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MTR-87W00131 Rev. 1

AD-A219 475

Filmless Radiology: The Design, Integration, Implementation and Evaluation of a Digital Imaging Network

Subtitle: Potential Investigations to be Conducted in Conjunction with the Digital Imaging Network System (DINS) Evaluation Project

Annual Report

Michael B. Harrington, Ph.D.
John R. Cerva
Marcus E. Glenn
Lawrence D. Nadel, Ph.D.
Barbara Kerlin, Ph.D.

June 1988

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Supported by
U.S. Army Medical Research and Development Command
Fort Detrick, Frederick, Maryland 21701-5012
Contract No. DAMD17-86-C-6145

The MITRE Corporation
7525 Colshire Drive
McLean, Virginia 22102-3481

90 03 20 042

Department Approval: Barbara D Kerlin

MITRE Project Approval: Barbara D Kerlin

This document has been peer reviewed by: Laura Brennan
Laura Brennan

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION The MITRE Corporation

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS *(City, State, and ZIP Code)*
7525 Colshire Drive
McLean, Virginia 22102-3481

7b. ADDRESS *(City, State, and ZIP Code)*

8a. NAME OF FUNDING / SPONSORING ORGANIZATION U.S. Army Medical Research & Development Command

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. DAMD17-86-C-6145

8c. ADDRESS *(City, State, and ZIP Code)*
Fort Detrick
Frederick, Maryland 21701-5012

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO. 3S4	TASK NO.	WORK UNIT ACCESSION NO.
63732A	63732D836	AV	127

11. TITLE *(Include Security Classification)* Filmless Radiology: The Design, Integration, Implementation and Evaluation of a Digital Imaging Network

12. PERSONAL AUTHOR(S) Michael B. Harrington, Ph.D.; John R. Cerva; Marcus E. Glenn, Lawrence D. Nadel, Ph.D.; Barbara Kerlin, Ph.D.

13a. TYPE OF REPORT Annual Report

13b. TIME COVERED FROM 3/1/87 TO 2/28/88

14. DATE OF REPORT *(Year, Month, Day)* 1988 June

15. PAGE COUNT

16. SUPPLEMENTARY NOTATION
Subtitle: Potential Investigations to be Conducted in Conjunction with the Digital Imaging Network System (DINS) Evaluation Project

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
06	02	
06	05	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
RA II; Radiological Information Management; Data Communications; Digital Images; Digital Radiography, Teleradiology; Volunteers; Filmless X-Ray; Communications Network Models

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This document describes evaluation studies and technical investigations proposed for the three-year Digital Imaging Network System (DINS) prototype project, sponsored by the U.S. Army Medical Research and Development Command, Ft. Detrick, Maryland. The project has three overall goals. The first is to install and operate a prototype DINS at each of two University-based hospitals for test purposes. The second is to evaluate key aspects of each prototype system once it is in full operation. The third is to develop guidelines and specifications for an operational DINS suitable for use by the military and others developing systems of the future. This document defines twelve overall evaluative questions for use in meeting the second and third objectives of the project and proposes studies that will answer these questions.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL Mrs. Virginia M. Miller

22b. TELEPHONE *(Include Area Code)* 301/663-7325

22c. OFFICE SYMBOL SGRD-RMI-S

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

FOREWORD

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Accession For
NTIS GRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist A-1 | Avail and/or Special

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EXECUTIVE SUMMARY

This document provides an overview of desirable investigations in connection with the three-year Digital Imaging Network System (DINS) project. The three objectives of the document are: to provide an overview of the studies that could be conducted during the course of the DINS project; to describe how the participating organizations would carry out each approved study, either individually or cooperatively; and to focus discussion on the priority each approved study should have in the project. A companion MITRE document, The Digital Imaging Network System Project Management Plan, establishes priorities and discusses details regarding the management of these investigations.

This document begins by discussing the U.S. Army medical care system, including both its peacetime and combat casualty care missions and the potential role DINS might play in carrying out both missions. Against this background, the three overall project objectives are discussed. They include: installing and operating prototype DINS at each of two university-based hospitals, Georgetown/George Washington Universities and the University of Washington; evaluating key aspects of each prototype system in operation; and developing guidelines and specifications for an operational DINS suitable for use by the military medical care system and others in the early 1990s.

The second section of this document sets forth twelve major questions about the performance of the DINS that provide overall guidance to project activities. It also shows how proposed studies, taken as a whole, will provide answers to these questions.

Section 3.0 presents four proposed baseline and post-installation studies. Suggested are studies dealing with: the overall performance of the university sites prior to installation of the DINS prototypes; their performance after installation; costs and benefits attributed to the DINS in operation; and special cost/benefit estimates made for planning purposes on behalf of the U.S. Army Medical Research and Development Command (USAMRDC).

Section 4.0 presents six proposed studies concerned with DINS workstations. They include: the development of a normative, analytical model of the workstation; an investigation of the design of prototype DINS workstations; an assessment of display requirements for contrast and spatial resolution; an investigation of the capabilities and uses of a personal computer-based (PC) workstation in connection with the DINS; an exploration of the value and requirements for multi-modality image analysis capabilities; and an investigation of automated decision support systems suitable for use in combat casualty care.

Section 5.0 presents six proposed studies focussed on network performance and architecture. Included are studies which: assess the overall efficiency and effectiveness of the prototype architectures; investigate requirements for integrating the Radiology Information System (RIS) with the DINS; model the DINS network under varying operating conditions to assess overall efficiency; examine the requirements for communication among two or more DINS; examine methods for linking a teleradiology system with the DINS; and investigate the impact of image compression techniques on network performance.

Section 6.0 is concerned with education, implementation, and training issues. Included are studies concerned with: methods for developing a cadre of knowledgable clinicians and administrators; the overall effectiveness of DINS user training materials; and ways to exploit the use of DINS as a teaching device for radiologists.

Section 7.0 discusses clinical studies proposed by Georgetown and George Washington Universities. Proposed are studies concerned with: the acceptance and impact of DINS upon radiology subspecialty services; the acceptance and impact of DINS-assisted radiology service on other clinical services in the hospital; the acceptance and impact of the DINS electronic image archive as an alternative to film archiving; the role of hard copies in the DINS environment; and the reliability of DINS in operation.

Section 8.0 proposes clinical studies for conduct at the University of Washington. Included are studies that: characterize clinically-oriented DINS functions; identify unique clinical requirements the DINS should meet; develop a clinical evaluation methodology; evaluate the DINS from a radiology department-wide perspective; evaluate the impact of the DINS on emergency room/intensive care unit performance; and evaluate the teleradiology link between the University of Washington and Sitka, Alaska.

Section 9.0 is concerned with combat casualty care studies. Proposed are investigations of: standards for field-oriented electronic equipment in medical care; compatibility of equipment among various Department of Defense (DoD) echelons of treatment from a data interface standpoint; specifications for a field-deployable PC workstation; integration and testing of other DINS-compatible medical imaging equipment in conjunction with the DINS; and the ability of the DINS prototypes to perform under simulated disaster or combat casualty conditions.

Section 10.0 examines trends in the development of major DINS elements. It proposes studies that: determine the major DINS elements--medical, organizational, and electronic--that are likely to change in significant ways over the next five years; and forecast this evolution as accurately as possible so these trends can be taken into account when developing plans and specifications for future DINS.

A glossary of key terms related to DINS is included.

1.0 INTRODUCTION

Under the sponsorship of the U.S. Army Medical Research and Development Command (USAMRDC), MITRE is currently collaborating with three universities to deploy, test, and evaluate two prototype Digital Imaging Network Systems (DINS). A prototype system developed by Philips Medical Imaging, Incorporated will be installed at the University of Washington Medical Center. The other, developed by AT&T Medical Systems, will be installed at Georgetown University, serving both Georgetown and nearby George Washington Universities. The project affords an excellent opportunity to study the two DINS prototypes in operational environments. Lessons learned from this project will be used in developing and acquiring operational DINS for deployment in U.S. military hospitals and elsewhere.

1.1 Document Purposes and Audience

This document provides an overview of desirable investigations in connection with the three-year DINS project. The objective has been to identify as many useful research ideas as possible. As might be expected, the number of good ideas exceeds the resources available. Accordingly, priorities must be set. A companion MITRE document, The Digital Imaging Network System Project Management Plan, establishes these priorities and discusses details regarding the management of these investigations.

