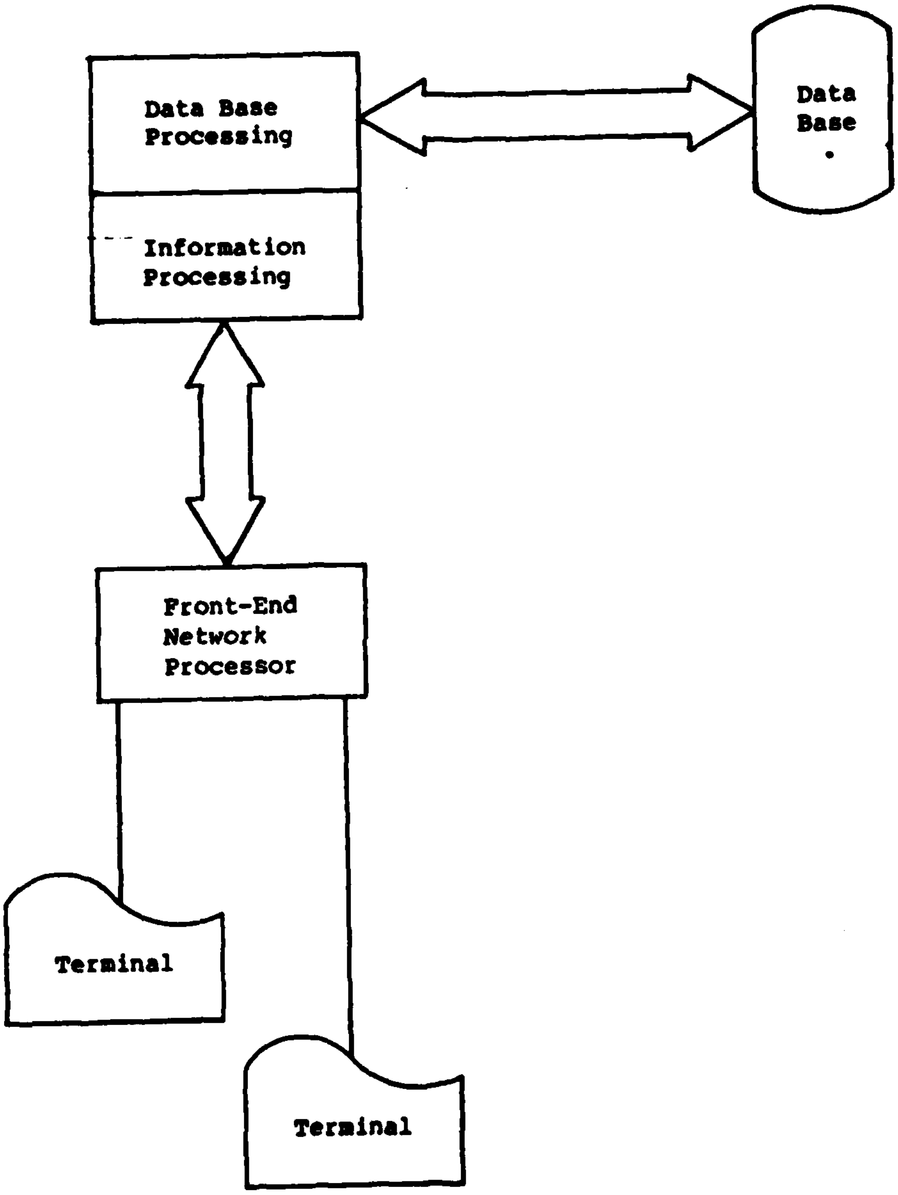


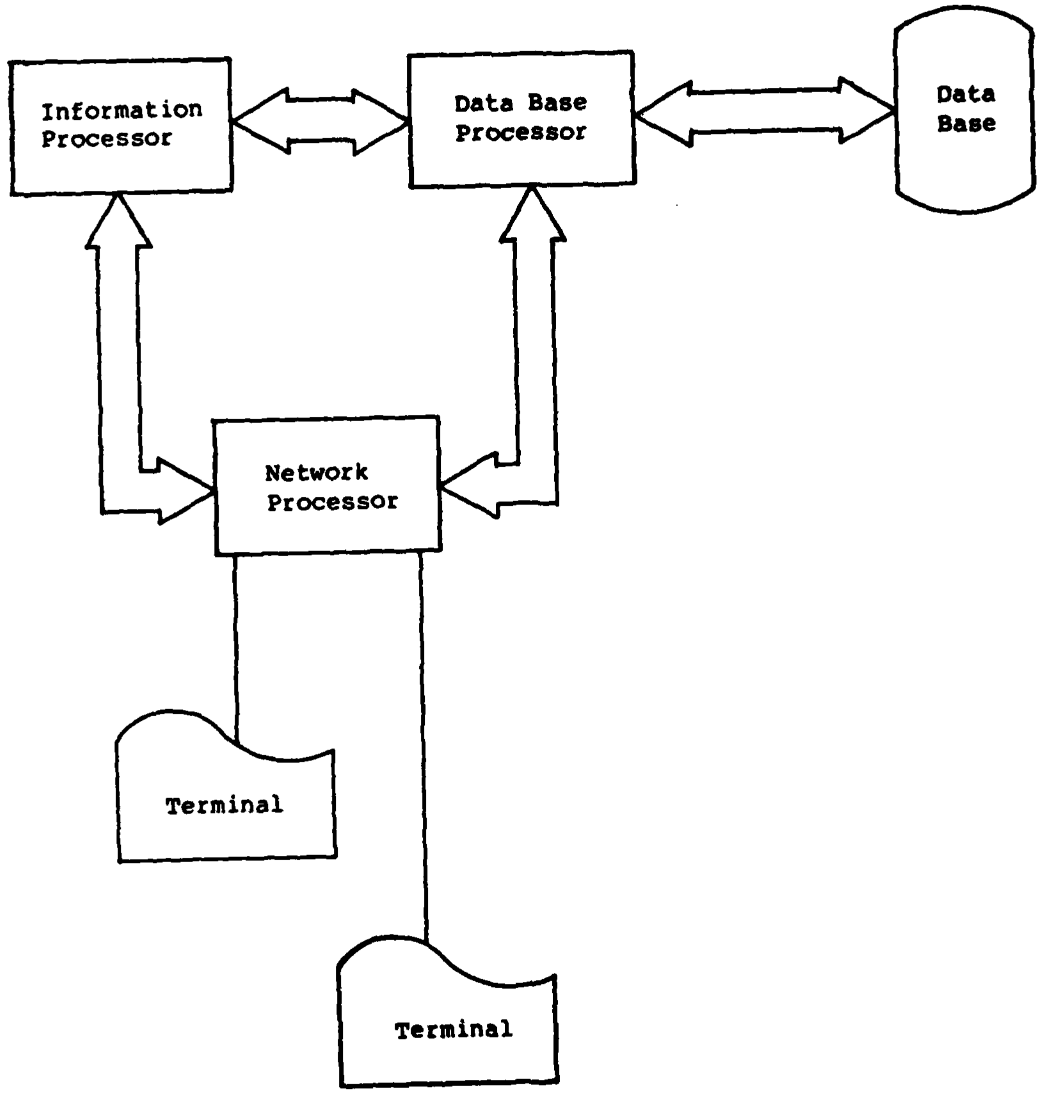

Figure 2-1

Centralized Configuration



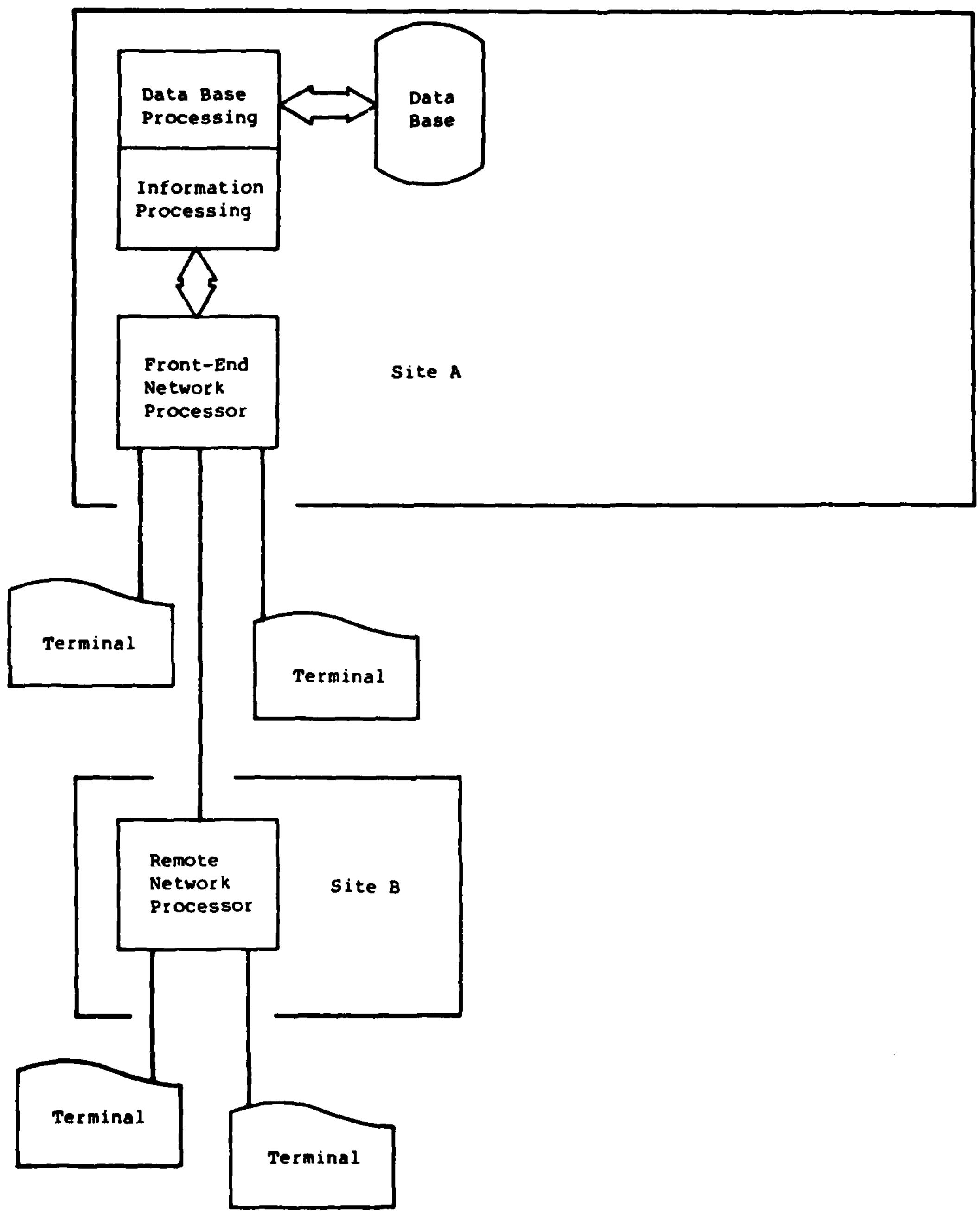

Central Configuration
Front-End

Figure 2-2



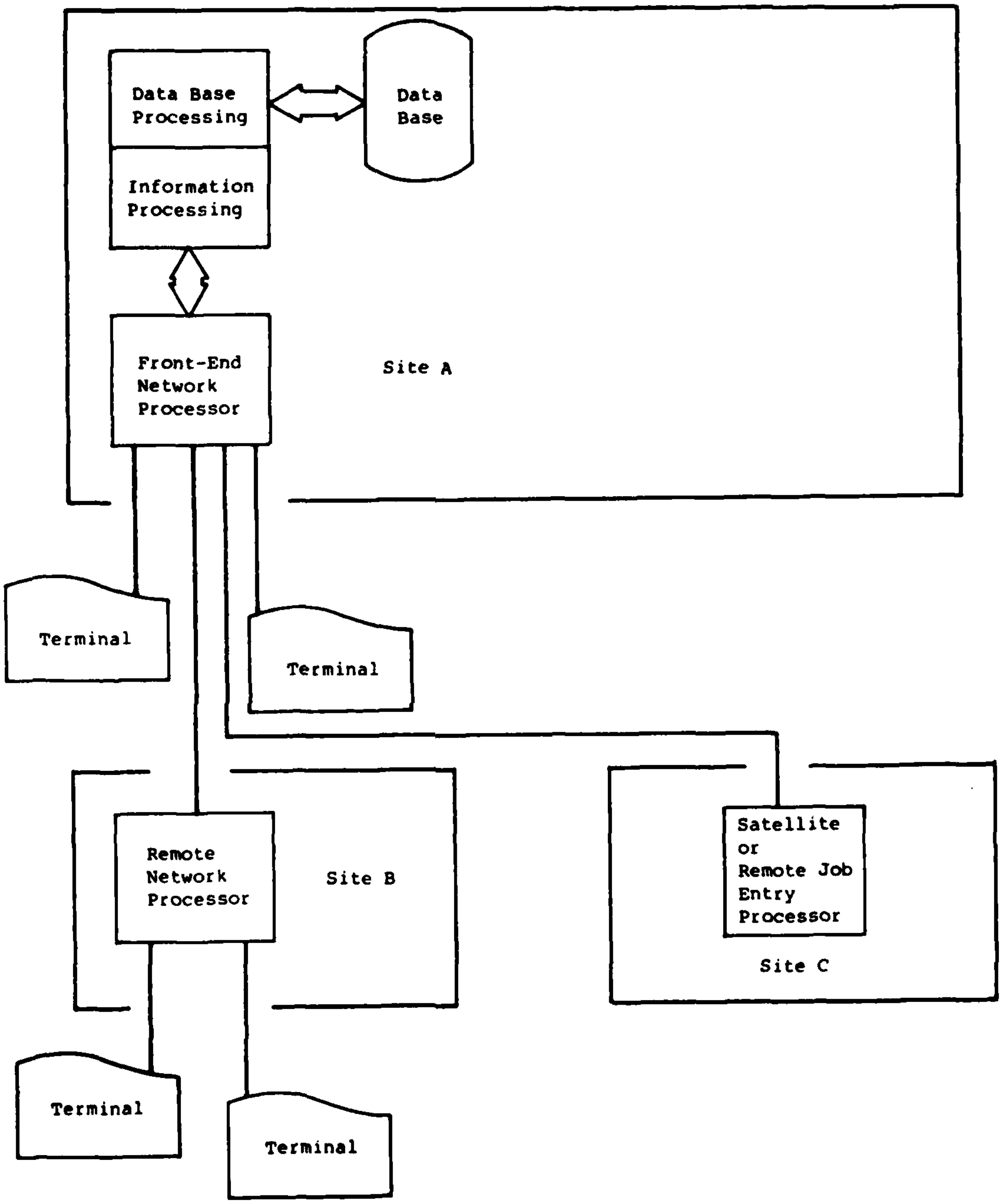

Central Configuration
Back-End

Figure 2-3



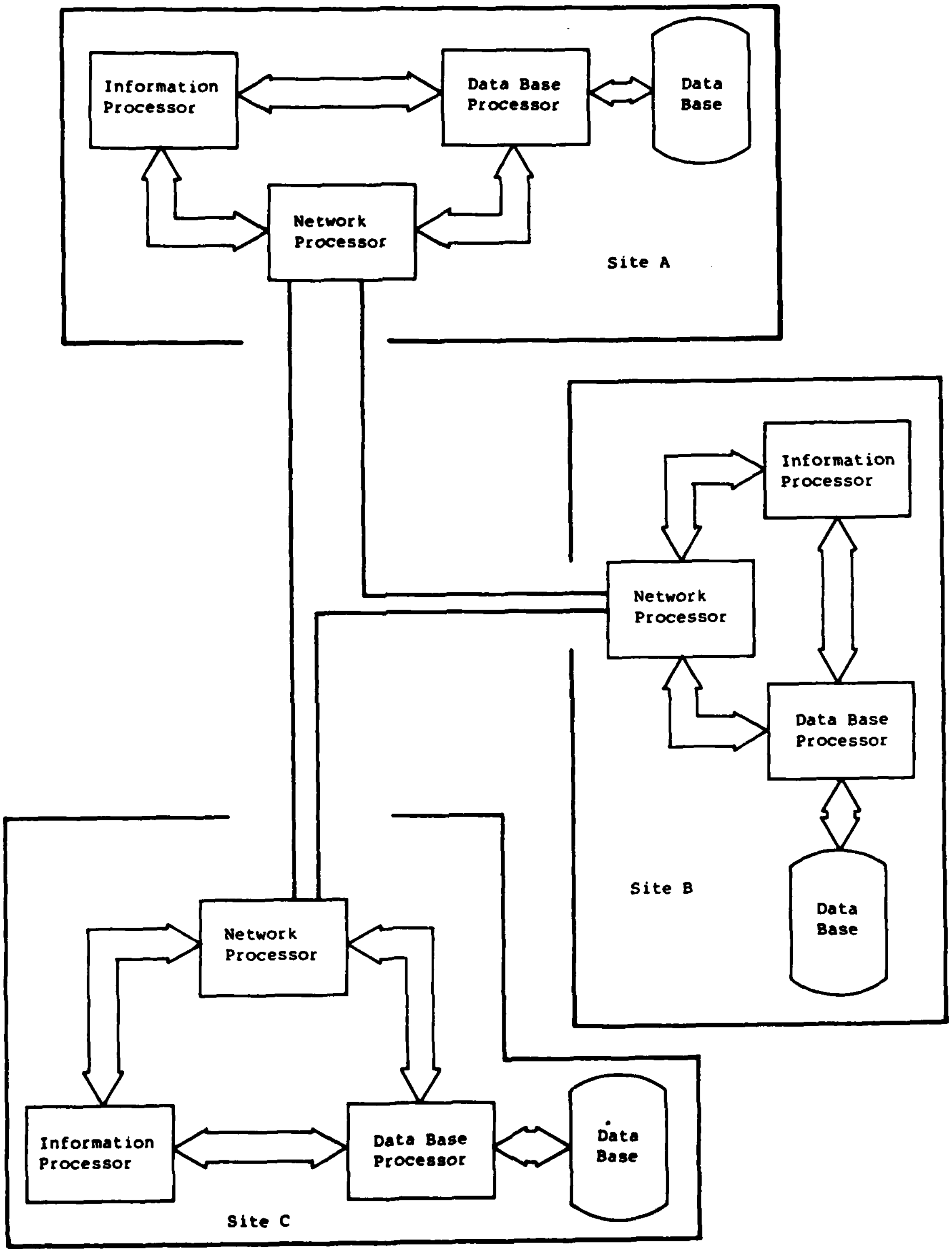

Partially Distributed

Figure 2-4




Semi-Distributed

Figure 2-5




Distributed

Figure 2-6

# 3.0 TECHNOLOGY ASSESSMENT

## 3.1 Introduction

A computer-supported system, when addressed from a technical viewpoint, can be divided into four subelements: the system in its entirety, hardware, software, and communications. It is anticipated that Army ISs of the post-1985 time period will be designed to adopt some form of network system as described in Section 2. This section addresses the current and projected state of the art for each element. In addition, a summary of Eurasian communist countries' automation capabilities is provided.

## 3.2 Systems

Systems which employ variations of information, network, and data base processing in numerous sites are expected in the post-1985 period. The field of distributed processing has seen rapid growth in recent years. The basic rationale for users adopting this concept is to enhance interactive user support, increase throughput, and to process large quantities of real-time I/O without saturating the computing system. While there have been numerous advocates of this approach, there is little guidance based on performance currently available for the designers of ISs. One of the factors which has fostered the development of networks in support of information processing is technological advancement in the mini/micro-computer field. As hardware has become cheaper, the advantages of network processing have become more enticing. However, there are many areas in which research must be done to solve the problems of effective use of network processing systems.

Functional decomposition is one area which needs to be studied further.

Better modular concepts of systems must be developed to properly decompose the functions of the network system.

The complexities of network operating systems and communications protocols must be more clearly understood. Data base management systems must be developed to handle distributed data bases along with distributed file managers to handle the distributed file systems. The distributed data base management system must be able to handle decentralized data while maintaining data base integrity and security. The problems with handling remote site information must be solved.

In addition, there are significant problems in developing an effective man-machine interface. The complexities of file transfer and distributed processes must be made transparent to the user.

## 3.3 Hardware

The cost of computer hardware has fallen remarkably in the past 20 years largely as a result of advances in large scale integration (LSI) technology. Hardware that cost tens of thousands of dollars in the 1960s now can be duplicated with LSI components for a few hundred dollars. New developments should support this rapid rate of progress into the 1980s.

3.3.1 Processors and Memory. To continue the rapid growth promoted by LSI, very large scale integration (VLSI) technology is being developed. LSI technology refers to chips with 100 or more gates/chip. VLSI technology refers to chips with 1,000 gates/chip or more. Although enormous increases in gate density may yet be achieved, there are some limitations imposed by current production techniques.

Optical lithography is approaching its limit of usefulness as device geometries shrink toward a micron. However, two new methods, electron-beam and x-ray lithography, offer an increase in resolution by a factor of up to a thousand. VLSI fabrication technology will face challenges in the 1980s, but these problems will be met with the new techniques.

Pin connection density also imposes limitations on the size and density of chips produced. Pin density has increased at a much lower rate than gate density. The current state of the art in pin density is 64 pins. No breakthrough to solve this problem is in sight; however, a new packaging technology must be developed.

Power dissipation is also a limiting factor on chip design. Power dissipation has a direct effect on the number of gates which can be placed on a chip. An increase in chip density increases the demand for cooling and the problems of power distribution. To increase chip density the power per circuit must be lowered.

Two future trends are anticipated for arithmetic units. With the higher density level predicted for integrated circuits, many arithmetic units will be replaced by a high-speed microprocessor that performs addition, multiplication, and division at the same speed. In this case the trend will be to integrate a multichip system into a single-chip system. The second trend will be to increase the speed of a chip with new technology and retain the same level of integration.

Semiconductor memory has provided a dramatic rate of progress in basic hardware technology by driving the costs of memory down. Semiconductor memories may be mass produced, which is one of the reasons they have helped reduce the costs of memory. The older magnetic core memory requires a tremendous amount of hand labor during production which has not allowed a significant reduction in price for this type of memory. Reduction in basic device geometry is expected for semiconductor memory through the use of the new lithographic techniques. This reduction will allow further increases in memory density with a decrease per bit in cost.

Charge-coupled devices (CCDs) and magnetic bubble memories (bubble) are potential successors to the memory technologies in use today. CCD technology is fast, with data rates of about five megahertz, but it is also volatile memory requiring periodic refreshing. Bubble memory is slower than CCD, with data rates on the order of a few hundred kilohertz; however, bubble memory is nonvolatile.

At this point in time it is not certain that CCDs will ever have a cost advantage over semiconductor RAM (random access memory). Bubble memory is expected to become more cost effective as more knowledge is gained about this technology. RAM may still enjoy a cost advantage over CCDs and bubble memory due to its well advanced development.

Both memory and processor prices are expected to continue to decline in costs per unit as well as increase in speed characteristics in the next ten years. These increases will come about primarily from advances in VLSI technology.

Magnetic disk is expected to remain the primary form of secondary storage for the next twenty years. The moving head disk provides a relatively fast access time with a cost per bit in the range of millicents. With technological innovations in the areas of disk surfaces, heads, and basic electronics, the rigid disk should remain an important mass storage device.

Optical video disk storage is a new technology which provides a higher recording density than magnetic disk. Currently, the materials used for optical recording are not reusable, which makes this device suitable for write-once multiple playback applications only. The advantages of this technology include instantaneous playback, very fast random access, high recording density, and archival storage. To make these devices more advantageous, recording materials must be reusable and small efficient GaAs lasers for recording and playback must be developed.

The flexible or floppy disk is expected to become increasingly competitive with the rigid disk in the 1980s. The original design goal of the floppy disk was to provide an easy-to-handle, low-cost media for data entry. Now this disk is beginning to be viewed as a low-cost direct access device. The relatively low cost of both rigid and floppy disk technologies should allow them to remain the predominant secondary storage technologies of the 80s.

3.3.2 <u>I/O Devices, Terminals and Displays</u>. Cost, performance, and reliability improvements for I/O devices have not kept pace with the dramatic improvements in processor and memory hardware. These peripheral devices contribute to a major portion of the cost of a computer system.

In spite of the lower level of progress of the peripheral devices, there are still a number of promising new techniques, such as laser printers, full-strike matrix printers, thermal printers, and nonimpact printers. Nonimpact printers are expected to cut into at least 30% of the impact printing market in the 1980s. Nonimpact printers are expected to provide a lower cost, higher speed device than those currently available.

With the continuing decline of batch processing, terminals will become increasingly more important. The CRT is expected to remain the dominant form of display technology in the 1980s. Intelligent terminals are declining in cost relative to "dumb" terminals and are beginning to hold a larger share of the marketplace. Intelligent CRTs will be the most widely used terminal of the 1980s.

There is a need to replace the bulky, high voltage CRT with a solid state, low power, flat screen display. Unfortunately, this new display is not likely to be developed in the near future, since there are no technologies being developed which will solve this problem in a cost-effective fashion.

The addition of voice input/output to terminals will be a tremendous asset to the computer system. User interaction will be greatly improved by such an addition. Voice output is available in a limited form now, but the problems of recognizing vocal input have yet to be solved.

Graphics, in particular color graphics, will become increasingly important in terminal displays as resolution increases and price drops. Printers and plotters capable of good graphics reproduction will also be important.

3.3.3 Microcomputer Systems. The microcomputer revolution which began in the early 1970s was made possible by LSI technology. In this period, microprocessors were distinguished from minicomputers by their smaller size, lower cost, and general lack of software. Microprocessors were first used as components in intelligent terminals, word processors, and communications equipment. Now, however, microprocessors are being utilized in a stand-alone capacity as microcomputer systems. Their versatility and low cost are allowing microcomputer systems to challenge the low end of the minicomputer market.

Microcomputers are being used in more and more control and dedicated applications which were originally in the domain of minicomputers. Just as minicomputer systems are beginning to have performance characteristics formerly found only in the larger mainframes, microcomputers are beginning to have some of the performance characteristics of minicomputers. More sophisticated software is being produced for microcomputer systems, particularly in the area of high level programming languages.

The uses of microcomputers are expected to continue to grow, particularly gaining use in the low end of the minicomputer market. The expected advances in LSI and VLSI technology will allow the development of faster, more functionally sophisticated systems.

3.4 Software

Software is a set of instructions provided to the computer which either handles the operation of the machine itself (operating system) or solves real-world problems (application programs).

3.4.1 Operating System. The operating system is undoubtedly the single most important piece of software in any computer system. The operating system acts as an interface between the user and the machine, as well as controlling scheduling of resources, providing systems for managing files for storage and retrieval of information, and supporting other utility programs. Special purpose microcomputers and embedded systems may not require an operating system since such systems may be dedicated to one activity.

Current theoretical research is largely concerned with vigorously defining the specifications and the logical structures of an operating system. The design of an operating system is dependent on the structure of the target computer system. The design of the operating system is also influenced by the approach used to model the system (the hierarchical levels approach, the kernel approach, etc.).

The operating system should exploit the special features of a computer system, such as distributed processing, parallelism, and "intelligent" peripherals. Other more mundane features, such as the memory hierarchy, virtual memory capabilities, interrupt mechanisms, and peripheral devices, will have an impact on the final design of the operating system.

Operating systems vary in size from the small, elegant versions found on some minicomputers to the large, bulky, and cumbersome versions found on the large general purpose machines.

Operating systems in support of network processing are currently being developed, but further research is needed.

3.4.2 Application Programs. Application programs are written to solve real-world problems. Languages used to write these programs are categorized as assembly, directly executable, and high order languages.

3.4.2.1 Assembly Language. Assembly is generally used when either extreme efficiency of code is required or some function or capability is not present in a high order language (HOL). The use of assembly language has been declining and is expected to continue to decline due to its nonportability and general lack of structured programming constructs. New and expanded versions of HOLs will gradually take over the majority of the functions of assembly language. While a small amount of assembly code may be necessary in some programs, HOL will be used for most software development. Optimizing compilers will be important to generate highly efficient machine code for HOLs.

3.4.2.2 Directly Executable Languages and Language-directed Architectures. A directly executable language (DEL) is translated by an interpreter. The object language produced by the interpreter is composed of micro-instructions. A language-directed architecture contains operations and data structures implemented at the machine level which are loosely related to operations and data structures implemented in one or more HOLs. The instruction set is typically implemented in microcode. The use of DELs and language-directed architectures may eliminate a number of intermediate layers of software translation found in typical computer systems. The language-directed architecture may also generate more efficient codes since the higher level constructs are supported in the microcoded instruction set. These new developments in architecture and languages provide flexibility within a single computer system. Not only can the languages be changed or expanded, but also the instruction set of the machine may be changed or expanded dynamically. In the next ten years very large scale integration (VLSI) will make the implementation of a variety of instruction sets and DELs feasible within a given machine. The Army is currently planning to develop DELs and architectures in support of their embedded computer program.

3.4.2.3 <u>High Order Languages</u>. A HOL is a programming language which allows the user to write concise portable programs in problem oriented terms without being aware of specific machine features. The language may be viewed as a notation for the description of algorithms and data structures which may be translated into computer executable code. The HOL is a general purpose language which allows a wide variety of algorithms to be programmed. One language may provide certain facilities not found in another language. Some examples of popular HOLs are FORTRAN, COBOL, ALGOL, PASCAL, and PL/I.