Against this background, this document has three purposes. They include the following:

- Provide an overview of the studies that could be conducted during the course of the DINS project

- Describe how the participating organization(s) would carry out each approved study, either individually or cooperatively

- Focus discussion on the priority each approved study should have in the project

The intended readers for this document include key staff members within the U.S. Army Medical Research and Development Command (USAMRDC), and members of the DINS project team at MITRE, the University of Washington, Georgetown University, George Washington University, and other interested parties.

1.2 Major Topics in This Section

This section of the document discusses the following topics:

- The U.S. Army medical care system

- The DINS as it is expected to operate on a day-to-day basis in support of the Army medical care system and elsewhere
- Relevant project history
- The current DINS prototyping project
- The project's goals

1.3 The U.S. Military Medical Care System

The U.S. military's medical care system is responsible for meeting the continuing needs of over nine million beneficiaries, including active duty personnel, their dependents, and retirees. To meet these needs, the Department of Defense (DoD) maintains 168 hospitals, 310 free standing clinics, and many ancillary health and dental care facilities worldwide. Collectively, these facilities are staffed by over 170,000 health care professionals. This complex system currently costs over $12 billion per year.*

Military health care can be thought of as having two basic missions. The first is meeting the day-to-day health care needs during peacetime. The second involves casualty care during armed conflicts. Both components of the Army's medical care system are expected to be major beneficiaries of a successful DINS. To better understand these possibilities, a brief description of the Army medical care system follows.

1.3.1 The U.S. Army's Peacetime Medical Care Mission

The Army's health care system is responsible for meeting the continuing needs of active duty personnel, their dependents, and retirees. To meet these needs, the Army maintains 161 hospitals and many ancillary health care facilities worldwide. In most respects, these "fixed facilities" operate much like their civilian counterparts. They treat much the same mix of patients and diseases though with a much larger outpatient volume due to an absence of the private office care found in civilian life. They have the same basic objectives for patient welfare.

The DINS directly supports hospitals--military or civilian--in meeting their continuing objectives for prompt access to patient images, accurate diagnosis, reliable record keeping, and dependable archiving. As such, the benefits of a DINS are the same in military hospitals during peacetime and in civilian facilities.

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*Caspar Weinberger (June 1987), Annual Report To Congress: Fiscal Year 1988, U.S. Department of Defense, p. 315.

1.3.2 The Combat Casualty Care Mission

Medical care in the combat area is provided at the unit, division, corps, and communication zone echelons. From forward battle areas to stateside hospitals, each succeeding echelon deals with patient needs of increasing severity (see Figure 1-1). Care at the first three echelon levels is delivered from mobile facilities located up to 10, 40, and 150 kilometers from the forward edge of the battle area (FEBA), respectively.

There are seven types of Army hospitals used in wartime theaters of operation. They range from Mobile Army Surgical Hospital (MASH) units in the combat zone to general hospitals in the Communications Zone (COMMZ). Each is composed of standard modules such as operating rooms, laboratories, X-ray units, and wards. These hospitals rely on Deployable Medical Systems (DEPMEDS). Such hospitals use modularized medical technology and equipment (e.g., power units, Tent Extendable Modular Personnel tents, tactical shelters, and heating and air conditioning) as standardized throughout the DoD. These standard modules improve mobility and flexibility. This enhances the Army's ability to meet changing mission requirements as dictated by shifting military threats and fluctuating patient distributions. The hospitals can be deployed under all climatic conditions, providing adequate but austere care. All are affordable, maintainable, relocatable, modular, quad-service compatible, and transportable by strategic air.

Fixed Army hospitals and clinics located overseas, as well as general hospitals in occupied zones or in friendly nations, also provide combat casualty care. If additional treatment or rehabilitation services are required, the soldier is transported stateside to a hospital or medical center. Final disposition may involve return to active duty, discharge to civilian status, or entry into a Veterans Administration (VA) hospital.

As outlined below, the DINS is expected to contribute significantly to meeting the Army's requirements for both the fixed facility and combat casualty care missions. This project seeks to determine the specifications for a DINS that will support both missions with full effectiveness. In addition, the DINS is expected to have many benefits applicable to civilian health care. This project will identify these as well.

1.4 DINS Overview

As illustrated in Figure 1-2, DINS is an electronically-based system for performing the following functions:

- Capturing medical images in digital form together with related demographic and diagnostic patient information from the hospital information system and various processes in the hospital radiology department

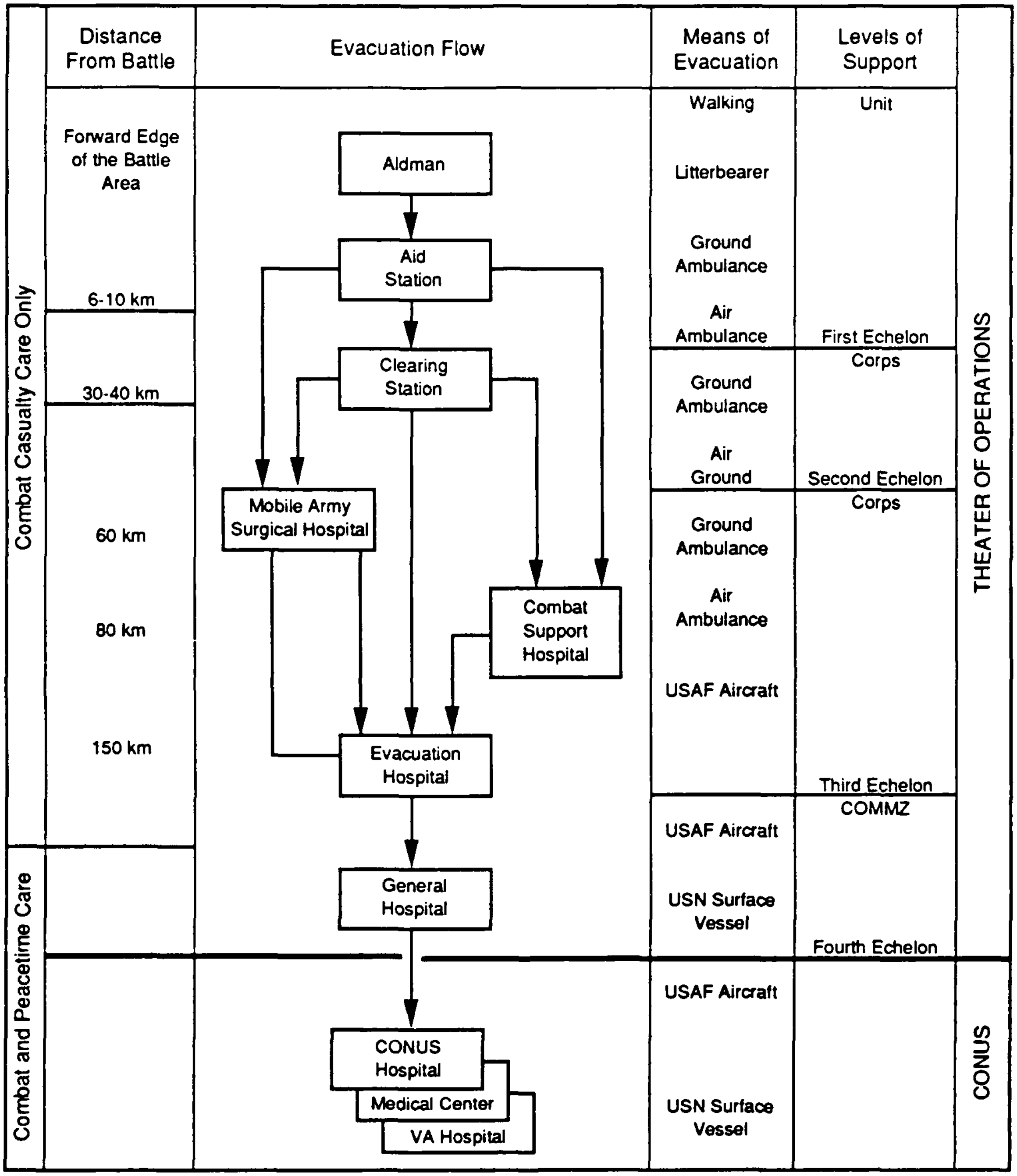

FIGURE 1-1
U.S. ARMY MEDICAL CARE TREATMENT AND EVACUATION SYSTEM

- Storing this information in active case data storage
- Transferring this information at the user's command among various storage and display locations
- Displaying this information for use by clinicians and others for diagnosis, review, and treatment
- Archiving all patient data in a convenient, readily-accessible electronic form

A fully operational DINS would reside in a military hospital serving patients in peacetime and treating casualties in wartime. In the Army medical care system, it would reside in major medical centers and large community hospitals. Its expected operation is summarized below.