Special purpose languages such as GPSS, SIMULA and SIMSCRIPT are task specific languages developed to facilitate problem solving in a particular domain (in this case simulation).

These special purpose HOLs are sometimes referred to as very high order languages (VHOLs). VHOLs are often based on a HOL and may be implemented by using a preprocessor to translate the VHOL into its HOL base. Current programming languages have evolved with computer hardware and are expected to continue to develop and improve with changes in hardware technology. As technology has advanced, the need has arisen for new languages which support the use of parallelism, distributed processing, real-time control, graphics, structured programming, documentation, and verification. The special purpose VHOLs are expected to continue development in proportion to the number of new applications and areas of computerization.

As computing environments continue to change, HOLs and VHOLs will continue to change and adapt to meet the needs of the user community. Software is rapidly becoming the most expensive portion of a computer system. In light of this fact, HOLs and their software support systems must facilitate the development of programs and software systems. The HOL will evolve into the HOLS (high order language system). The HOLS will include support for the following:

1) Text-editing capabilities for developing, modifying, documenting, and maintaining programs.

2) Debugging compilers to assist with program development and production compilers for generation of efficient machine code.

3) Run-time facilities for debugging and tracing program execution.

4) Graphics oriented displays for editing, debugging, and tracing execution of programs.

The inclusion of these support facilities should increase programmer productivity and proportionately decrease the amount of time required for program development.

3.4.2.3.1 Ada. One HOL developed for the military is worthy of note. Ada is the proposed DoD standard high order language for use in all new embedded computer systems. Ada offers a large number of special features including structured control, built-in checking, parallel processing, task synchronization, and exception handling. The use of a standard language in conjunction with the Military Computer Family (MCF) standards should permit a broad range of portability of software among military systems.

The advantages of Ada are that it has been designed to:

- o enhance the reliability of software,
- o facilitate program maintenance,
- o be easy to compile into efficient code,
- o make the level of complexity consonant with its extensive repertoire,
- o employ uniform syntactic conventions, and
- o be machine independent.

Ada was designed in accordance with the Steelman requirements which call for a HOL with considerable expressive power to cover a wide range of applications. In addition to the classical facilities found in a language such as PASCAL, Ada also contains facilities normally found in specialty languages. The design goals of Ada were strongly influenced by the importance of program reliability and maintenance, efficiency, and a concern for programming as a human activity.

Work is currently under way to develop compilers, testing and validation tools, and a standard environment for Ada. Ada has been enthusiastically received by industrial representatives who have participated in the recent test and evaluation of the language. The enthusiastic support of industry, along with the availability of Ada compilers and support software in the public domain, should pave the way for Ada to become a widely used programming language for both military and non-military applications.

## 3.5 Communications

There is a variety of highly active technical areas which have or may have a profound influence upon the military's ability to communicate with its forces. So that the significance of these technical issues may be fully appreciated, a brief description of the military's present communications structure is provided.

### 3.5.1 Present Communication Structure.

The authority for control of U.S. Strategic Forces rests with the National Command Authority (the President or his designated successors), and the actual control is carried out by the Joint Chiefs of Staff (JCS). Orders pertaining to the deployment and execution of strategic forces are distributed through the World Wide Military Command and Control System (WWMCCS) via the Defense Communications System (DCS). The DCS consists of a variety of elements such as the Defense Satellite Communications System (DSCS) and the Minimum Essential Emergency Communications Network (MEECN). These relationships are shown in Figure 3-1.

The DSCS presently provides communications channels for three important communications services: the Automatic Voice Network (AUTOVON), the Automatic

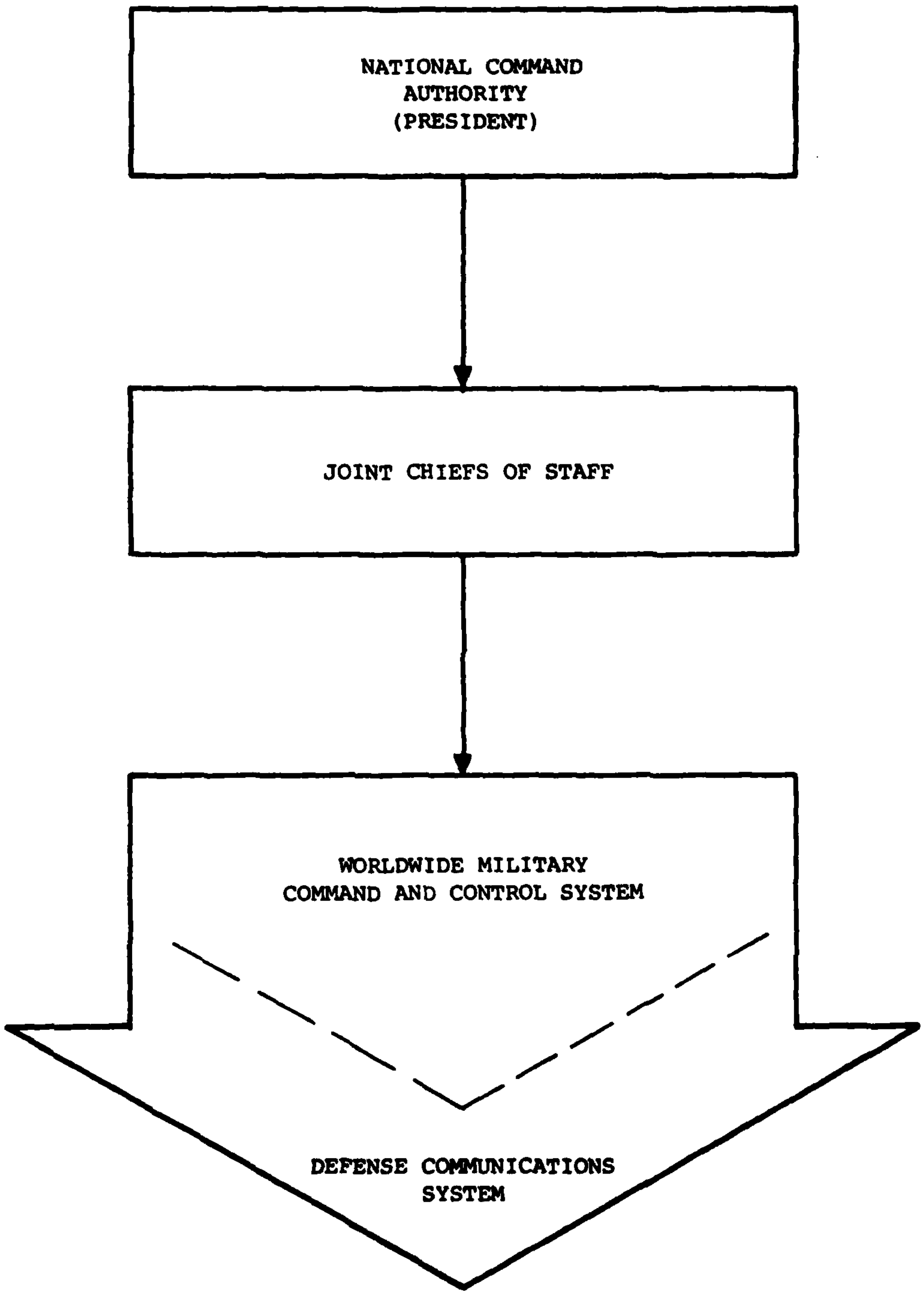



Figure 3-1. Flow of Control for Strategic Forces

Secure Voice Communications (AUTOSEVOCOM), and the Automatic Digital Network (AUTODIN). The latter system is of interest since it supports digital traffic transmitted by ADP systems.

There are several important characteristics of AUTODIN II, which was designed to complement rather than replace the capabilities of AUTODIN I. AUTODIN II is a packet-switched network, and its design is based in part upon the experience gained with ARPANET. This implementation employs high capability satellite channels which make possible very high transmission rates. Ordinarily, this factor would be highly desirable since it would expedite traffic flow; however, it should also prompt us to consider what the alternate or back-up channels are. This consideration leads us to the MEECN.

The MEECN is a communication system which was designed to survive nuclear attack and still provide minimum but essential levels of communications. The types of communication systems in this set include, among others not listed here, extremely low frequency (ELF) systems, very low frequency (VLF) systems, and high frequency (HF) systems. A characteristic predominant among these transmission modes is low ($<$ 100 baud) data rate and basically one-way communications (CONUS to overseas forces).

There are at least two implications for a packet-switched network utilizing a low speed channel. Obviously, the low transmission speed will increase packet/message delivery time. Secondly, the exponential back-off in the collision control algorithms will compound the delays in packet/message delivery. Therefore, when alternate, low-capacity channels (such as HF channels) are used, the amount of data circulating must be cut to an absolute minimum. A further possibility is that when the low-capacity channels are in use, some transmission form other than packet switching may be more efficient.

Recent commercial experiments with packet-switched computer networks using radio links have indicated that variations in propagation delay time in a given channel can have a significant impact upon network performance. Among the channels which are being considered as alternates or backups for AUTODIN II is HF. Since the variations in propagation delays in such channels over long distances have been known for many years, it appears that some technique other than packet switching should be employed in such a channel.

3.5.2 Communications Security. End-to-end security is another topic of concern to both military and commercial data networks. At the moment, the solution for the commercial sector appears to be the Data Encryption Standard (DES). This encryption technique is currently available as either a firmware implementation or as a software implementation, and there are significant differences in the performance of these two approaches. Typically the firmware implementation requires five microseconds to produce a single 64-bit encrypted packet containing 56 data bits. The software version typically requires 100 milliseconds to perform the same task. Obviously this discrepancy indicates noticeably different rates at which data enters or leaves the transmission backbone.

As noted, DES appears to be suitable for commercial data security, but its suitability for military security is questionable for at least two reasons. The first limitation of a DES approach for a military application is shown in Figure 3-2. Assume that end-to-end security is required in a packet network such as AUTODIN II. Since each individual packet must carry addressing information, the addressing can be contained either within the data block leaving a given host, or it can be attached to the output of the encryption device.

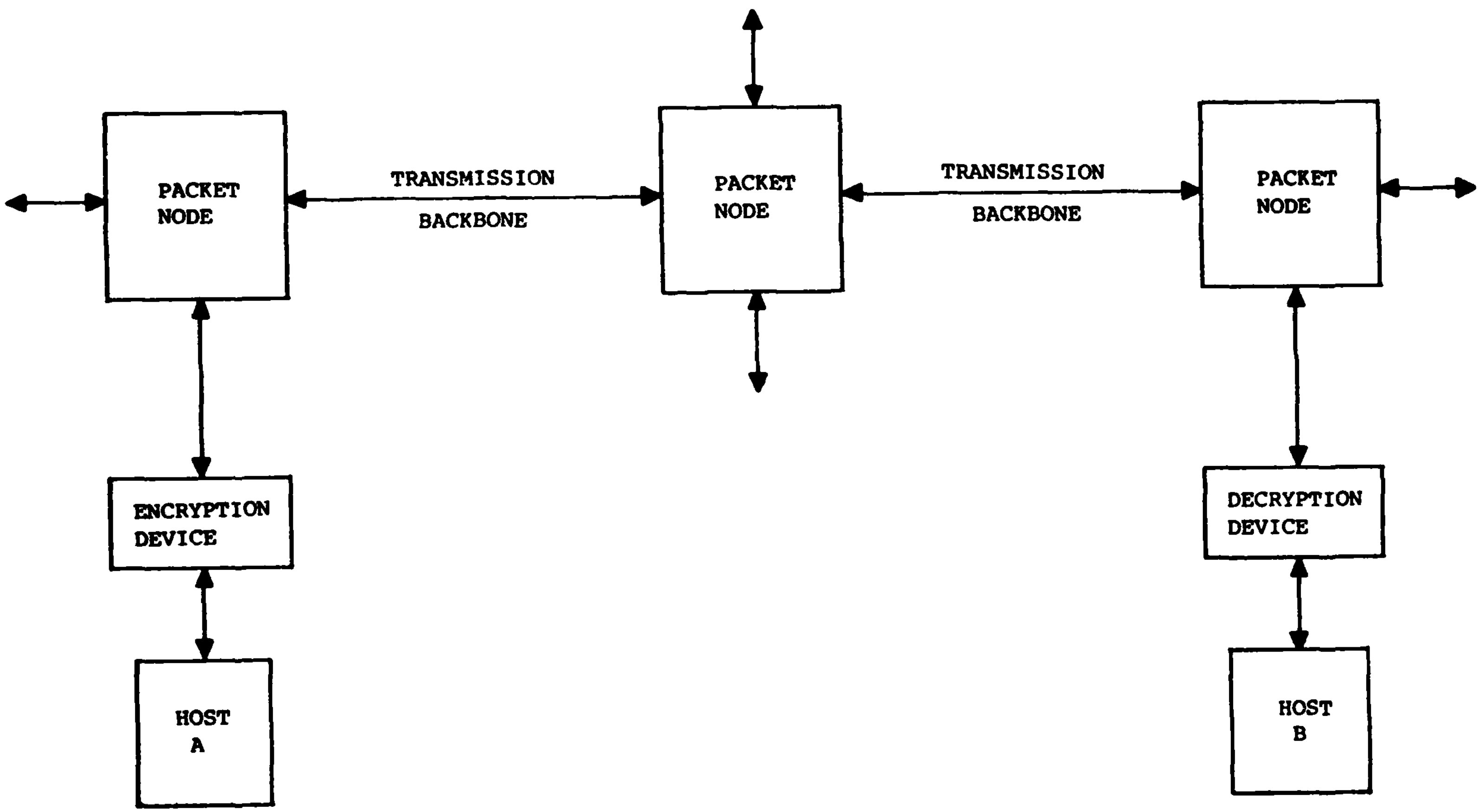



Figure 3-2. A Possible Structure for Secure Communications on a Packet-Switched Network

If the addressing information is a part of the data block leaving the host, then it would appear that maximum security is obtained since both the data and its destination are protected; however, this is not true. Each packet node must examine each packet's address, requiring the entire packet to be decoded. In other words, both the address and data are available as plain text in this arrangement at each node in the network.

If the packet address is attached to the encrypted data, then it should be possible for each node to read the address without having to decode the data. In this case, the data is protected; however, it should be possible to analyze traffic flow anywhere on the transmission backbone by simply observing the number of packets flowing to a given address.

One possible solution to the security problems mentioned above would be a two-level encryption process. In the first level, the data block itself would be encrypted, and in the second level the combination of the packet address and the encrypted block would be encrypted. At each node a decryption of the second level could be performed, the address could be read, the address and encrypted block could be re-crypted, and the entire packet could be sent to the next appropriate node in the network, where the process could be repeated until the packet arrives at its destination. It should be noted, however, that this approach has at least two serious problems. Noticeable transmission delay will be introduced by the multiple encryption-decryption processes, and additional cost will be incurred in providing the multiple encryption-decryption units.