1.4.1 DINS Operation within Fixed Facilities

The DINS would integrate digital images from a variety of medical imaging systems, including those used at forward facilities to support combat casualty care (see Figure 1-2). Patient data from a Radiological Information System (RIS) and perhaps a broader Hospital Information System (HIS) would be available as well. These data would be maintained in a data base which clinicians could access in a unified, convenient way. A clinician or other investigator could query the DINS from conveniently located workstations to obtain the patient's images, history, and related demographic data.

DINS workstations could be located within the radiology department, in other departments of the hospital, and at geographically remote facilities closer to the battlefield. Workstation capabilities could vary, depending on cost and user needs. For example, high resolution diagnostic workstations with four to eight screens could be located within the radiology department to support detailed, multi-modality, multi-disciplinary investigations of a patient's condition. Moderate resolution workstations could serve other hospital departments, promoting improved communication among clinicians on difficult cases. Comparatively low resolution workstations with one or two screens could be employed to meet the somewhat simpler needs of remote sites or forward area hospitals.

Diagnostic images and associated patient data, whatever their source, could be reviewed in any order, at any time, and in any detail using these workstations. In this way, the DINS could assist the clinician with patient care or support the investigator with his or her research. Links to remote sites would allow clinicians at these sites to tap into the complete body of historical information on a patient stored at the central site, as well as to gain access to radiological expertise on current cases.

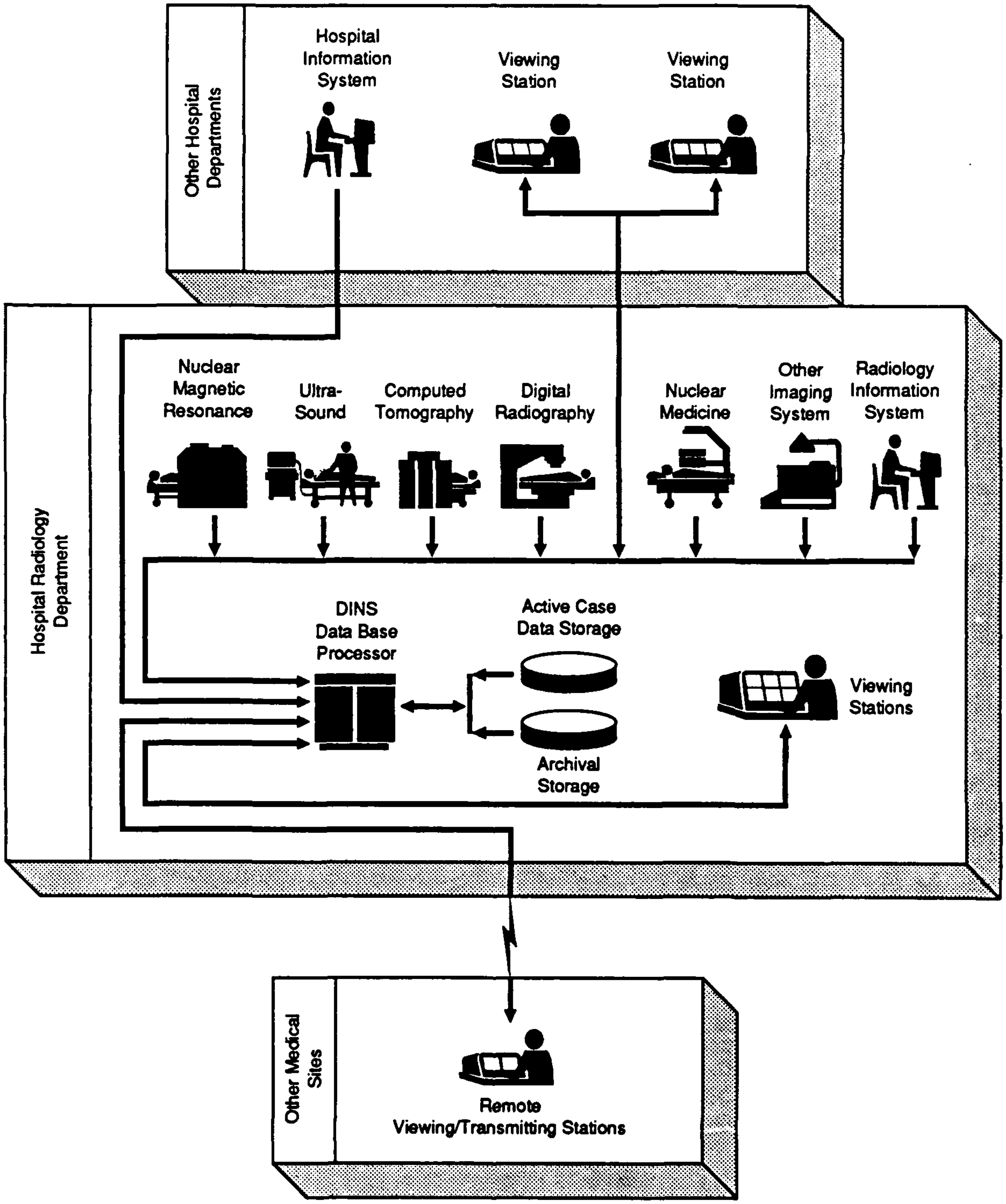

FIGURE 1-2
DIGITAL IMAGING NETWORK SYSTEM WITHIN FIXED FACILITIES: A SCHEMATIC VIEW

Automated reading devices would allow convenient input of case images captured in forward battle areas, stored on hardened, portable media, and transported along with the patient as he or she is evacuated to the rear.

1.4.2 DINS Operation among Combat Casualty Facilities

As shown schematically in Figure 1-3, patients and their digital images must move among the several echelons of care. While the most sophisticated imaging equipment is located in rearmost general hospitals, digital, electronically-based systems can play an important role at comparatively forward treatment facilities. For example, images taken in forward areas clearing stations (if transported with the patient) can provide valuable insights into reasons for initial treatment and reveal subsequent changes in the patient's condition. This knowledge has the potential to enhance quality, continuity, and effectiveness of medical care. Second, in combat casualty care, time is critical, especially in surgical cases. Timely diagnosis can be the difference between success and failure. Light, reliable, readily-deployed imaging devices can assist physicians treating casualties close to the FEBA, reducing time lost in transport and saving lives.

Compatibility of digital imaging components is a critical element from a combat casualty care system viewpoint. Ideally, any digital image generated anywhere within the military's medical system should be viewable on any digital image display device or stored on any digital image storage unit within the military medical system. For example, images taken as far forward as the second echelon should be readable at all other echelons of military medical facilities and beyond. Images must be movable across echelons despite variations in format, acquisition method, or storage medium.

If an armed conflict were to break out today, only conventional X-ray equipment, described years ago as inadequate for field use, would be available for diagnostic imaging. Fortunately, this situation is being remedied. A high capacity (HICAP) X-ray system is currently under development by Picker International that will replace the existing conventional X-ray equipment in the facilities at the Corps level by the late 1980s. A low capacity (LOCAP) X-ray system for deployment as far forward as the Division level is being procured. A proof-of-concept study has been funded to investigate the feasibility of a field computed tomography (CT) scanner. The Army is cautiously optimistic about the Navy's progress in developing a light-weight ultrasound device with possible applicability to the Army's combat medical care system.

The urgent need to develop filmless imaging systems for field use was highlighted in the 1986 Operational and Organizational Plan for Field

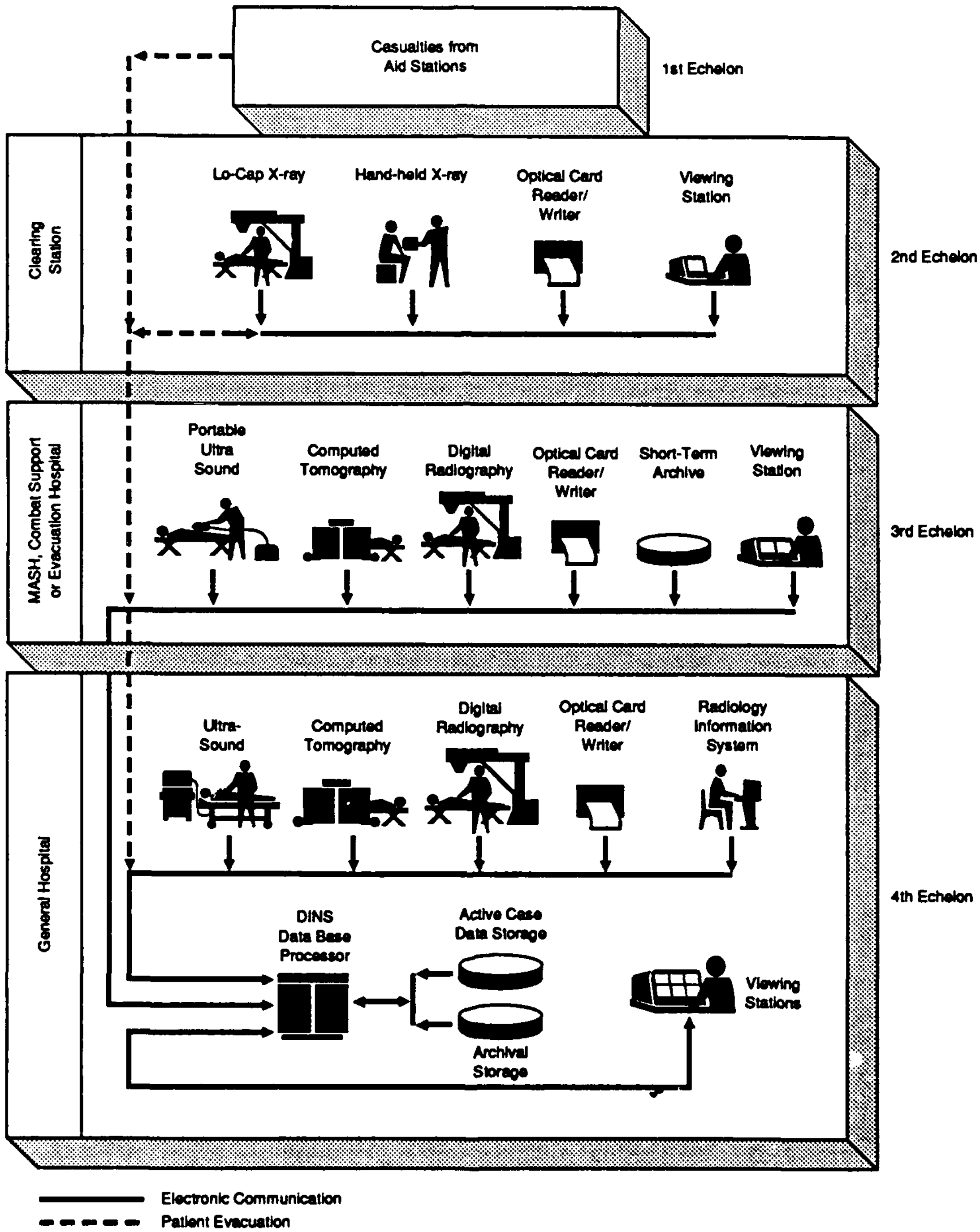

FIGURE 1-3
DIGITAL IMAGING IN COMBAT CASUALTY CARE: A SCHEMATIC VIEW

Diagnostic Imaging Systems.* The deployment of a spectrum of equipment, from very lightweight/portable systems through mobile CT systems, could improve patient care and reduce logistical support while improving diagnostic imaging capabilities. Table 1-1 contains key items related to the delivery of care in the theater of operations. It includes a list of diagnostic imaging systems that have been cited in the literature or at professional meetings, as appropriate to the various levels of the combat care medical system.

1.5 Potential DINS Benefits That Would Improve Quality of Care

There are many potential advantages to employing a fully developed DINS. Some of these benefits accrue to hospitals and their satellite facilities in peacetime. Others accrue at several levels of combat casualty care as well.

1.5.1 DINS Benefits to Fixed Facilities

Some of the most important hospital-oriented "fixed facility" benefits accrue during both peacetime and wartime, as listed below:

- Workstations for acquiring images can be designed to standardize image acquisition and handling, thereby improving the quality of images available to clinicians

- Workstations can be located where most convenient to users, improving the likelihood of their effective use

- Since all images and related data are stored electronically, several users of the DINS at different locations can examine a given case at the same time, improving the convenience and effectiveness of consultations among busy clinicians

- A user at a DINS workstation can acquire complete patient file information through a single workstation, saving much search time, promoting faster reporting, and potentially improving medical decision making

- Images stored electronically can be conveniently indexed, grouped, and retrieved in any useful combination, increasing their availability to users

*U.S. Army Materiel Development Activity, 1986 Operational And Organizational (O&O) Plan For Imaging Systems Field Diagnostic, Ft. Detrick, Maryland.

TABLE 1-1
POSSIBLE USES FOR DIGITAL IMAGING AT EACH ECHELON IN THE COMBAT MEDICAL CARE SYSTEM

ECHELON OF CARE	ACQUISITION OF IMAGES	COMMUNICATION OF IMAGES	ARCHIVAL STORAGE FOR IMAGES	IMAGE DISPLAY
Clearing Station	• LOCAP X-ray • Hand-held X-ray Unit	• Hand carry	• None	• Small, ruggedized display
MASH CSH Evacuation Hospital	• Mobile CT • EPID • Portable ultrasound • Hand-held X-ray (bedside use) • HICAP X-ray unit	INTER-SITE • Hand carry memory packs • Possible use of communications channels for consultations INTER-SITE • Small local area network (LAN) for two nodes	• Possibly a ruggedized portable unit • Hand carry images to next echelon	• Small, single screen units • Possibly, display attached to imager
General Hospital (Non-CONUS)	All imaging modalities	INTER-SITE • Hand carry memory packs to CONUS INTER-SITE • Large LAN, multi-channel, multi-media 4 to 8 nodes • Mobile DINS	• Larger, fixed archive • Needs not be ruggedized	• Larger, multi-screen displays
General Hospital (CONUS)	All imaging modalities	INTER-SITE • High speed LAN • Satellite and Landline communications INTER-SITE • Large LAN,, full scale DINS, 8 to 20 nodes	• Mass storage, optical jukeboxes	• Sophisticated, multi-screen workstations

- There is a much lower risk of losing case materials, including images, in busy hospital environments

- Image processing transfer and storage costs can be dramatically reduced

- Digital image manipulation techniques, including those that employ expert systems and artificial intelligence, can be made available to all users, improving the information obtainable from each patient image

- Patient length of stay in the hospital may decrease somewhat due to the greater speed with which certain imaging functions can be conducted, due to improved diagnoses, and due to the likelihood of more appropriate care as a result

- The DINS is an expandable "backbone" for the radiology department of the future, with the potential to accommodate new digital imaging modalities as they emerge, to encourage their use, and thus to spur the rate of technological development in a rapidly expanding field

- The DINS can help the hospital attract and retain higher quality staff due to the contribution it makes to better, more efficient radiology practice

1.5.2 DINS Benefits in Combat Casualty Care

The DINS can also capitalize on several innovations being developed by the military to improve patient care under combat conditions. For example, the DINS can accommodate the Army's HICAP X-ray system intended for use at division level medical units near the FEBA. It also capitalizes on the "smart card," a hand-held card containing the patient's complete medical record--including X-rays--in electronic form. The smart card can be pinned to the patient's clothing as he or she is transported among care facilities allowing easy, more reliable transport of medical records.

DINS can also help promote and accommodate still other improvements being considered by the military and others. These include improved field diagnostic imaging systems (e.g., the LOCAP X-ray, the hand-held X-ray, dry silver printers, re-usable image panels, low power capacitor discharge devices, image storage cassettes, the mobile CT scanner, and the Electrophoretic Image Display). These show promise in improving the tools available to the combat clinician. They also promise logistical savings resulting from the need for fewer chemicals, storage facilities, and other transportables needed to support radiology. It can also incorporate computer-based diagnostic aids to assist the heavily burdened clinician near the FEBA.

As these developments suggest, the DINS has the following potential benefits in combat casualty care:

- It encourages and accommodates the development of lighter, more reliable, electronically-based medical imaging devices for use in forward areas

- It encourages and accommodates the development of "hardened" electronic storage media for digital images, such as optical disks or "smart" cards, which are lighter, more readily transported, and less susceptible to environmental degradation in hostile environments

- It encourages simplified, more dependable inter-echelon movement of patient images stored on such media

- It promotes a reduction in the logistical burden associated with acquiring, processing, using, and storing medical images at all echelons of care, but particularly in forward areas

- It speeds arrival of the day when digital images obtained in forward areas can accompany the seriously sick or injured patient to major hospitals in the rear, and when these images are capable of immediate use, capitalizing on all the advantages cited in connection with fixed facilities

These potential benefits currently account for the significant interest in DINS technology within both the civilian and military radiology community. A summary of these advantages to both fixed facilities and DEPMEDS, organized in terms of imaging functions, appears in Table 1-2.