Another important question surrounding the use of encryption techniques such as DES is integrity, which is related to the word length. The DES word has been chosen so that, using techniques and equipment available to most commercial organizations, it would take approximately 10 years to determine the key used for a given transmission. However, should an organization, such as a government, elect to develop a special purpose piece of hardware to determine DES keys, then the system is quite vulnerable. For example, given a machine which consists of one million chips, each of which can execute the DES algorithm in one microsecond, the complete DES key table can be exhausted in 20 hours. On a statistical basis, it is highly likely that the correct key would be discovered within 10 hours. It has been estimated that such a machine could be developed at a cost of ten to fifty million dollars.

### 3.5.3 Transmission Mechanisms

3.5.3.1 Commercial Satellites. The use of satellites for communications by private concerns has enjoyed significant growth in recent years, and there is every indication that this increasing use will continue. The expansion in capacity which has permitted this growth is attributable to developments in several technology areas.

The major changes have been within the satellite itself. The objective has been to increase the channel capacity, and development efforts in several technology areas have permitted significant growth in capacity. First, there has been the allocation of new and higher frequency bands for satellite communication. Traditionally, commercial satellite communication has taken place in the 4- and 6-GHz bands. Because of limited bandwidth, it was necessary to seek allocations in 11-, 14-, 20-, and 30-GHz bands.

Once the frequencies became available, it was necessary to develop the hardware to support the new bands. The most elementary aspect of this development was primary power generation. Over the last 15 years, the power budget for commercial satellites has increased by a factor of 30 as reflected by Intelsat I and Intelsat V. Part of this increased power capacity stems from physically larger satellites, which require larger launch vehicles, but part of this increased capacity comes from the use of improved stabilization techniques.

Traditionally, satellite stabilization has involved the rotation of the satellite about its axis perpendicular to the plane of radiation. In Intelsat I and II, the entire satellite rotated. This stabilization technique resulted in reduction of primary power due to rotation of solar cell panels and reduction of effective transmitted and received signal power. The latter problem was overcome in Intelsat III with the use of a despun antenna. The latest approach to stabilization appears in Intelsat V: body stabilization. In this technique, a rotating momentum wheel provides the torque to produce stabilization.

The availability of a highly stabilized satellite platform provided the opportunity to employ highly directional antennas, or spot beams, to enhance channel capacity. In this approach, a given channel may be used repeatedly. In particular, users in sufficiently separated locations may use the same channel if the on-board antennas can isolate the users.

The next logical step in enhancing system capacity is the use of on-board switching. In this case, the satellite interprets the data on an uplink, determines its destination, and then routes the signal to the appropriate downlink antenna. Before this process can be carried out effectively, two things are necessary: a significant on-board processing capacity, and an all-digital signal format. The former depends primarily upon the ability to produce a space-qualified processing capacity. For commercial applications, this capability is relatively simple since most commercial satellites are synchronous and are therefore not passing through the radiation belts which traditionally cause problems for logic circuits in a space environment. Also, it is not expected that commercial satellites will be subjected to countermeasures.

The use of digital signalling is a problem which both commercial and military systems share. In both areas, analog signals dominate; therefore, both analog and digital traffic exist on the network. One solution being explored in commercial circles is the conversion of frequency division multiplexed (FDM) analog signals to time division multiplexed (TDM) digital signals.

Another technique which is now being applied in commercial satellite systems to increase signalling capacity is polarization diversity. In this technique, one group of signals is transmitted using an antenna employing one polarization, and another group of signals is transmitted or received by an antenna employing a different polarization. The effective utilization of this technique depends upon having a highly stable satellite platform.

All of the features discussed above are associated with the design of the earth station-satellite system; however, there is one other major consideration in the implementation of a satellite communications link. The orbit of a satellite has a profound impact upon its mode of operation. One of the most desirable orbits for a commercial system is a synchronous orbit. The synchronous orbit is usually long-lived and requires very few satellites to achieve global coverage. It greatly reduces the tracking requirements associated with earth station antennas, and it also eliminates Doppler shift, which means that the earth station's receiving equipment can be simpler and less expensive.

The number of synchronous orbital positions available is related to the beam width achievable on both satellite and earth station terminals. In general, the beamwidth of an antenna of fixed aperture decreases as the operating frequency increases; therefore, more synchronous positions are available at the new, higher satellite frequencies. Most of the synchronous orbital positions are presently occupied, based upon the spatial separation required for antennas in the 4- to 6-GHz bands.

3.5.3.2 Military Satellite Systems. The responsibility for coordinating the military's approach to satellite communication (MILSAT Com) rests with the MILSAT Com Systems Office (MSO). At present, military users of satellite services have been divided into three groups, and each of these groups is served by a separate satellite system.

The first user category is the wideband user. Users in this category have transmission requirements which range to multiple megabits per second. This user community is currently supported by Phase II of the Defense Satellite Communications System (DSCS II) which consists of four operational satellites and one orbiting spare satellite. The DSCS II satellites were designed primarily as analog systems, and they operate in the super high frequency (SHF) bands. The satellites employ spin stabilization with despun antennas, and the transponders can accommodate reception and transmission of Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) signals. Also, these satellites have a limited capacity for on-board switching of transponders and global or spot antennas.

Note that most of the features mentioned above are typical of the commercial satellites in service at this time. It should also be noted that as military systems, deficiencies have been observed, and the deficiencies of greatest concern appear to be inadequate transmission capacity and inadequate jam-resistance.

It is anticipated that in the early 1980s there will be a transition to Phase III of the DSCS, and the third phase is expected to demonstrate advancements in jam-resistance, capacity, flexibility, in-orbit life, and decentralized control (Alexovitch '79). It is further anticipated that by the end of the 1980s another upgrade to DSCS III will occur. This upgrade will most likely involve the use of extra high frequency (EHF) transponders to allow increased capacity and the use of on-board processing to improve the system's anti-jam (AJ) characteristics (Alexovitch '79).

The second user group is the mobile or tactical user. A combination of factors, both technical and operational, have led this user community to employ the ultra high frequency (UHF) band for communications. This community is presently served by the Fleet Satellite Communications (FLTSAT Com) System and GAPFILLER. The service of the former satellite group will terminate in the early 1980s and will be replaced by the Leased Satellite (LEASAT) System. One major modification which will be associated with the transition to LEASAT is the use of Demand Assigned - Time Division Multiple Access (DAMA), and it is expected that this will substantially increase the capacity of LEASAT when compared to FLTSAT. Typical of the terrestrial equipment which will utilize LEASAT are the AN/PSC-1 and the AN/MSC-65. The PSC-1 is a manpack terminal which will support digitized voice in the half-duplex mode at a rate of 16 kilobits/sec. or burst communications at a speed of 300 bits/sec. The MSC-65 is intended for vehicular use and operates as a half-duplex transceiver.

Possibly by the late 1980s a successor to FLTSAT and LEASAT will appear. This successor is currently referred to as the General Purpose Satellite Communications System (GPSCS). It is expected that this satellite will operate at EHF rather than at UHF and that it would perform on-board processing, allow multifrequency cross banding, provide antenna nulling, and offer a high AJ capability (Waylan '79).

The third user group is the nuclear capable community. This community has a requirement for a low speed, 75 bits/second, highly survivable communications link. Currently this need is being met by Air Force Satellite Communications (AFSAT Com) packages carried on FLTSAT units. It is expected that in the near future this need will be met by incorporation into the DSCS III system. The major improvements in this system, however, are slated for the mid-1980s and the deployment of the Strategic Satellite System (SSS) which will emphasize AJ capability and survivability (Wright '78 and Tuck '79).

The military is emphasizing the need and desire to enhance its satellite systems in three major areas: capacity, AJ capability, and survivability. These desires must be tempered with the realization that by the mid-1980s, the investment in earth terminals will exceed the investment in orbiting satellites. It is expected that this fact will tend to slow the evolution of military satellite systems. In particular, it is expected that for several years into the future, all changes to the orbiting satellites design will be structured for compatibility with the present terrestial terminal's capabilities.

An additional area of technological exploration influencing satellite communications which merits some discussion is laser communications. Two different utilizations are of interest here: surface-to-satellite communications and satellite-to-satellite communications. Of the two, the surface-to-satellite communications is the more challenging since it involves overcoming the atmospheric effects: attenuation and distortion.

The motivation for use of laser satellite communications is in two of the areas of concern previously noted for conventional satellite systems:

capacity and AJ capability. The high transmission capacity of laser systems is widely known, and a recent experiment demonstrated the ability to achieve a bit error rate of $1 \times 10^{-6}$ at a transmission speed of 1,000 megabits/second over a 40,000 kilometer link using a laser system. The significant AJ capability of laser systems stems from the extremely narrow-beam width of both transmitting and receiving systems. In other words, the spatial version of barrage jamming is virtually impossible given current laser technology.

3.5.3.3 Army Tactical Communications Systems. The Integrated Tactical Communications System (INTACS), begun in 1972 by the Combat Developments Command, is a systematic program for the development and deployment of Army communications. The INTACS literature defines Army communications over the 1980-1995 time period by describing the transition between the current communications system and the objective system which is to be operational by 1995.

The trends in Army communications as indicated in INTACS are presented below through a comparison of the present structure with that of the objective system.

At present, communications between battalion and lower eschelons, company and platoon, is by FM combat net radio. These radios support voice communications. For communications between battalion and brigade, the FM combat net radio is employed for voice communications, and record traffic is transferred by HF radio teletype (RATT). In the objective system, the Single Channel Ground and Airborne Radio Subsystem (SINCGARS) will be used for transmission above and below battalion and for both voice and record traffic. In this arrangement, 30 second-per-page facsimile (FAX) will replace the conventional 60 word-per-minute RATT.

In the current Army communications system there are several links between brigade level and division. Record traffic is transmitted by HF/RATT, and voice traffic is conveyed via FM combat net radio and by multichannel radios.

In the objective system, record traffic transmissions will employ tactical record traffic terminals (TRTT) which can transmit a 240-word page in 12 seconds. There are three transmission mechanisms for this record traffic to division: TACSAT, SINCGARS, and the mobile suscriber access (MSA) subsystem. Voice traffic between brigade and division will employ the same three transmission systems.

Record traffic between division and corps levels currently utilizes HF/RATT; however, in the objective system the TRTT will be used in conjunction with satellite (TACSATOM), MSA, or SINCGARS channels. It is further expected that in the objective system, message switching will be done automatically by processors at the division level.

Voice communications between division and corps levels currently uses multichannel radio, and some of this multichannel equipment will be retained in the objective system. In particular, this multichannel equipment will serve DISCOM, RGAR, ACS, and ADA. For the objective system, voice traffic may also flow over SINCGARS channels and multichannel TACSATCOM.

At the corp level, there are three communications systems: HF/RATT, FM radio, and multichannel radio. The HF/RATT is used for record traffic to both division and theater levels. The FM radio provides voice capabilities for connection to both division and theater.

In the corps level objective system, the available communications forms include single channel TACSATCOM, multichannel TACSATCOM, multichannel terrestrial radio, and SINCGARS. Basically, both voice and record traffic can be routed over all of these systems, and in the objective system, all switching for both voice and data is automatic.

At present, theater level communications is very similar to corps level communications. The main difference is that FM radios are not used. Record traffic is transmitted via HF/RATT, and voice traffic is carried by multichannel terrestrial radio.

Similarities to corps level communications also exist for the objective theater level system. The most notable difference is the absence of SINCGARS.

The major transitions which are a part of the objective system are summarized below. FM radios are replaced by SINCGARS, HF/RATT is replaced by either FAX or TRTT, and terrestrial multichannel equipment is largely replaced by multichannel satellite equipment. The motivations for these changes are:

(1) increased security in the case of SINCGARS,

(2) increased transmission speed in the case of FAX and TRTT, and

(3) increased capacity and mobility in the case of multichannel satellite systems.

The preceding paragraphs describe the initial INTACS architecture. In March of 1979, the U. S. Army Signal Center issued a current evaluation of INTACS, identifying several alternatives which are currently being explored for inclusion in INTACS. There appear to be two primary motivations for these expansions: enhanced communications reliability through diversity of communications types and accommodation of a significant increase in data transmission on the battlefield as reflected in the Battlefield Automation

Management Program (BAMP). The major alternatives which will be discussed here are Packet Radio, PLRS, JTIDS, SCRA, and improved SINCGARS.

### 3.5.4 Trends in Tactical Communications

3.5.4.1 Improved HF. An attractive feature of HF is its long-range propagation capability; however, the initial INTACS design called for most HF links to be replaced by single channel TACSAT channels. Technically this change is possible, and in some respects the TACSAT channel can provide performance superior to that offered by the HF channel, but recent studies have pointed out vulnerabilities of the satellite system. Thus, R&D efforts are being supported to enhance HF capabilities so that the HF channel can at least be used as a backup for the satellite channels. This R&D activity has concentrated in several areas: improved modulation techniques which lead to low probability of intercept (LPI) performance, real-time and adaptive propagation prediction models, wide bandwidth antennas to support both data transmission and LPI techniques, voice processing techniques to reduce the bandwidth required for voice transmissions, and small, portable, and efficient antennas for use at HF.

3.5.4.2 Packet Radio. Packet radio (PR) is primarily to support data communications, and it does so by transmitting data in blocks referred to as packets. These transmissions occur at a speed of 100 KBS and are time-division-multiplexed (TDM) among the users in a local packet radio net (PRN). The packet radios employ carrier frequencies in the 1710-1850 MHz range; therefore, the communications capability is inherently line-of-sight for a given net. However, provisions have been made for linking multiple nets through the use of repeaters. The security of this system is largely attributable to its use of a direct sequence PN code spread spectrum modulation.

3.5.4.3 PLRS (Position Locating and Reporting System). The Position Locating and Reporting System (PLRS) is a network designed for the Army and Marine Corps to provide position information, navigation data, and secure data transfers for a variety of users. The system consists of two major components: a Master Unit (MU) and Multiple User Units (UU). The MU consists of (1) a Command Response Unit (CRU) which provides the RF signal processing and system timing, (2) an AN/UYK-20 network control processor, (3) an AN/UYK-7 which does position computations, and (4) an AN/UYK-20 display processor. All of this equipment is housed in the standard S-280 shelter which can be transported by either a 2 1/2 ton truck or by helicopter. The complete MU housed in an S-280 shelter weighs 6,300 pounds and has a volume of 620 cubic feet.

The UU's basic package is designed as a manpack unit and has adapters which permit its installation on various platforms. The major modules in the UU are (1) RF/IF signal processor, (2) an encoding/decoding network for encrypted messages, (3) a timing network, and (4) a control panel processor. The manpack version of the UU weighs less than 15 pounds, has a volume of 500 cubic inches, and has a battery capacity of 24 hours.