1.6 Potential DINS Shortcomings to be Investigated

There may be shortcomings to DINS operation that should be investigated. Possible disadvantages to be explored during the prototype study and, if possible, eliminated in future systems are summarized below:

- The DINS may be expensive to obtain, install, operate, and maintain

- It may require additional specialized skill and training for the staff who use the system

- Maintenance of the computer-based aspects of the system may be highly specialized

- The DINS may be susceptible to catastrophic failure, temporarily disabling all functions

TABLE 1-2
BENEFITS OF A DIGITAL IMAGING SYSTEM BY FUNCTION

Image Acquisition	• Obviates use, storage, and transportation of chemicals, water, and film in combat zones • Promotes better quality control by standarzing methods • Reduces the "re-shoot" rate and its waste of patient and clinician time
Image Archive	• Allows fast, convenient access to all images • Reduces storage costs • Eliminates problems due to lost films • Prevents degradation of archived images
Image Display	• Suppports image processing and computer graphics techniques to enhance diagnostic skills • Allows use of artificial intelligence techniques to aid in diagnosis • Improves the convenience of case review
Communications Networks	• Supports fast, reliable transport of images between acquisition stations, viewing stations, and the archive • Allows interconnection of departments and geographically separated facilities • Establishes a "backbone" for integrating new imaging modalities as they emerge
Clinical Management and Patient Care	• Allows for multiple users of same case materials simultaneously • Improves communication and consultation among physicians • Supports improved clinical teaching and educational programs • Improves the quality of care based on imaging

- During downtime periods, there may be no convenient way to read many of the medical images processed by the system

- The management of the hospital's radiological imagery may become more specialized and more centralized

- There may be professional resistance to aspects of the new system, particularly in its early stages of installation and use

- Currently, only about 20 percent of medical images are obtained in digital form; the remaining 80 percent must be converted to this form for effective use on the DINS network

These possible factors will be investigated during the project. If significant, their existence argues for a careful balancing of advantages and disadvantages so that decisions concerning the implementation of a DINS are made in full light.

1.7 History of the Current DINS Project

The current DINS prototype project builds on over eight years of successful work in the field of video-based radiology by MITRE, the three universities, and others under federal sponsorship. Of particular interest relative to the DINS project are the two most recent efforts. Each is discussed below.

1.7.1 The DINS Specifications Development Project

This project was funded by the Department of Defense (DoD) with the participation of the Uniformed Services University of the Health Sciences (USUHS) and the Center for Devices and Radiological Health (CDRH) of the U.S. Public Health Service. In the spring of 1985, as a result of an eight-month investigation, functional requirements for a hospital-based DINS were prepared (Imaging Systems Group, April 1985). This document described the consensus among participating radiologists, scientists, engineers, and radiological physicists concerning requirements for a prototype DINS to be installed in one or more test sites.*

Following that effort, a similar working group prepared the technical specifications for a hospital-based digital imaging network (Imaging Systems Group, January 1986). This document described detailed technical

*Imaging Systems Group (April 1985), The DIN Report: Functional Requirements for a Hospital-Based Digital Imaging Network and Picture Archiving and Communications Prototype System, The MITRE Corporation: McLean, Virginia.

specifications for a DINS prototype to be installed and tested at university hospital sites. This document contained the technical specifications for the equipment to be used in the current evaluation.*

1.7.2 Test Sites for the Current DINS Project

In the fall of 1985, two university medical centers were selected through a competitive bidding process to serve as test sites for the DINS project. On the U.S. east coast, Georgetown University (in conjunction with George Washington University) in Washington, D.C., was selected. On the west coast, the University of Washington in Seattle was chosen. These sites were chosen for:

- The broad range of academic and clinical disciplines available to the project at each site
- The radiological assistance each site could provide during the course of the evaluation
- The ability of each site to provide a test bed where the prototype equipment and supporting procedures could be thoroughly evaluated
- The ability of each site to provide all films, images, and other materials needed for the prototype study from existing medical imaging capabilities

University hospitals were deemed appropriate for this project rather than military hospitals for two reasons. First, the former could more readily adapt to the increased workload without adversely affecting the quality of patient care. Second, the universities have the ability to conduct the variety of project studies required using existing research staff and medical/engineering facilities.

1.7.3 The Current DINS Prototype Development Project

During the current DINS project, vendors will install the DINS prototypes at the two university sites, and MITRE/university teams will carry out studies and evaluations. The two university sites participated in selecting the DINS equipment vendors. Two significantly different prototype systems were selected. In this way, important comparisons could be made regarding DINS technologies and architectures.

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*Imaging Systems Group (January 1986), Technical Specifications For a Hospital-based Digital Imaging Network, MTR-85W242, The MITRE Corporation: McLean, Virginia.

1.8 DINS Project Goals

The current DINS prototype project has three overall goals. Each relates to the Army's desire to deploy DINS in an Army Medical Center on a pilot basis during the early 1990s. Each goal is discussed below.

1.8.1 Install and Operate Prototype DINS at Each of Two University-Based Hospitals

As noted, the prototype systems will be installed on the east coast at Georgetown University Hospital with links to George Washington University, and on the west coast at the University of Washington Medical Center. The universities will provide clinical expertise and technical support to operate the DINS prototypes for the duration of the project. They will also conduct many of the studies described in this study plan.

1.8.2 Evaluate Key Aspects of Each Prototype System in Operation

Once the prototype systems are installed and have undergone initial testing, evaluations will determine the strengths and weaknesses of each prototype and the feasibility of using them for intended purposes in operational settings. The project will determine the applicability of DINS technology to combat casualty care, the overall performance of the technology, and its cost/efficacy.

1.8.3 Develop Guidelines and Specifications for an Operational DINS Suitable for Use by the Military Medical Care System and Others in the Early 1990s

While the equipment is being evaluated in civilian university hospital settings, this project will evaluate digital image and communication technologies used in radiology as applied to combat casualty care situations. Guidelines, specifications, and standards for a DINS suitable for military use, based on the results of this project, will be developed.

2.0 POSSIBLE STUDIES OUTLINED IN THIS DOCUMENT

A number of evaluations and investigations are proposed in this document. Included are proposals from all four participating organizations. To place the proposed studies in context, this section discusses the following four topics:

- The major questions to be addressed during the current project
- Study categories defined in this document
- Justifications for an integrated hierarchy of studies
- The relationship between the study topics and the overall questions the project seeks to answer

2.1 Major Questions to be Addressed during the Current DINS Prototype Project

Twelve overall questions will be addressed during the course of this project. To the maximum extent feasible, the results obtained will be extrapolated to the military medical care environment, concentrating on combat casualty care. The twelve questions include the following:

- Is a DINS that can perform all functions currently identified as important technically acceptable at reasonable cost?
- Is such a DINS operationally acceptable to its various users?
- What are the technical, operational, and procedural specifications for high quality image acquisition, processing, presentation, and storage in the intended DINS environments?
- What are the technical, operational, and procedural specifications for establishing links between the DINS and other data management systems commonly used in radiology departments (e.g., RIS or HIS)?
- What are the costs and benefits of the DINS in day-to-day operation, and who is likely to bear these costs and reap these benefits?
- What are the principal performance advantages and disadvantages of each prototype as revealed during the project?
- In what ways are the practice of radiology and the delivery of radiologically-related health care affected by the DINS?

- Are there unique specifications a DINS must satisfy in the U.S. Army's four-echelon combat casualty care environment, and if so, what are they?

- What improvements or changes are needed in the DINS concept, operation or procedures, as exemplified by the two prototypes, based on the answers to the above questions?

- What system-oriented standards must be observed or developed for future systems to assure smooth functioning and inter-operability of DINS equipment?

- What technological and cost trends exist in relevant fields that should be taken into account when planning future DINS for military deployment?

- What educational and training requirements must be met to assure the smooth, effective implementation of an operational DINS in Army medical centers?

Each of these questions is discussed in more detail below.

2.1.1 DINS Technical Acceptability

Evaluations during the project will determine if the DINS is technically acceptable for use within the hospital at reasonable cost. These evaluations will consider the performance of the system from such technical perspectives as: effectiveness in handling images for users' purposes, convenience and efficiency of workstations, speed and efficiency of network functions, and capacity and flexibility of storage functions.