The radio link associated with PLRS operates in the 420 to 450 MHz range (UHF) and employs spread spectrum modulation. In this case, the frequency spreading is achieved by a combination of pseudo-random noise (PRN) coding and frequency hopping (FH). A time-division multiple access (TDMA) protocol is used in the PLRS network, and each epoch is 64 seconds long. The epoch, which is the minimum time period for performing all network functions in the fully deployed system, consists of 128 time slots. The time slot is the basic transmission interval, is 1.95 milliseconds in length, consists of an 800 microsecond data burst of 94 bits preceded and followed by guard times, and is the minimum transmission period assigned to an active user in an epoch.

The position of an individual user is determined by PLRS through multilateration. In particular, since each user is assigned a specific transmission time, the distance between the point of reception can be determined through the signal's time of arrival (TOA). In general, the site of the MU and two UUs are surveyed into position. These three receiving sites then provide three independent range measurements which are sufficient to determine the location of the other user units. The AN/UYK-7 in the MU uses the observed ranges to compute position, and the computed position is reported in either Universal Transverse Mercator (UTM) or Universal Polar Stereographic Coordinates. In field tests at Camp Pendleton, the manpack unit exhibited an (X,Y) accuracy of 7 meters for line-of-sight (LOS) conditions and 13-26 meters for non-LOS conditions.

3.5.4.4 <u>JTIDS (Joint Tactical Information Distribution System)</u>. A new architecture, the Joint Tactical Information Distribution System (JTIDS), has been defined for military communications. This system has been designed to serve the communication, navigation, and identification (CNI) needs of the four services in the 1980s. JTIDS accomplishes its objectives through the use of a nodeless, time-division, multiple-access (TDMA) configuration. The basic JTIDS signal is a spread-spectrum signal generated through a combination of pseudo-random noise coding (PRN) and frequency hopping. The details of this system are provided below.

The key to the JTIDS concept is time division multiplexing, which makes it unnecessary to transmit even continuous analog signals to achieve an accurate transfer of information. In short, data from several different sources is combined and transmitted as one composite signal. Most commonly the process of combining data sets actually amounts to interleaving the various data pulses.

In JTIDS, one complete communications cycle is called an epoch and is 12.8 minutes in duration. The epoch consists of 64 frames of 12 seconds each, and each frame consists of 1,536 time slots of 7.8 msec each. The time slot is the basic transmission interval for JTIDS, and the time slot consists of a synchronization burst, an identification segment, the data to be transmitted, and a guard period.

The synchronization burst is typically a pseudorandom number (PRN) code which is used to synchronize the receiver to the incoming transmission. Additionally, the burst serves to add a degree of security to the transmission process since decoding the transmission without knowledge of the PRN code is virtually impossible.

The identification segment allows the receiver to automatically determine if the received transmission is of interest. The guard period is simply a quiet period to minimize interference and allow the transmission to propagate to its intended recipient(s) before the next transmission begins.

As noted earlier, JTIDS provides some navigational information in addition to its communications functions. In particular, the current version of JTIDS provides a two-coordinate system using standard geodetic latitudes and longitudes or a relative rectilinear grid tangent to the earth's surface. The former system requires one member of the JTIDS net to serve as a position reference, which must be known with high precision. In the latter system, any net member may serve as the reference. It has been estimated that the JTIDS positioning system is capable of determining location with a precision of 9 meters. It should be stressed that the positioning feature of the JTIDS system is restricted in coverage to the basic communications coverage area. JTIDS has been designed to provide communications over a 300 nmi range.

Implementation of the phase one JTIDS hardware and software is well underway, and utilization of advanced technologies is allowing significant reductions in the size and weight of the JTIDS package. For example, the JTIDS package currently being developed for use on fighter aircraft occupies about 1.25 cubic feet. The major system component which is receiving intensive scrutiny is the modulator/demodulator unit, and at present two different technologies appear to hold equal promise for size, weight, and power consumption reductions. These technologies make use of surface acoustic wave (SAW) filters and charge coupled devices (CCDs). Application of these technologies in addition to the use of large scale integration (LSI) offers the hope of future reductions in size and weight.

3.5.4.5 Single-Channel Radio Access (SCRA). There is an obvious need for a mobile subscriber radio in the INTACS structure, and earlier studies indicated that systems such as SINCGARS or PLRS would provide this capability. In the INTACS update study, various NATO SCRA systems were reviewed: the UK's PTARMIGAN, the French RITA, and the German AUTOKO. Technical evaluation suggests the superiority of SINCGARS or PLRS units; however, it appears that the NATO units will be deployed well before SINCGARS or PLRS. This fact has led to a reevaluation of mobile suscriber needs and how best to meet those needs.

3.5.4.6 SINCGARS (Single-Channel Ground-Air Radio System). SINCGARS is the next generation of tactical VHF combat net radios to eventually replace present radio sets such as the VRC-12 series, PRC-77. Spread spectrum transmission modes will be used, and the U. S. Army currently has two variants under development - slow and fast random frequency hopping. Detailed technical characteristics are classified.

### 3.6 Eurasian Communist Countries' ADP Capabilities

Lessons learned from previous technology assessments indicate that it is worthy to examine the state of the art of foreign technology; specifically, the Eurasian Communist Countries (ECCs) and their use and implementation of automated command, control, and information systems. It is possible that, from an examination of this nature, something might be learned which is appropriate for duplication, emulation or exploitation in U.S. battlefield automation. In this case, a review of available information indicates several areas are worthy of highlighting.

The Warsaw Pact nations recognize the need for command, control, and supply of a force which is highly mobile. Furthermore, they recognize the need for interoperability of forces developed in and deployed from different geographical regions. Accordingly, information systems are being deployed to the field at a rather rapid rate, and a coordinated effort is under way to develop information networks that will provide the requisite interoperability. Although the digital computer capability being deployed is approximately ten years behind the U.S. in terms of state of the art, the ECCs are fielding second generation automation capability at a rate that will place them ahead of U.S. fielded capability in the near future. This rapid deployment of information processing capability is attributed primarily to an organizational structure that clearly defines areas of responsibility and establishes the essential elements of information needed at each level in the hierarchy. The equipment is then developed to perform the singular function for which it is needed. Moreover, the equipment is highly standardized and employs component parts that are highly interchangeable.

In the command and control and in the fire support areas, automation is deployed at every level down to and including the battalion. Logistics and administration have been the first military applications to emphasize automation techniques. Automation of these functions occurs at the U.S. equivalent of the corps level and includes decision support algorithms to assist decisionmakers in maintaining inventories, allocating resources, and routing supplies to the lower echelons.

In contrast to this apparent advantage, several deficiences are noteworthy. For example, there appears to be a dearth of applications programming talent. This deficiency might partially be explained by the lack of a large computer-consumer market; the requirement for education and training of programmers is primarily for military applications. In short, there is no large pool of talent to draw upon. This deficiency may also be the result of a high degree of dependence upon analog type computing which requires a different type of "programmer."

Second, the apparent inability of the ECCs to mass produce quality peripheral equipment (e.g., modems, disks, tape, CRTs) will probably severely restrict a rapid expansion of military automation.

Third, although a capability to communicate information does exist, it is also a second generation level capability. Communications from echelon to echelon is largely tape-to-tape, and digital communications over radio frequencies and land-lines is probably no faster than 1200 baud.

From the foregoing, the insights that may be drawn relevant to U.S. duplication, emulation or exploitation are as follows:

1) The U.S. should shorten its acquisition and fielding mechanism, as getting today's technology into the field would provide a ten-year advantage in our real capability compared to ECCs.

2) Protection of our applications and systems software would require the ECCs to develop their own, thereby placing additional stress on their economy and technological base.

3) Placement of logistics and administrative information systems into the hands of the US commander will give him an advantage over his ECC counterpart, who must obtain his information from several echelons away without the advantage of high quality communications links.

## 3.7 Summary

The expected advances in LSI and VLSI technology will allow a continuing reduction in the unit cost of memory and circuit components. The cost of peripheral components will decrease more slowly due to their highly mechanical nature. A continued increase in chip capacity as well as speed is expected.

Although current optical fabrication techniques are approaching the limits of their usefulness, new techniques such as x-ray and electron beam lithography are being developed to increase resolution. The limitations on chip density imposed by power dissipation and packaging technology must also be surmounted.

Although the cost of hardware components is expected to decrease rapidly, the cost of hardware will not be negligible. The cost of frames, power units and so on will be a lower bound on hardware price reductions. Peripheral costs will be lower, but they will continue to be a major portion of total system costs.

Video disk and floppy disk technology offer two low-cost media for storage. Rigid disk technology will remain the predominant form of mass storage in the 1980s; however, video and floppy disks will gain a large share of the rigid disk market.

Although hardware capabilities are increasing rapidly, software capabilities will continue to lag behind. Software engineering techniques need to be developed extensively to improve programmer productivity. All phases of the software engineering life cycle should be included in this development. In particular, good program testing techniques must be developed to avoid the costly bugs which appear after a system has been installed. As computers are used to control more complex systems, such bugs may have great impact on the safety and welfare of human beings.

Standardized languages and architectures should help increase programmer productivity. Secure operating systems are expected to improve steadily within the next decade. The continued decrease in hardware costs will make distributed processing a more economically feasible approach to decentralized computing. Improved man-machine interfaces will assist the user of a computer system by making the system more accessible to a person with little technical training.

For those providing user services in a network of computers, communications will play an important part. Some of the factors which should be understood by the developer are:

Type and quality of channels available.

Interoperability of the channels and their associated signaling equipment.

Survivability of the various types of channels.

Influence that multi-media traffic exerts upon the network in general and the switching systems in particular.

Type of data encryption/decryption employed and its impact upon network structure and performance.

Type of back-up channels that are available and the constraints that they place on volume of data traffic.

# 4.0 ENVIRONMENT ASSESSMENT
# AND
# IMPLEMENTATION OF ADVANCED INFORMATION SYSTEMS

## 4.1 Introduction

This section addresses issues related to sociological impact, human behavioral aspects, and regulatory constraints. Based upon examinations of these issues, schemes regarding the transfer of technology and enhanced implementation of advanced information systems are assessed and propounded.

The development of information systems has generated both practical and theoretical concern with respect to the interaction of these systems with the work organization and environment. It is apparent that information systems that are automated do not simply substitute for previous manual modes of data-handling within the organization. Advanced information systems have an affect on the organizational structure and processes; however, the nature and dynamics of this effect are yet to be applied as organizing principles.

The following sections are concerned with: man-machine information processing concepts; automation and organization; and laws, policies, and regulations. These environmental or external factors play an indirect but essential role in the implementation and use of advanced information systems.

## 4.2 Background

The process of developing an advanced information system is characteristically described as a three-stage linear ratchet process (e.g., Hedberg, et al., 1975). The development process is represented as a step-by-step progression from application definition to system design to system operation (see Figure 4-1). However logical this linear progression may appear, in actual practice every system designer finds that specifications are constantly in flux. Inevitably, as the operational phase is reached, the user has changed the demands placed on the system.

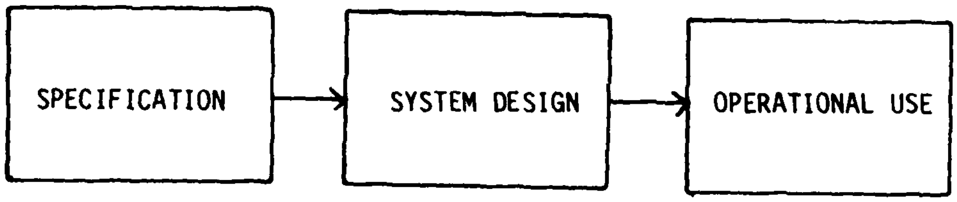



FIGURE 4-1. THE SYSTEM DEVELOPMENT PROCESS

The dynamic nature of the systems development process should be expected, even though it is troublesome. The "consumers" of information systems have often not recognized (or have not been told) that the process of developing and using information systems will inevitably change the organization, require new policies and guidelines, create new opportunities and niches for individuals, and, generally, upset the stability of power and control within the organization. Until the nature of these changes is better understood, there is little that can be done to prevent misunderstandings.

The next sections have been designed to consider some of the problems. Much of what is discussed could be organized around the theme: mechanical ideal versus organic reality. The mechanical ideal models which have been developed under the guise of General System Theory, are presented as examples of the existing system. Unfortunately, such models do not bring us any closer to understanding change, adaptation, insight, competition, and survival, the very elements which have made the development of information systems complex.

## 4.3 Information Processing Concepts

As generally conceived, information systems are designed to enhance results by making the flow and utilization of information more effective. Rather than relying solely on machines (computers, sensors, effectors) or solely on man, advanced information systems seek, ideally, to engage the best aspects of machines and man to effect a superior information processor. To achieve a superior processor, man and machine must work together for benefit without undue compromise, unnecessary restrictions, or added burden (especially to man). This requirement has proven elusive thus far.

4.3.1 Machine Information Processing. Although there are many representational schemes for describing the computer, some with sophisticated architecture, a simple model serves to illustrate the basic computer configuration. The computer has fundamentally only four components: input, treatment, storage, and output. Each of these components can be more or less complex, can act in "real" or delayed time, and can function more or less efficiently for certain types of data and problems.

The computer provides a tremendous source of power for information processing, but it has several limitations which must be addressed. First, input must be preplanned and formatted. There is little or no power of discovery or adaptability available on input. Input sensing devices may be used, but these require either direct wiring, radio, or other telemetry to an input device. Otherwise, some other form such as keyboard entry is required.

Similarly, output is limited to a few media, chiefly displays and print. Just as input must be preplanned and formatted, output is also highly specific. Furthermore, there is no language or symbology which is universally understandable, unambiguous, and optimally efficient.

The treatment or processing component of the computer is typically serial and limited. That is, the computer can actually operate on only one thing at a time and has definite limitations as to the size (i.e., storage requirements) of the problem. (The capacity limitation is primarily a hardware problem, although innovative software can overcome some difficulties.) An important asset of the computer is that data treatment occurs at extraordinarily rapid rates. The most critical limitation is that the computer is confined to deductive or, more precisely, Boolean, logic. Therefore, the computer cannot make unplanned inferences or generalizations, and it is incapable of insight and creativity.

Finally, the memory of the computer is permanent but limited, although new storage technology may eliminate many practical limitations on computer memory in the near future. This memory capability is another important asset of the computer.