2.1.2 DINS Operational Acceptability

A system that is technically acceptable may be operationally awkward, limiting its usefulness. Evaluations will determine the extent to which the DINS is acceptable from the point of view of those who must use the system, including referring physicians, combat casualty care physicians, radiologists, radiological technicians, and administrative and other support staff.

2.1.3 Technical, Operational, and Procedural Specifications for DINS Image Processing

A system as complex as the DINS must successfully integrate many elements to function smoothly and effectively. Based on project experience, modifications improving the operation of future DINS equipment in medical centers and in the field will be identified. Procedures will be defined for assuring high quality images wherever they are obtained, for linking the various sources and users of DINS data, for selecting appropriate image processing techniques, and for assigning images and patient data to appropriate storage levels within the archive.

2.1.4 Technical, Operational, and Procedural Specifications for Links to Other Systems

In large radiology departments, computer-based systems for handling patient data will become increasingly common. Such systems include patient information systems, but may include others as well as computerized information processing expands. It will often be desirable to link such systems to the DINS. In this way, images and text from the DINS can be combined with data from subsidiary systems in an integrated fashion. For each prototype, the technical, operational, and procedural requirements for establishing interfaces between the DINS and related systems will be explored. Attention will be directed initially to systems already in existence at each university in an effort to develop lessons based on real interface problems. As time and effort are available, these lessons will be generalized to a wider range of interface problems.

2.1.5 Cost/Effectiveness and Cost/Benefit Analysis

A radiology department which adopts a DINS will incur certain costs, particularly in the short run. In return, it is expected that important advantages will accrue to the department. Some existing functions will be performed more effectively. Some new functions will be available, improving overall hospital performance. Costs and benefits may be different from place to place within the department. This category of studies will determine the costs and overall efficacy (i.e., effectiveness and benefits) of the DINS, both in dollar terms and otherwise, and assess their relative magnitude. This will require development of performance measures and methodologies which heretofore have not existed in fully satisfactory form.

2.1.6 Comparative Strengths and Weaknesses in Prototype Performance

The project will compare the performance of the prototypes installed at each of the two universities to determine capabilities of each prototype that are effective and those that require improvement. Additional capabilities that should be incorporated into future DINS will be identified. This evaluation will include both engineering and human factors aspects. As such, it will draw on the judgments of engineers, radiologists, other physicians and medical physicists, among others.

2.1.7 Impact on the Practice of Radiology

The DINS has a number of features that could significantly change both the practice of radiology and those aspects of medical care that depend directly on radiology. The DINS will bring together images from imaging modalities that heretofore have been separate. It will allow radiologists to manipulate the various images on a patient in ways previously not possible. It will make images and related patient data available to clinicians faster and more completely than ever before. For these and other reasons, a preliminary assessment is desirable concerning the extent to which the DINS affects the practice of radiology in the departments in which it is installed. From this assessment, some of the implications for the future practice of medicine can be inferred.

2.1.8 Specifications Unique to Combat Casualty Care

Special emphasis will be placed on developing specifications unique to the military regarding the DINS. Of particular interest will be such subjects as communications among the four care echelons defined by the military (see Section 1.3.2), communications within each echelon of care, applicable data communications standards, transportation needs (both physical and informational), and skills necessary for providers at all user levels to capitalize fully on DINS capabilities.

2.1.9 Recommended Improvements in the DINS Concept, Operation, and Procedures Based on Experience with the Prototypes

The results of the prior studies will be used to formulate recommendations concerning improvements in the DINS, particularly in combat casualty care. Future directions in the development of DINS equipment will also be identified, based on project experience. New technologies that should be explored will be identified. Suggested improvements in existing technologies will be discussed.

2.1.10 System Standards

A system of the complexity of the DINS involves numerous components and interfaces. Some of these have been examined by authoritative bodies (e.g., the National Electrical Manufacturers Association) with a view toward developing standards to assure compatibility. Others have no authoritative standards associated with them. The project will assemble all available information on the standards that apply to the DINS. Evaluations will be made of the relevant standards, highlighting areas where standards are sufficient, where refinements are needed, and where new or additional standards are needed.

2.1.11 Technological and Cost Trends

The fields of radiology, digital imaging, and electronic networking are changing rapidly. Improvements are introduced at a rapid rate in all three fields. The costs of certain kinds of technology are dropping quickly. Trends in these factors over the next five years will be identified, studied, and appraised for their potential impact on plans for future DINS.

2.1.12 Educational and Training Requirements for Implementation

A system as complex as DINS has the potential for overwhelming the unprepared radiology department when first installed. To smooth the implementation path, it is desirable to educate key persons within the department receiving a DINS well in advance. In this way, a sufficient body of knowledge will exist to deal successfully with DINS implementation issues. Moreover, more realistic expectations are likely to exist concerning what the DINS will and will not do.

2.2 Study Categories Defined in This Document

Seven study categories have been developed to answer the questions posed in Section 2.1. Each category, which corresponds to a section in this document, is introduced below.

2.2.1 Studies of the Impact of the DINS Prototypes on the University Hospitals

Four sets of studies fall under this heading. First, baseline studies characterize the operation of the Radiology Department at each site prior to the installation of the DINS prototype.

Second, post-installation studies help compare the pre-DINS operation of each university medical center with its post-DINS operation. This comparison will determine improvements, if any, in the workflow of cases, the quality of diagnoses resulting from the availability of better image files, and the overall quality of radiological support for patient care resulting from the DINS. It will also help determine whether there have been changes in the Department's operation over the project period that are unrelated to the DINS but nonetheless affect its operation. There will necessarily be differences in the baseline and post-installation study data collected between eastern and western DINS sites. Still, there should be as much consistency as possible between sites to facilitate comparative analysis.

Third, cost/efficacy studies help gauge the relationship between the costs of the DINS and its overall value to the medical center. The cost/effectiveness of certain functions will be investigated. The range of costs and benefits associated with its operation will be assessed.

Finally, preliminary estimates of the costs and benefits of the DINS as installed in U.S. Army medical centers will be made. These estimates will focus on both fixed facility and combat casualty care implementations.

Baseline, post-installation, cost/efficacy studies, and "first look estimates" are discussed in Section 3.0 of this document.

2.2.2 Studies Focussed on the Workstation Capabilities of the Two DINS Prototypes

These studies investigate the capability of DINS workstations to provide imagery of high diagnostic quality and to support DINS users in other ways. Included are studies of the effects of workstation design on the various DINS users, requirements for image contrast and spatial resolution, capabilities of a PC-based workstation, image enhancement techniques, automated image acquisition systems, decision support systems for use in combat casualty care situations, and related topics. These studies are described in Section 4.0.

2.2.3 Studies Focussed on the Network Performance and Architecture of the DINS Prototypes

These studies investigate the prototypes from a data communications network standpoint. Included are studies assessing the network capacity of the prototypes under various conditions, the impact of various data compression techniques on network capacity, the strengths and weaknesses of the network architectures employed by the two prototypes, the requirements for communications links with other systems, the strengths and weaknesses of existing standards as they relate to the DINS, methods for linking systems at remote sites to the DINS, archival storage capacity and throughput, image storage and retrieval time, and overall archive architecture issues. These studies are described in Section 5.0.

2.2.4 Education, Implementation, and Training Studies

Education, implementation, and training studies concentrate on two overall subjects. The first concerns ways to educate key people within the USAMRDC and Army medical centers slated for receiving a DINS well in advance of implementation as a means for smoothing this implementation. Important topics here would include such things as the technical capabilities of the DINS, site planning requirements, probable implementation strategies to pursue, likely changes in radiological practice to expect, and the like. The second concerns ways to improve the interaction between the human user and the system. These studies focus on interfaces with the system, images and human perception, appropriate presentation of data to users, the effectiveness of training materials, and methods for using the DINS as a teaching device. Education and training studies are discussed in Section 6.0.

2.2.5 Clinical Impact Studies

Clinical studies are designed primarily by the radiology departments at each university. However, these will be discussed thoroughly before implementation to assure compatibility with other studies and to minimize overlap among studies from site to site. Several clinical studies are suggested by Georgetown University and by the University of Washington in Sections 7.0 and 8.0, respectively.

2.2.6 Combat Casualty Care Studies

Combat casualty care studies ways in which the DINS can support battlefield care effectively. The project will investigate all standards, both electronic and otherwise, that apply to data transfer among care facilities, including operations in which data acquired on the battlefield are transferred to the field system and viewed by radiologists. Procedures will be investigated for moving data among field units using PCs or other electronic media and for determining the disposition of a patient's data once entered into the medical system. Compatibility standards among echelons of care in the military services will be studied. A simulation of the ability of the DINS to deal with medical emergencies and certain combat casualty care situations is proposed. These studies are discussed in Section 9.0.

2.2.7 Trends Studies

Since the technologies and disciplines associated with digital radiography are changing rapidly, forecasts of these trends and their probable effects on DINS of the future are desirable. Studies will be conducted of relevant trends in the practice of radiology, in the technology of digital imaging, in the field of electronic networking, and in the cost of producing relevant electronic transmission, display, and storage devices over the next five years. These studies are discussed in Section 10.0.

2.3 Justifications for an Integrated Hierarchy of Studies

All studies conducted under the project must either provide results used to answer questions posed in Section 2.1, or be used in concert with other project studies to answer these questions. There are four justifications for establishing this hierarchy, discussed below. This hierarchy itself and the priority of each study are presented in the Project Management Plan mentioned in Section 1.1.

2.3.1 Conservation of Resources

The project should avoid overlap and duplication. Proper conservation of project resources will ensure that all high priority studies are pursued and the best distribution of resources is attained among sites and projects.

2.3.2 Coordination of Efforts

Efforts at each site and at MITRE should be coordinated to ensure all studies are connected in a logical manner producing compatible test results that can be usefully compared, leaving no important gaps in knowledge at the project's conclusion.

2.3.3 Focus of Studies on Key Issues

Study efforts should focus, to the maximum extent feasible, on issues of interest to the military from a combat casualty care standpoint. A well-defined hierarchy maintains this focus.

2.3.4 Sequence of Studies

Interdependent studies should be performed in the correct order so that data obtained from one study, wherever conducted, will be available when a subordinate or dependent study begins. A well-defined hierarchy facilitates this sequencing.

2.4 The Relationship between the Study Topics and the Overall Questions the Project Seeks to Answer

Table 2-1 shows the study categories arrayed against the overall questions posed in Section 1.5. The table indicates that each major question has at least one study devoted to it. Most questions are addressed by several studies.

TABLE 2-1
THE RELATIONSHIP BETWEEN OVERALL STUDY QUESTIONS AND PROPOSED STUDY TOPICS

Study Topics / Major Questions	Impact on Cost	Workstation	Network/ Archive	Education and Implemenation	Clinical Impact	Combat Care	Trends
Technically acceptable?		X	X		X	X	X
Operationally acceptable?	X	X	X	X	X	X	
Requirements for image management?	X	X	X		X	X	
Requirements for external interfaces?	X	X	X			X	X
Costs, benefits, and efficacy?	X				X	X	X
Advantages/ disadvantages of prototypes?	X	X	X		X	X	
Radiology practice changes?	X	X	X	X	X	X	X
Combat casualty care requirements?		X	X	X		X	X
Improvements needed?	X	X	X	X	X	X	
Standards needed?			X			X	X
Future trends?	X	X	X		X	X	X
Implementation requirements	X	X		X	X	X	

3.0 STUDIES OF THE IMPACT OF THE DINS PROTOTYPES ON THE UNIVERSITY MEDICAL CENTERS

The DINS prototypes are expected to have a major impact on the two university medical centers. When fully operational at these centers, each prototype should perform many existing radiological functions more quickly. Perhaps of greater importance, each should offer capabilities not previously available. As a result, the DINS prototypes may significantly affect the practice of radiology and perhaps certain aspects of medical practice generally. The prototype project is of long term interest because of what it will reveal about the impact of the prototypes an operational DINS will have on hospitals, both military and civilian, that adopt it.

Given these possibilities, the impact of the prototypes on the university medical centers should be evaluated. Studies in this section examine:

- The baseline structure and functioning of each university medical center PRIOR TO the installation of the DINS prototype
- The structure and functioning of each medical center AFTER the prototypes have been installed and are in full operation
- The cost/benefits, cost/effectiveness, and resulting overall cost/efficacy of each prototype DINS with a view to estimating the probable impact a fully operational DINS would have in a typical hospital, civilian or military
- The potential impact of the DINS on costs and quality of care in the U.S. Army medical care system under both combat and peacetime conditions

Each of these proposed studies is summarized in the following subsections.

3.1 Baseline Studies of the Pre-Installation Structure and Functioning of the University Medical Centers

Baseline studies will characterize the radiology departments before DINS installation takes place. Careful measurements will provide a baseline against which subsequent evaluations can be judged. They will highlight current procedures essential to the successful practice of radiology as distinguished from those that are simply an artifact of film-based radiology. Finally, they will provide a basis for determining the similarities and differences that exist between the university medical centers used in the project and military hospitals for which DINS are intended.

Objectives

The five objectives of the baseline study are to:

- Describe in operational detail the organizational structure of participating university hospitals prior to installation of the DINS prototype
- Characterize the work flow in the departments using appropriate work measurement techniques
- Gather behavioral and attitudinal information about the functioning of the department using surveys and structured interviews
- Gather economic information about departmental and hospital-related operations in whatever form this information is available
- Develop hypotheses concerning the potential costs and benefits of the prototype systems, and those within the hospital bearing these costs and reaping these benefits

Summary of Approach

The baseline study will be planned in conjunction with the Post-Installation Studies (see Section 3.2). The approach at each medical center will be to gather consistent, comparable data on the radiology department, as indicated below, prior to installation of the DINS. Much of the information specified below has already been provided by the two universities in their proposals to MITRE. This information can be updated by university personnel, as needed. The development of other information may require the use of interviews, mail surveys, and direct observation on a sample basis. Information contained in the RIS or HIS at each university medical center will also be used.

Summary of Data Collection Requirements

Four types of data will be collected during the baseline study period. These include data characterizing the structure of the radiology department, its functioning, user satisfaction with key aspects of this functioning, and current costs of providing service.

Department Structure. Data collected to describe the structure of the radiology department will include, but not necessarily be limited to, the following:

- Basic university site description, to include medical facility size, number of beds, equipment, staffing, organizational structure, image and film management procedures, patient information management methods, the physical configuration of the radiology department, and its relevant organizational subsidiaries

- Patient volume for a pre-determined time period, including average patient census, average length of inpatient stay, average number of outpatient visits per day, and other specialized utilization data as defined by each site

- Radiology examination workload, expressed in procedures, by type of examination, to include (as applicable) plain films, CT scans, Nuclear Magnetic Resonance Imaging (NMRI) scans, ultrasound (US), angiography, and fluoroscopy

Department Functioning. Data characterizing this functioning will include, but not necessarily be limited to, the following:

- Current methods for managing information regarding the patients treated in the Radiology Department (e.g., RIS, HIS)

- Total volume of transcription effort for a pre-determined time period, including the average number of transcriptions, average preparation time, and average number of words per transcription

- Current methods for assuring both security for, and convenient authorized access to, clinical images and associated patient data

- Current ability, if any, to provide the radiologist with images on a patient from multiple imaging modalities (e.g., plain films, CT scans) in an integrated fashion for viewing

- Processing time required for key steps in the request/report cycle for each imaging modality, to include such steps as:

  - Initial receipt of request for imaging service

  - Arrival and departure times of patient in X-ray department for imaging service

  - Initiation of imaging examination

  - Completion of imaging examination

  - Films or other images sent to file room prior to reading and reporting by radiologist

- Search time for films requested by clinicians from file room
- Films hung by file room for reading and reporting
- Films read by radiologist and reported on
- Transcription of radiologist's report completed
- Report approved and signed by radiologist
- Radiologist's report filed in patient's file jacket and films archived
- Typical lost film search times

- Typical flow of radiological traffic from one place to another within the hospital, particularly those aspects of this flow that would be taken over by the DINS, to include such aspects as:
  - Number of images that flow among hospital users daily, on the average, by type of imaging modality and by organizational unit
  - Estimated percentage of referral cases received by a given imaging modality from each of the other imaging modalities in the hospital during a given time period

User Satisfaction. This aspect of the Department's functioning will be described in terms of:

- Clinician satisfaction with key aspects of the radiology department's performance (e.g., the efficiency and reliability of the conventional file room for obtaining images in day-to-day medical care, and the ability to obtain and use imagery from two or more modes of examination simultaneously)
- Hospital administrators' satisfaction with radiology department functioning relative to other departments
- Perceptions of clinical and non-clinical personnel concerning the likely strengths and weaknesses of the DINS prior to its installation
- Strengths and weaknesses of the existing system for handling radiological images and information as viewed by a cross section of support staff, and (independently) by the research team

Costs of Providing Service. The current cost of providing service will be described in terms of:

- Direct costs (e.g., fixed and variable costs, time spent by key staff, equipment purchases) versus indirect costs (e.g., overhead)

- Estimated opportunity costs (e.g., better uses for staff time if staff members could be freed from the burdens of the current manual system for running the department)

Hypothesis Development. In addition, hypotheses will be developed on at least two subjects. The first concerns ways that the costs of radiology and related services may increase or decrease when the DINS is fully operational. The second set of hypotheses concerns the operational impact the DINS may have on the radiology department and on other departments within the hospital. These hypotheses will be provisional, of course; the precise ways that the DINS will affect hospital performance cannot be anticipated fully. Table 3-1 presents illustrative hypotheses. These are based on the anticipated benefits shown in Section 1.5.