4.3.2 Information Processing in Man. In the classic account by Newell and Simon (1972) the brain of man is modeled as analogous to the computer. Unfortunately such a model is terribly oversimplified. If such a "unified" model is adopted, the natural conclusion is that all information processing can be modeled as a machine function. This is equivalent to Fitts (1951) comparability (between man and machine) hypothesis and leads, eventually, to the conclusion that all information processing is best handled by the computer. As Jordan (1963) pointed out, any such conclusion which leaves man out of the process of enterprise in favor of machines is erroneous on its face, and models which lead to such conclusions are in error.

Less simple, but more realistic, is a truly complementary model of decisionmaking. In such a view, each decisionmaking element is a joint result of man and computer, utilizing the relative advantages of each rather than one or the other. Such a model first requires an interpretation of the decisionmaking process in man. It also requires that any oversimplified view of man as a decisionmaker be discarded. Characteristically, such an oversimplified view includes the following assumptions (McCombs, 1972; Shapero, 1978):

- If information is made available, it will be noticed.
- If noticed, the information will be considered.
- If considered, the information will be comprehended.
- If comprehended, the information will be accepted.
- If accepted, the information will be used.

That is, the human decisionmaker is seen as deterministic (Boolean), linear, and logical.

The actual human decisionmaking process appears to be far less mechanistic. Human cognitive processing typically exhibits stereotypes, artificial dichotomies, oversimplifications, overly rapid closure, and unjustified attributions (Katz and Kahn, 1978). This "shortsightedness" in man, combined with organizational constraints and influences, results in decisionmaking which is decidedly fragmented rather than continuous and is intuitive rather than logical. The resultant decisionmaking process may be characterized in the following manner (Schoettle, 1968):

- Choices reflect small deviations around the status quo.

- A narrow array of consequences is considered for any policy.
- Ends and means are often confused.
- Problems are poorly perceived, and the problem solved may not be the problem at hand.
- Analysis and evaluation occur sequentially, resulting in a long chain of amended choices.
- Effort is directed towards remedying immediate problems rather than reaching objectives.
- The focus of activity is fragmented.

This process has been termed "incrementalism" (Braybooke and Windbloom, 1963), a term which is descriptive of man's limited ability to recognize relevant decision parameters and to make correspondingly accurate judgments.

The decisionmaking ability of man has positive aspects. Indeed, many of our institutions have survived only because of successful decisionmaking. These positive aspects reflect man's flexibility and adaptability. Man is particularly adept at seeking and using novel data, at making inferences, at operating when suboptimal solutions exist, and at changing strategies. In general, these positive aspects have been ignored or sacrificed in advanced information system design.

4.3.3 A Complementary Man-Machine System. There are some apparent considerations for the development of a complementary advanced information system. First, an advanced information system requires that the individual sacrifice some flexibility, but, for the individual to give up flexibility, he must gain extensity of power or control. Second, the individual will be curious and insightful, changing to reflect new perceptions. Advanced information systems which limit this growth will quickly fall into disuse or misuse. Finally, advanced information systems will require expenditure of specialized effort (e.g., data entry, programming). This effort must pay dividends, yielding benefits over and above expenditures as perceived by the user.

## 4.4 Automation and Organization

The modern era of industrialization began about 150 years ago. The age of mechanization, as it has been called, was marked chiefly by the widespread displacement of man (and animal) as a source of energy for manufacture. First, the waterwheel and, later, steam and electric power were substituted as sources of energy in enterprises ranging from production to farming. The movement was often remarkably quick and pervasive. The fascination and value placed on novelty and innovation may indeed have exceeded that in contemporary society (Gimpel, 1976). With industrialization came a strong mechanistic imperative. Davis and Taylor (1979) referred to this imperative as technological determinism: The view that technology evolves, inexorably, according to its own inherent logic. With technological determinism as the prevailing ethic, only the "heretic" or "misfit" would question the values of each new technological artifact. The social, psychological, cultural, and environmental effects of some new artifact would be irrelevant as long as it was technically more efficient.

Furthermore, technological determinism meant that it was man's place to adjust to machines. This was the premise first expressed by Babbage (1835) and later formalized as scientific management by Taylor (1911). In scientific management, machine-like efficiency is the goal of the practice of enterprise.

Wasted motion, unnecessary action, and disruptive procedures are to be eliminated both in man and machine. With the "well-oiled" machine as the ideal, Weber (1947), Gulick and Urwick (1937), and Taylor (1911) expressed the bureacratic prototype:

- Process specialization of tasks. Efficiency can be attained by subdividing any operation into its elements. These partial tasks can be taught, expertness in their execution can be readily attained, and responsibility for their performance can easily be fixed.

- Standardization of role performance. As tasks become fractionated, their performance becomes standardized. There is one best way to perform a task, and it should be taught and enforced. Such institutionalization of functions also protects against costly blunders. At higher levels in the organization the same logic is followed by prescribing not only the purpose of the role but the means for achieving this purpose.

- Unity of command and centralization of decisionmaking. The organization is conceived of as a machine, but it is not necessarily self-directing. To maintain the coordination of the whole, decisions must be centralized in one command, and to attain perfect coordination there should be person-to-person responsibility down the line. There should be no bypassing of hierarchical levels as messages are relayed up and down the line. To further ensure unity of command there must be a limited span of control, so that no person at any hierarchical level has more immediate subordinates than he or she can control.

- Uniformity of practices. Not all behavior in the organization can be prescribed by task standardization. Much behavior must be controlled by the specification of uniform institutionalized practices. Thus the same personnel procedures should be followed with respect to all individuals in a given status.

- No duplication of function. One part of the organization should not duplicate functions being performed by another. Operations for the whole organization should be centralized. For example, different departments in an enterprise should not have their own travel and transportation units but should have their needs met by one centralized section.

- Rewards for merit. Selection and promotion of personnel should be on the basis of technical proficiency for the task and achievement in its performance. This means recruiting and upgrading people for performance and formal qualifications, not on the basis of personal friendship nor ascribed status. Membership in a social class or race is irrelevant; in theory meritocracy replaces either personal or institutional favoritism.

- Depersonalization of office. The office is independent of the particular incumbent, who is responded to not because of personal attributes but because he or she occupies an official position with limited and prescribed prerogatives. (Katz and Kahn, 1978, pp. 260-261).

One of the chief aims of scientific management was to analyze jobs into tasks or elements. Each task could then be studied and made as efficient as possible. Indeed, the hope was that as ability to automate increased, these tasks could be modeled and automated, eliminating man entirely (Fitts, 1951). Man was left to do only those jobs which were not practical or economical to automate, which resisted modeling with known techniques, or which were required to keep his "attention." The ultimate expression of this philosophy was illustrated in the design of an assembly line described by Davis and Taylor (1979):

> A number of parallel operating, automated machines for filling and capping aerosol spray cans, with one operator attending each machine, are arranged far enough apart so that there is no communication among the operators. The most frequent human intervention in terms of sheer time and effort required is the insertion of a small plastic tube into a large hole at the top of the upright cans which pass on a circular conveyor belt in front of the operator. The second human intervention and the basic reason for the presence of the operator in the first place is to press a stop switch placed on a post directly in front of him. In the event of perceptible trouble anywhere in the machine, the operator is expected to shut off the machine and seek help to resolve the problem. In this case, the machine design did not include the needed sophisticated sensing devices requiring human intervention as a substitute for them. At the present time, however, it was clear that workers were designed into the system as human machine elements to perform the isolated, technologically unnecessary, and tedious task of inserting the tube which could be easily done by the machine. The decision is one in which the human task of inserting tubes into cans was developed simply because the primary task of sensing and diagnosing required human eyes and ears and, by hiring those, one also acquired a set of hands which were not to be left idle. (pp. 106-107)

Recent reassessments of job design have consistently found that the efficiency which might be gained by mechanistic approaches to work design is often lost because of the dehumanizing character of the task required and by the often demotivating nature of job fractionization. Emery (1979) considered the question of job fractionization: the breaking of jobs into irreducible tasks to be controlled in their execution by standards and rules. He found that unexpected breakdown, not efficiency, was the rule. Furthermore, standardization tended to require the formulation of more rules to handle exceptions. This rule formulation was dynamic, each rule eventually requiring clarifying rules, continuing with no apparent limits. The dehumanizing character of fractionated jobs has been considered frequently by several theorists, most notably Maslow (1943). Man resists taking on machine-like tasks and finds little to be satisfied with in situations requiring such tasks. Thus, the following shortcomings of technological determinism and associated mechanistic approach to job design are now widely recognized:

- Efficiency is a property of machines and automation which reflect a superior capability to perform accurately and reliably in response to a fixed or deterministic environme[nt]. In a complementary fashion, effectiveness is a property of man who responds to a stochastic environment in a superior fashion (Sutherland, 1973).

- Rules and regulations used to the exclusion of measures to achieve commitment and motivation are doomed. Coercive ru[les] inevitably require more rules (Merton, 1957).

- If effectiveness rather than efficiency is the goal, devic[es], machines, and technological artifacts can be made responsi[ve] to the needs of man more successfully than man can respond [to] the needs of machines (Jordan, 1963).

- Worker motivation is as essential to achieving an organization's purpose as is mechanistic efficiency (Davis and Taylor, 1979).

- Often errors, violations of rules, inefficient procedures [and] other mechanistically inefficient behaviors are the hidden keys to adaptation, growth, and survival (Thomas, 1974).

Recently, these principles which consider the psycho-social as well as technological aspects of work have been used to develop more effec[tive] industrial environments. Concern has been moved from efficient devices to development of organizational structures which support and enhance soci[al] values and to the design of jobs which develop healthy, satisfied, motiv[ated] workers. Technological artifacts are used only as they support achievement of these goals. Thus, technological determinism has been displaced with increasing frequency by socio-technical analysis: the view that effective enterprise requires the merger and balance of both social and technical aspects.

4.4.1 Organizational Design Strategies. The advanced information system designer must recognize that the design strategy will be ineffective if it neglects social considerations in the organization in favor of technical ones. Indeed, the development of an advanced information system singly should not proceed without assessing the effect of organizational structure and possible changes to that structure (Galbraith, 1975).

The following factors appear to be important determinants of information processing requirements and capabilities within the organization:

- Autonomy vs. Dependence. Work group autonomy is an effective means to reduce the information processing load. However, greater work group dependence increases the capacity to process information. Obviously, there is a need to balance autonomy vs. dependence with the need to respond to novel situations and demands vs. the need for control as an important determining variable.

- Slack vs. Tight Resources. Slack resources will enhance the capability to adapt and respond without imposing a need to control. Tight resources require high levels of control but provide correspondingly high information requirements not needed with slack resources.

- Lateral vs. Hierarchical Relations. A well-defined hierarchy will create a natural network for the flow of information. Lateral relations require more care in designing information networks. The trade-off is between adaptability for lateral orientations vs. controllability for hierarchical orientation.

- <u>Distributed vs. Centralized Data Bases</u>. The information itself may be maintained centrally or, alternatively, distributed close to the points of collection and use. Central maintenance will enhance control and short-term efficiency. Distributed maintenance will enhance long-term use and survivability but will decrease central control. With new "hybrid" (central/distributed) computer networks, a balance may be within reach on this factor.

The "bottom-line" with respect to organizational design is that too much "systemization" results in inflexibility and, therefore, threatens use and survivability. Current informal organizational structures provide important mechanisms for the flow of information. Often these unofficial structures form the impetus for action. Should advanced informatior systems be imposed which destroy this organic fabric within the organization, the organization will swiftly succumb to the need for other change.

### 4.5 Laws, Policies, and Regulations

Large public organizations inherently have extensive and important responsibilities to their collective constituencies: the public, suppliers, those served directly, and the government. The charters of such organizations necessarily involve doctrines of effectiveness and efficiency and doctrines of competitive bidding. It is often argued that the doctrine of competitive bidding has a chilling effect upon efficiency. For example, the Army would point to computer equipment which is obsolete if not antiquated by the time it is operational as the net result of the inherent inability of that organization to strike a balance between the two doctrines.

To examine this further, advanced information system implementation decisions can be categorized on the following variables:

- Reversibility. Once a decision to design and implement is made, how easy is it to change? For example, can new technologies, requirements, or functions be added? Is the decision irreversible in practical terms? Can it be stopped if it is not working properly?

- Scale. What is the level of impact of the system? Is it limited to a special use or function or is it to apply generally? What is the life-cycle investment which must be made? (Note: <$500K:small; $500K to $20M:moderate; $20M to $50M:moderately large; >$50M:large.)

- Urgency. Is this required to meet a pressing need without which effectiveness will dramatically and rapidly deteriorate? Can a new requirement not be met without such devices?

- Proprietorship. Do systems fall under the special expertise of one company? Does system production require special investments, otherwise irrecoverable?

The extent to which a system is small scale vs. large scale determines the necessity to invoke doctrines of competitive bidding. A small system is usually not cost effective for a corporation to specially build. Thus, an "off-the-shelf" system would necessarily be bid. Hence, there is little protection afforded and little enhancement of equity by insisting that high degrees of fairness be observed at this level. However, as scale increases, fairness is required correspondingly.

The extent to which a system is reversible directly influences the need for effectiveness and efficiency (i.e., flexibility). Reversible systems place few demands on flexibility. Irreversible systems require flexibility as an essential design element. Regulations which "chill" flexibility are essentially dooming to the pursuit of irreversible systems, even those which may be essential.

Obviously, the greater the urgency, the less fairness and flexibility are required. Low urgency demands that fairness be scrupulously observed.

Finally, proprietorship requires that possible savings from collective bidding be balanced against the rights and investments of the proprietor. One-of-a-kind systems may require the relaxation of fairness (competitive bidding) in order to protect patent and other ownership rights respected in law and practice.

To the extent that laws, regulations, and rules pertinent to approval and acquisition are incongruent with these requirements, some changes would be required. Examination of current regulations (AR 18-1, AR 18-3, OMB Circular A-76, STAMMIS, SOMISS, SOMAC, PL 89-306, S.240(FCPA 1979), etc.) reveal the following interesting patterns:

First, the traditional, formal competitive bid process is mandatory for large-scale systems. The burden is on the designers to assure that specifications are exact and responsive to needs. This should be assured during the approval process. Obviously, this process is not responsive to urgency and irreversibility once set in motion.

Circular No. A-109, OMB, requires that all acquisition within the government follow the same procedures. Within the military, A-109 is enacted through DoD Directives 5000.1 and 5000.2. Major systems must adhere to 5000.1, while 5000.2 places all equipment acquisition under A-109. The key provisions of A-109 are (Backus, 1979):

- Formal mission-oriented structure for front-end.

- Clear decision on mission need, at time of new program start.
- Resource issues resolved at outset.
- Mission based RFP/requirements with flexibility maintained.

o Competitive continuity.
  - Start early, and maintain complete technical freedom so evolution can be rewarded in design.
  - Maintain direct head-to-head contract competition through direct support when necessary.
  - Pursue logical evolution of alternatives and task oriented funding.
  - Extend effort through system demonstration in an operational environment.

Figure 4-2 summarizes the acquisition process under A-109.

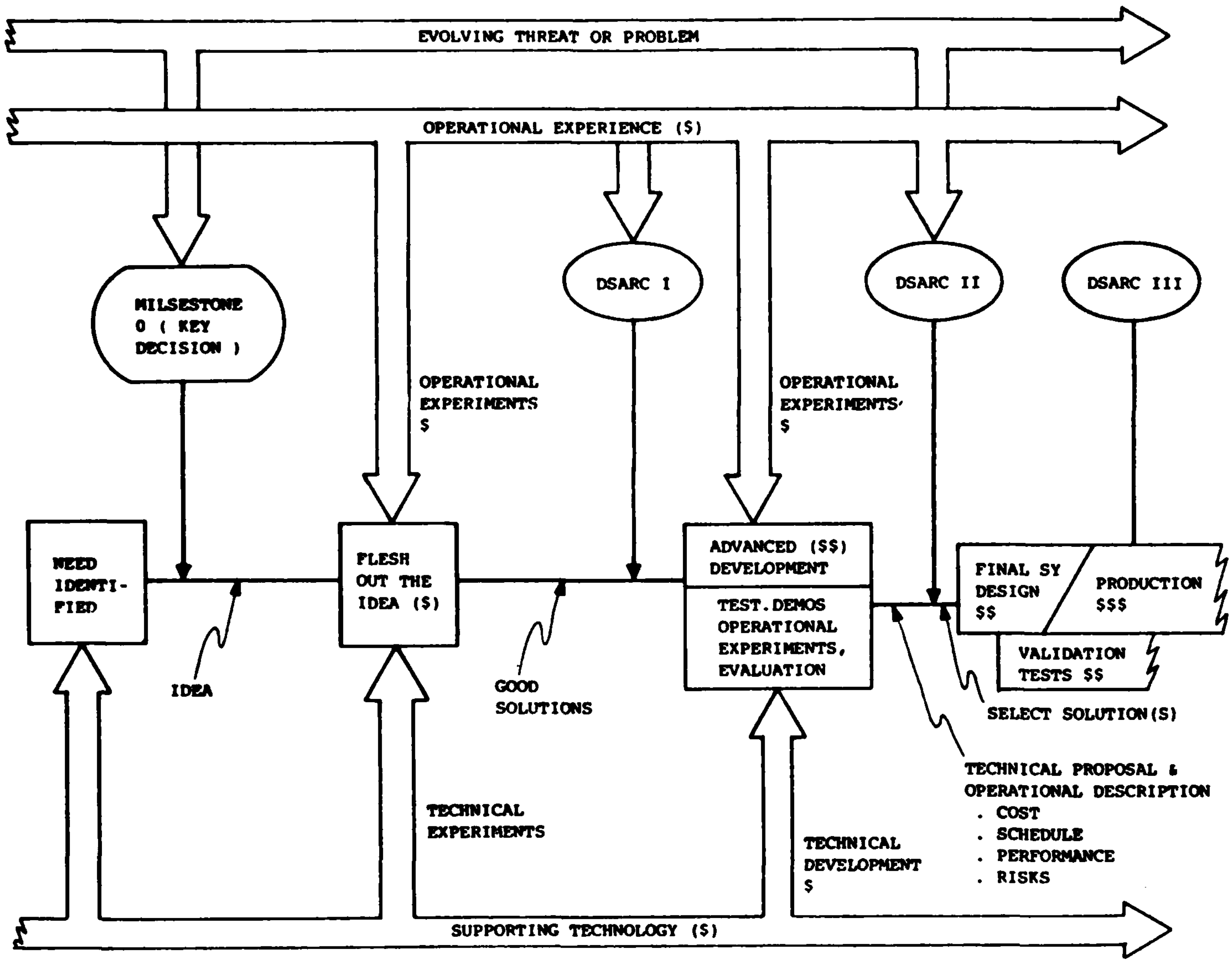



Figure 4-2. The Acquisition Process (Adapted from Backus, 1979)

Secondly, small-scale systems (<$500K life cycle cost) may be bought off-the-shelf. Assuming that the procurement decision is reasonable, this fact allows a high degree of responsiveness to small-scale, limited applications. Indeed, with emerging macro-mini's, this policy may be ideal for resolving local factions.

Finally, there is a hybrid acquisition process available (in A-109) which allows statements of initial requirements to be responded to by bidders who provide concepts and approaches. At that point, up to three bidders may be chosen to build prototypes at Army expense. The "winner" can then be chosen on the basis of how well the actual prototype performs. (There is no obligation to pick a winner.) This hybrid acquisition process may be ideal for computer system acquisition if utilized properly.

Before A-109 can function up to its potential, a realistic testbed will have to be created. In particular, the testbed will need to simulate the effects of:

- Context.
- Structural alternatives.
- Coordinating and managing methods.
- Organizational alternatives.
- Individual roles.
- Dynamic relationships.

Without a realistic testbed for trial and error, prototypes will not be adequately tested. The first test will come only after implementation -- far too late.

Thus, current laws, rules, and regulations are not, in themselves, the barriers to effective advanced information system implementation. The process for acquisition is workable, but the gap between designer/developer and user in specifying and testing advanced information system concepts must be closed, or at least shortened.

A process which is more amenable to the necessary evolution of advanced information systems may be a coordinated program of research, development, test, and evaluation in a use-learn-develop cycle. Such an approach will take advantage of advanced technology and of the experience of Army commanders. The process can be described in two phases: The Conceptual Development Phase and the Implementation Phase.

The Implementation Phase is in no way different from the current engineering development, production, and deployment phases of the existing acquisition process. However, the Conceptual Development Phase is different. The structure of this phase would generally consist of two steps:

Step 1, "Concept Formulation," consists of (1) analysis of the identified operational needs and deficiencies of the existing capabilities; (2) an assessment of fiscal, timing, interoperability, standardization, and other constraints; and (3) a program plan. Advanced Prototype Demonstrations (APDs) and engineering and development facilities may be initiated during Step 1 if required to aid in the formulation of the initial concept.

Step 2, "Use-Learn-Develop," consists of two major elements. The first element takes full advantage of the Engineering and Development Facility and/or Advanced Prototype Demonstrations. The second element provides for the preparation of detailed development specifications.

- Engineering and Development Facility and/or an Advanced Prototype Demonstration refines the requirement, assesses the technical approach, and validates the concept. The using command participates directly in this step. Maximum use is made of existing military and commercial hardware and software which is functionally acceptable to the using command and is suitable for subsequent Field Evaluation trials.

- Advanced Prototype Demonstrations transfer the system developed in the engineering and development facility to the using command for further evolution and evaluation in an operational environment. Evolution of the system is directed at tailoring the system to meet the identified need under the stresses of field operations.

The second element results in a detailed definition of the information system requirements and specifications (including software requirements) for subsequent use by a program manager (PM) in the acquisition and deployment of the system. The figure 4-3 illustrates the relationships of the Use-Learn-Develop approach.

Phase II encompasses, to the extent required, modification of an existing system, full-scale engineering development, or production and development of the system for operational use. This structure may take one of four possible forms depending upon the availability of appropriate hardware and software at the initiation of Phase II. The four possible forms are:

(1) Modification. In this form the system already exits and only a modification is required. It is to be anticipated that the needs for, and employment of, information systems will change in an evolutionary way over the lifetime of the systems.

(2) Deployment. In this form, sufficient hardware exists in either military or suitable commercial form, and the software has been developed on this equipment during the design and development phase. The system may already be deployed in Phase I, or all that remains to be done is to deploy the hardware or the software to the using command(s).

(3) Production and Deployment. In this form, suitable system hardware designs exist in either military or commercial form, and the software has been developed on this equipment during the design and development phase. A few of

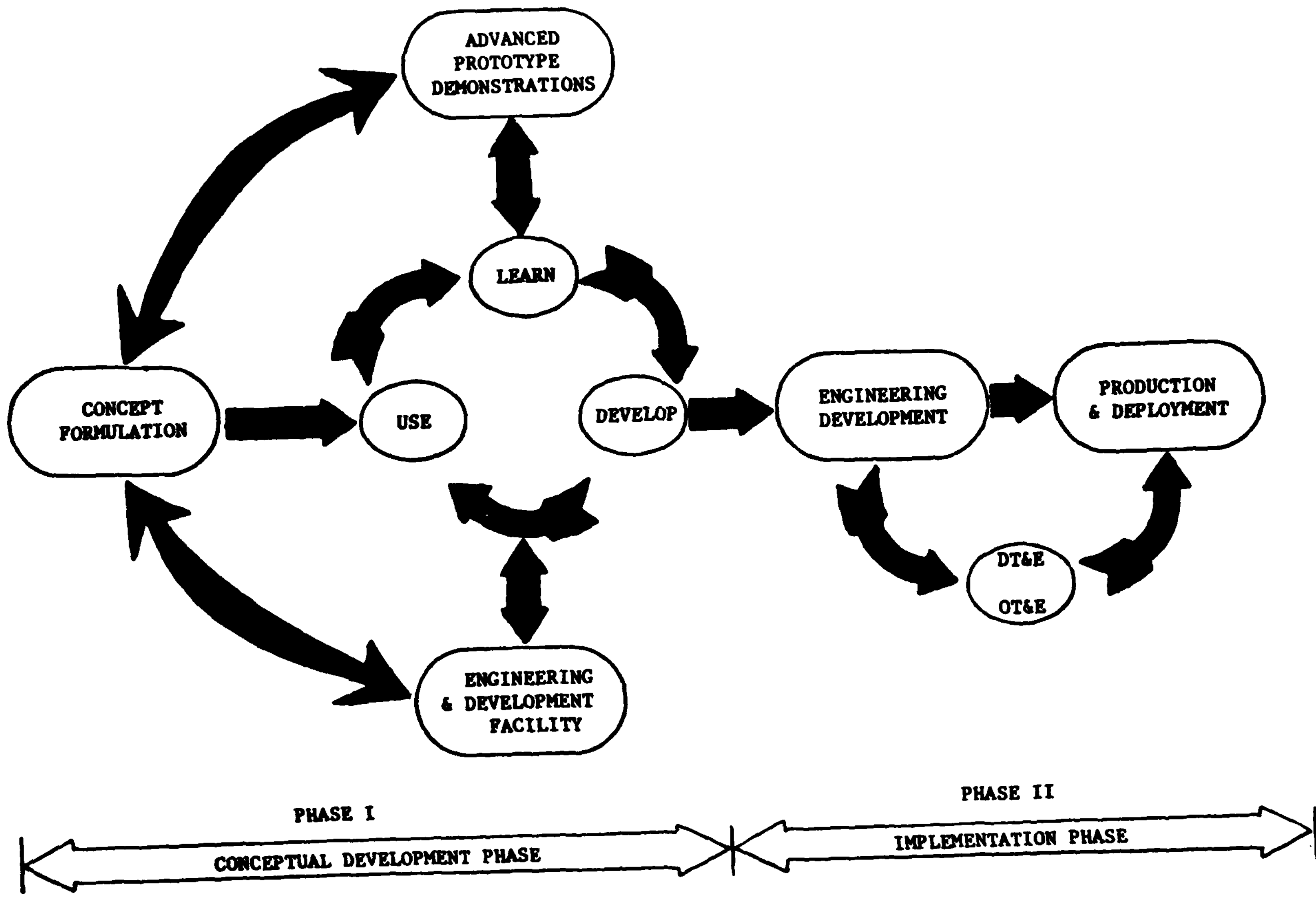



FIGURE 4-3. ADVANCED INFORMATION SYSTEM DEVELOPMENT.

the systems or portions of the system may have already been deployed in Phase I. What remains to be done is the production of sufficient quantities and deployment to the using command(s).

(4) Engineering Development, Production, and Deployment. In this form, the design and development phase was conducted with modified or brassboard equipment (either military or commercial) which is not operationally suitable for the intended application. Thus, full-scale engineering development is required. This form may also include revisions to the prototype software used in the design and development phase.

# 5.0 GENERIC REQUIREMENTS AND TECHNICAL RESEARCH ISSUES

## 5.1 Introduction

As documented in Section 2, the current Army ISs are not responsive to the battlefield commander and his staff. In addition, there is a growing recognition that these ISs should change from the current card input, batch processing to a more interactive mode of operation to meet future needs. These systems will be constructed with an aim of satisfying user information needs on the battlefield on a real-time basis. The user will not have to wait for a scheduled cycle to obtain information. Nor will he be required to manually sort through a bulk record printout to find the particular piece of information desired. Rather, the user can directly query the system to obtain information when desired and in a suitable format.

Future Army ISs should take advantage of the low cost, modularity, and flexibility of mini/micro-computers. These systems will be responsive to the needs of the user (vice system operator) by providing information when needed, be more survivable by being distributed, and could require reduced loading on communication channels by being located nearer the user. They will be built from the viewpoint of complementing the skills of the soldier; computers are not intended to be a replacement for the human being. Ownership of system resources will be with the user, similar to the manner in which radios are now assigned to him. Finally, these systems will have an organizational impact which may cause structural change within the Army.

## 5.2 General Requirements

Requirements for Army ISs of the post-1985 period comprise the following:

- o system overview,
- o input,
- o processing,
- o output,
- o data base,
- o communications, and
- o decision support aids.

5.2.1 System Overview. To meet the needs of the modern battlefield, the user requires interactive access to and from the supporting IS. This interaction can best be obtained by use of the current and emerging mini/micro-computer family linked together in networks supported by communications. These networks should be first viewed by organizational levels. Thus, the information needs of a battalion are analyzed, and supporting equipment is provided to assure flow of information. Connectivity, provided by communication resources, will be between nodes within the organizational level. In addition, connectivity between lower, adjacent, and higher command echelons will be assured. Finally, there is connectivity between mutually supportive systems, such as command and control and combat service support.

This network is complex in nature, but provides benefits to the user community. These benefits are in system flexibility, modularity, responsiveness and survivability. Flexibility is gained by designing information nets of sufficient magnitude to accommodate the commander

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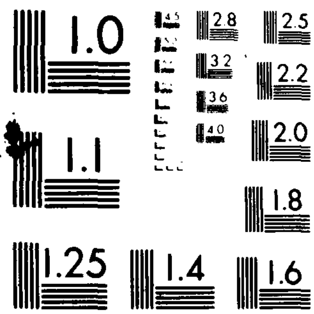


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

worst case basis (e.g., nine battalions subordinate to a brigade). By the flexibility inherent in a network, the IS will not be a constraint to the commander and allows him to adopt courses of action at will. As with flexibility, the nature of the network assures modularity in meeting various operational environments. While the system must meet battlefield requirements in addition, it is also desired that peacetime and crises situations be handled. A network system of mini/micro-computers has the capability to meet these needs. Finally, responsiveness is obtained by refocusing design criteria towards meeting the users' information needs at nodes rather than the system operators needs of economies of scale gained by daily cycles. In addition, the standardization gained by exchangeable mini/micro-computers enhances responsiveness and continuity of operations as devices can be moved from less important to critical functions.

5.2.2 Input. Input devices of the near-term will be "intelligent" mini/micro-computers located at information nodes. Keyboard and functional key input by the user is expected to be the primary means of providing data to the system. User prompting and assistance will be available at the device to reduce the training required for operation. In the long-term, input devices are boundless, with investigation under way on voice input. It is anticipated that compact devices would be available which might allow specialized input (e.g., supply related information from the logistics NCO).

5.2.3 Processing. Processing as described in Section 2, will be information, network, and data base. The potential is for the use of any of the six configurations described in that section at any information node, depending on responsiveness criteria and economies of communications resources.

5.2.4 Output. In the near-term, output from the system can be expected on the same "intelligent" device used for input. Major changes from current operations will include display of replies to user queries (in the format and detail desired) on CRTs, which are part of the "intelligent" devices. Therefore, no paper is generated unless requested by the operator. Backup to the CRT will be line printers; magnetic tape; floppy, fixed, and removable disks; and possibly microfiche. As with input devices, there is much work to be accomplished in output media in the long-term. Expected are small, specialized devices which may respond to pre-established queries (e.g., commander determining status of ammunition by pushing a single functional key).

5.2.5 Data Base. Discussions held in the user-developer workshop conducted in December 1979 indicated that the user had no requirements concerning the location of the data base. (Concerns included responsiveness to user needs rather than locations of the data itself.) Considerations discussed during that workshop were (1) "sanctuary processing," where the data base is located in a single, safe haven; and (2) "entirely distributed systems," where the data base is local to the user. The decision as to the appropriate location will be based on operational doctrine and the particular needs of the system under design.

5.2.6 Communications. Communications in support of a network system is key to successful implementation. If interactivity is to be employed on the battlefield, communications support is essential whether the data base is in a single location or distributed locally. Availability and reliability of communications systems will be the guiding principles for program managers as they design the battlefield ISs of the future. As such, the knowledge of trends in development of communications is essential if there is to be a successful marriage between communications and ISs.

5.2.7 Decision Support Aids. As the user becomes more sophisticated through exposure to computer power and modern management techniques, more demands will be placed on the system to display data in a variety of ways. Users, particularly intelligence officers and commodity managers, will require information in graphic form (e.g., line charts and histograms), in the form of statistical summaries, and in the forms used by operational researchers. In addition, the user will need the capability of writing programs to manipulate data in a form unique to his needs.

## 5.3 Potential Research Issues

The program manager of the post-1985 period will be faced with numerous problems in developing future ISs. This fact will not be new as he has always been encumbered with this burden; however, based on the current environment where present systems are not meeting requirements, particularly in a battlefield environment, his troubles will be new ones in the distributed, network arena. To reduce risk, it is appropriate to study some of the potential problems facing the program manager with sufficient lead-time to influence his development process.

5.3.1 C2 and CSS Interface. The next major war involving the U.S. Army can be described as one requiring excellent utilization of all resources. An emerging command and control (C2) system will focus on the control of forces. Combat service support systems will handle the material and services needed to support the Army in the field. The need for interface between the two systems is recognized in general terms. The commanders' needs can be met with summary information to support addressing courses of action, near and long-term planning, and other decisions. In the draft "Corps Commanders' Information Needs," these needs were expressed as follows:

- o Class III and IIIa
  - Required Corps Levels
  - Levels at COSCOM
- o Class V
  - Required Corps Levels
  - Levels at COSCOM
- o Class VII
  - Operational Ready - Corps
  - On-hand - COSCOM
  - GS Repair Estimate - COSCOM
  - Projected Gains - Corps
- o Class IX
  - Critical Shortages
- o Critical Personnel Shortages by MOS

The questionnaire completed by representatives of major commands and other agencies and those attending the workshop confirmed these needs. They also noted that the commodity manager supported by CSS systems have requirements for information in more detail in terms of the numbers of classes of supplies and the depth of knowledge concerning these items. The commodity manager requires information on which to make logistical decisions of forecasting, ordering replacements in personnel or equipment, determining schedules for receiving these replacements, and similar matters. (It was noted during the workshop that information concerning transportation was essential to the commodity manager, but not currently available in an automated, real-time system.) Therefore, while the two systems (C2 and CSS) are concerned with logistics, their needs are different: the C2 system requires summary information from parts of the available logistics and personnel information; CSS needs information in detail.

Work is needed to define the C2 and CSS interface requirement and to explore the possible means by which it will be accomplished in a distributed network environment.

5.3.2 Multiple Echelon Reporting Techniques. In its organizational structure, the Army has closely followed policies which are best expressed by Fayol's fourteen principles of management. Of particular interest to the information scientist is the scalar principle which refers to the chain of direct authority relationship from superior to subordinate throughout the organization. Fayol states that the scale is described as:

> The chain of superiors ranging from the ultimate authority to the lowest ranks. The line of authority is the route followed -- via every link in the chain -- by all communications which start from and go to the ultimate authority.

Army ISs have loyally followed this principle without note of some of the concerns expressed by Fayol. For he continues by indicating:

> This path is dictated both by the need for some transmission and by the principle of unit of command, but it is not always the swiftest. It is even at times disastrously lengthy in large concerns, notably in governmental ones.

Reaction to this caution can now be noticed in the draft "Corps Commander's Information Needs," which addresses concern for a command and control system. It is noted in this document that the requirements of the corps commander should not add to the information already required by the corps headquarters. It should be possible to simplify and streamline information flow by the use of "multiple echelon" reporting techniques. These techniques are defined in the study as "direct communications to the echelon capable of providing a decision or support, while concurrently keeping other pertinent echelons informed." It is recognized that the information provided (in this case to corps) may not have been through a complete collation and analysis at lower echelons. However, there is an increasing awareness of the importance of this uncorrelated battlefield information to support battle management and execution, particularly in mid to high intensity conflicts. The study concludes that multiple echelon reporting is particularly suitable for providing timely battlefield information for both weapons targeting and the allocation of resources.

Although Army leadership appears to be changing its concept of information flow, there has been little work to develop technology to support this concept. This deficiency is particularly noted in a distributed network environment where the establishment of program managers' "rules of thumb" would be extremely helpful as they attempt to develope and field such systems.

5.3.3 Digital Communications Requirements. With the recognition of the need to support the battlefield commander and with consideration being given to networks to support information exchange, dependence upon communications grows. Detailed information concerning the current and future communication systems can be found in Section 3 of this report. That section and a series of articles by M.G. Clay T. Buckingham and members of the Office of the Assistant Chief of Staff for Automation and Communications (in Army, April 1980) indicate that communications, particularly in support of automation, is only now coming to grips with modern support of the battlefield. Much of the delay in defining appropriate communications systems can be attributed to evolving doctrine within the Army, particularly in the area that affects echelons above corps. As Mullen states:

> Regardless of the alternatives chosen, the old, fixed communications facilities found in echelons above corps (EAC) today are vulnerable and subject to saturation under wartime conditions. They must be replaced. To accomplish this, however, EAC doctrine must be firmly established. Then, based on doctrine, developers can field a state of the art communication system which will satisfy future theater operational requirements.

The problems of communications and the array of potential solutions are beyond the scope of this report. However, one should be aware of the importance of communications on the modern battlefield and that systems requiring support of communications are being developed currently. Research issues abound in this field -- both in support of the communications systems and in establishment of the IS/communication interface.

5.3.4 Information System Network Analysis. The basis for this research issue is found in Subsection 2.4 where potential solutions to meet battlefield needs are presented. Simply stated, the research issue is the development of guidelines for program managers to assist them in selecting appropriate architectures to meet the needs of the Army. Parameters should be developed to guide the program manager. For example, consider the problem of location of a particular portion of the data base. The question to be answered is where to locate this portion, locally or in another place. The research would examine the problem to determine the economics gained via trade-offs of storage space at the local site versus communications costs. Obviously, these guidelines can be developed only if one knows or can estimate the frequency of requests for information contained in the portion of the data base and the number of updates in a given time period. The program manager seldom has time to develop these trade-off considerations given the requirements of fielding a system. The researcher does have the time and the objectivity necessary to develop the needed guidelines.

5.3.4.1 Network Security. Specific subsets of the information system network analysis can be identified. In any hostile environment, security is a major problem. This is particularly true on the battlefield where information needs are met by distributed data bases and networks linking nodes. The research issue is not one of physical security. (This is an important consideration, but should be left to the provost marshal.) Rather, the focus is on development of protocols necessary to assure that network, data base, and information processing can be accomplished only by authorized personnel.

5.3.4.2 Modern Continuity of Operations. Availability of the system was a key requirement derived from the workshop conducted in December 1979. The research issue is to develop procedures to assure continuous availability of information on the future battlefield. Interference with the flow of information can be caused by enemy action, failure of equipment, or the movement of the unit, if hardware is not capable of operating while in transit. These problems will be magnified for the post-1985 program manager as distributed systems are introduced and supported by complex communication techniques. Work leading to solutions assuring continuous information flow is required now so that they may be available for future wartime systems.

5.3.4.3 Future Data Base Management Systems. This research issue is highlighted because of the impact it will have in the conduct of the battle. It is a natural result of network analysis, particularly when considering the trade-offs of data base location. Data Base Management Systems (DBMS) must be compatible with other processing within the network. If efficient DBMS can be developed that will support distributed data bases, the physical signature of information support equipment will be reduced substantially. Those numerous vans identifying the location of nearby division trains will be removed from the battlefield. This should lead to improvement in the overall effectiveness of combat forces.

5.3.5 Decision Support System Applications. In addition to the rapid advance of mini/micro-computers and the expressed need for network processing, there has been technological progress made in the development of computer-driven displays which support operations research techniques. Further work in this area is needed in both establishing requirements and designing prototypes which demonstrate the capability. It is anticipated that the CSS commodity manager on the battlefield will need information in a variety of forms. Insight into his problem can be achieved by use of operations research tools such as regression analysis, linear programming queueing, decision trees, decision matrix, and statistical packages.

Currently, there is a need to determine which tool can be best applied in support of CSS on the battlefield. Once that is accomplished, prototypes should be developed and refined with the aim of showing the commodity manager the capabilities of these tools.

5.3.6 Input/Output Requirements. This is a continuing research issue based on the rapid technological improvements in the computer field in recent years. Only a few years ago, computers the size of IBM 360/30s required entire vans in which to operate. Today, the same computer power is contained commercially in a device that sits on an ordinary desk. In the past, the Army made decisions as to level of automation based on the equipment of the time and the burden it would be to the using unit. Increased technology has (or at least will have) effect in that decision as hardware becomes smaller and easier to use and maintain. This technological advancement should be tracked with the goal of providing state-of-the-art information to the program manager of the post-1985 period.

# 6.0 RESULTS/CONCLUSIONS

## 6.1 Current Information Systems

Current Army ISs are transaction oriented, using card input and employing batch processing. The key to initiation of activity is the punched card which indicates the item or personnel desired by the organization. These are entered into the system during periodic cycles, normally daily. There is limited user interaction, such as querying the data base. Systems were designed to meet functional requirements as defined by a particular staff office in the HQ, DA. Because of this orientation, they are "stovepipe" in nature with few interfaces with other systems.

ADP equipment to support these systems at the division level is the IBM 360/30. These computers and associated gear are housed in five vans organic to the Division Data Center. By its size, this set of equipment is difficult to camouflage and tends to indicate the location of division trains. Requirements for equipment operation to move and to set-up hinder the mobility of the center.

Based on the cyclic nature of processing, lack of user interaction to the computer, and difficulties of operation, the current Army ISs are not responsive to the requirements of the commander and his staff in combat.

## 6.2 Future Information Systems

Development of future Army ISs should focus on the needs of the battlefield with peacetime operation being a secondary goal. Army users and their representatives have been exposed to the technological development of the mini/micro-computers and have witnessed actual systems or demonstrations of networks supporting these computers to provide real-time processing. Systems of the future are expected to embrace the flexibility, modularity, and low cost inherent in the mini/micro-computer technology. Goals of the future systems will be modularity, functional ownership of ADP resources, discretionary access, responsiveness, improved data reduction, reduction of paper, data integrity, and quality of data. Trade-off considerations of future program managers will focus on providing the information at the correct node in time to affect the decision process rather than economy of scale.

## 6.3 Individuals and Their Relationship with Information Systems

Information systems should be designed to produce results by making the flow and utilization of information more effective. Rather than relying solely on machines or solely on man, ISs should seek to engage the best aspects of machine and man to effect a superior information processor. To achieve a superior processor, man and machine must work together for benefit without undue compromise, unnecessary restrictions, or added burden, especially to man.

Future Army ISs should incorporate the goal of a balanced man-machine interface with the aim of achieving the superior system.

## 6.4 Laws, Rules, and Regulations

Laws, rules, and regulations have affected ISs currently fielded by the Army. Primarily, the Study of Management Information Systems Support (SOMISS) was instrumental in the development of compartmented, "stovepipe" systems along functional lines. Although this is true, these current laws, rules, and regulations are not in themselves barriers to effective IS implementation.

A process more amenable, however, to the evolution of system requirements is a coordinated program of research, development, test, and evaluation in a use-learn-develop cycle. This process employs mini-test beds, termed Advanced Prototype Demonstrations (APD), to refine requirements, to assess technical approaches, and to validate concepts. APDs are manageable, "leading edge" experiments aimed at resolving research issues in an objective manner with the goal of providing technical reference to users, user representatives, system designers and program managers. Potentially, these demonstrations could transfer the system development from the engineering and development facility to the using agencies for further evolution and evaluation in an operational environment.

## 6.5 Technology Requirements

Technology has advanced greatly during the past two decades. Military equipment, to include communications gear and computers, is currently in a state of flux as new items and systems are entered into the inventory. Further change is forecasted as the Army enhances its battlefield information systems by introducing mini/micro-computers in networks connected by organic communications. To prepare for this change, research issues should be investigated with the aim of providing technical guidance to program managers and system designers. These issues lie in the area of:

- o System interface between command and control and combat service support;
- o Multiple echelon reporting techniques;
- o Digital communications requirements;

- Information system network analysis;
- Network security;
- Modern continuity of operations;
- Future data base management system;
- Decision support system applications; and
- Input/output requirements.

# 7.0 RECOMMENDATIONS

The following recommendations are submitted:

- o Adopt the Advanced Prototype Demonstration (APD) method for support of technical investigation and to assure that results are available to users, developers, designers, and appropriate agencies in the post-1985 period.

- o Study the research issues identified to determine those with greatest impact on the Army's needs.

- o Develop a plan to investigate these issues in depth using the vehicle of APDs.

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