Deliverable Products

The results of this study will be documented as shown in Table 3-2.

3.2 Post-Installation Studies of the Structure and Functioning of Each Medical Center

An important question concerning the DINS is its impact on the radiology department and on the other hospital departments it serves. Does the DINS improve efficiency, effectiveness, and timeliness of care? The post-installation studies, to be conducted at both university sites near the end of the project, consider this overall question.

Objectives

This study assesses the performance of the radiology departments at each university medical center after the DINS has been installed. This translates into the following four objectives:

- Evaluate the impact the DINS has had on departmental performance, including its ability to support other hospital departments

- Determine the strengths and weaknesses of the DINS prototype in operation, particularly as these might relate to combat casualty care

- Identify ways to improve the operation and value of subsequent DINS systems, in particular regarding combat casualty care

TABLE 3-1
ILLUSTRATIVE HYPOTHESES CONCERNING DINS PERFORMANCE

Image Acquisition Hypotheses	• Obviates use, storage, and transportation of chemicals, water, and film in combat zones • Promotes better quality control by standardizing methods • Reduces the "re-shoot" rate and its waste of patient and clinician time
Image Archive Hypotheses	• Allows fast, convenient access to all images • Reduces storage costs • Eliminates problems due to lost films • Prevents degradation of archived images
Image Display Hypotheses	• Supports image processing and computer graphics techniques to enhance diagnostic skills • Allows use of artificial intelligence techniques to aid in diagnosis • Improves the convenience of case review
Communications Networks Hypotheses	• Supports fast, reliable transport of images between acquisition stations, viewing stations, and the archive • Allows interconnection of departments and geographically separated facilities • Establishes a "backbone" for integrating new imaging modalities as they emerge
Clinical Management and Patient Care Hypotheses	• Allows for multiple users of same case materials • Improves communication and consultation among physicians • Supports improved clinical teaching and educational programs • Improves quality of care

TABLE 3-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR BASELINE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Baseline study results: University of Washington		X	
Baseline study results: Georgetown/George Washington Universities			X
Synthesis of baseline results	X		

- Contribute to the development of specifications for future DINS systems for installation in military hospitals and elsewhere

Summary of Approach

The basic approach will be to repeat key aspects of the baseline study after the DINS is fully operational. This allows the project team to compare the department's performance during the pre-DINS period with its performance during the post-DINS period and to study significant performance aspects of the DINS from an operational viewpoint. Both are a means of evaluating DINS strengths and weaknesses.

Summary of Data Collection Requirements

Ten basic types of data will again be collected. As in Section 3.1, these data will characterize the Department's structure, functioning, and user satisfaction during the post-installation period.

Departmental Structure. Data will be collected or updated that characterize changes (if any) in:

- Basic university site description, to include facility size, number of beds, equipment, staffing, organizational structure,

  imagery and film management procedures, patient information management methods, the physical configuration of the department, and its relevant organizational subsidiaries

- Patient volume for a pre-determined time period, including average patient census, average length of inpatient stay, average number of outpatient visits per day, and other specialized utilization data as defined by each site

- Radiology examination workload by type of examination, to include (as applicable) plain films, CT scans, NMRI scans, US, angiography, and fluoroscopy

Departmental Functioning. Data will be collected that describe changes (if any) in:

- Current methods for managing information on the patients treated in the Radiology Department (e.g., RIS, HIS)

- Total volume of transcription effort for a pre-determined time period, including the number of transcriptions and words per transcription

- Ability to provide the radiologist with images on a patient from multiple imaging modalities (e.g., plain films, CT scans) in an integrated fashion for viewing

- Processing time required by the DINS for key steps in the request/report cycle for each imaging modality, to include such steps as:

  - Initial receipt of request imaging service
  - Arrival of patient in X-ray department for imaging service
  - Initiation of imaging examination
  - Completion of imaging examination
  - Films or other images sent to file room or electronic storage prior to reading and reporting by radiologists
  - Search time for films or images requested by clinicians from file room or electronic storage
  - Films hung by file room or images filed for reporting
  - Case films or images reported
  - Case read by radiologist and reported on
  - Transcription of radiologist's report completed
  - Report approved and signed by radiologist
  - Radiologist's report filed in patient's file jacket and films or images archived

- Number of images that flow on the DINS network among hospital departments daily, on the average, by type of imaging modality

User Satisfaction With the DINS. Data collected on this subject will help characterize:

- Clinician satisfaction with key aspects of the post-DINS radiology department's performance (e.g., the efficiency and reliability of the DINS for obtaining images in day-to-day medical care, the ability to obtain imagery from two or more modes of examination simultaneously, such as plain films and CT scans on a given patient)

- Strengths and weaknesses of the DINS system for handling radiological images and information as viewed by a cross section of significant support staff

Deliverable Products

The results of this study will be documented as shown in Table 3-3.

3.3 Cost/Benefit and Cost/Effectiveness Studies Estimating the Likely Cost/Efficacy of the DINS in Operation Based on the Prototype Experience

The operation of two DINS prototypes over the course of the project affords an opportunity to estimate the cost/efficacy (i.e., cost/benefits and cost/effectiveness) associated with the DINS. For numerous reasons, definitive calculations that can be extrapolated directly into future environments cannot be made. For example, future DINS systems will almost certainly perform more effectively than current prototypes. Improvements will be made based, in part, on shortcomings found during the current project. Moreover, the prototype DINS at each site will duplicate some activities at the medical center already being performed in other ways to assure proper care of patients. Though necessary when evaluating an experimental system, this parallel operation will further muddy the DINS cost and benefit picture. It should be possible, however, to determine key DINS strengths from a cost/efficacy viewpoint and to identify improvements needed.

Objectives

There are four objectives for this study. They are to:

- Develop estimates of the costs associated with acquiring and operating the DINS in the university hospitals

- Develop estimates of the benefits the DINS can reasonably be expected to deliver, expressed in the most precise terms practicable

- Develop a cost/benefit model of a DINS in operation

- Perform cost/effectiveness studies on selected, well-defined DINS functions to show how the DINS compares with current methods

Summary of Approach

The terms "cost/effectiveness" and "cost/benefit" analysis have a variety of meanings in the professional literature on health care systems. As used in Study 3.3, they mean the following:

TABLE 3-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR POST-INSTALLATION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Post-installation study results: University of Washington		X	
Post-installation study results: Georgetown/George Washington Universities			X
Synthesis of post-installation results	X	X	X

- Cost/effectiveness analysis specifies a single objective and alternative ways to reach it. It then determines the costs associated with each alternative. Both the short- and the long-term are considered. Costs are almost always expressed in dollar terms. The method that achieves the objective at lowest cost is said to be the most cost/effective. If the objective cannot be achieved, there are said to be no alternatives. If it cannot be achieved at an acceptable cost, there are said to be no cost/effective alternatives.

- Cost/benefit analysis adds up all reasonable costs and all reasonable benefits associated with a system to determine which are larger. Both short- and long-term costs and benefits are considered. Costs are usually expressed in dollar terms. Benefits are sometimes expressed in dollar terms and sometimes simply enumerated. A system that, on balance, confers greater benefits than it costs is said to be cost/beneficial.

A system as innovative as the DINS requires investigations of both types. For comparatively simple, easily-specified functions, cost/effectiveness is suitable. For example, one objective of a radiology department is to maintain complete files of all X-ray examinations made of patients it has served over a defined time period. The DINS with its digitally-based archive and the conventional file room holding films in jackets are two methods for doing so. In this case, it is helpful to estimate the costs each method would incur in keeping "complete files." The method that does so at lower cost is the more cost/effective method.

At the same time, some of the most important functions of the DINS do not have simple objectives. For example, improving communication on patient care questions between radiology and other departments in the hospital is a possible function of the DINS in operation. Improved communication would be an important benefit. But it would not be possible (or even especially useful) to formulate an objective for this function. Nor would it be helpful to examine alternative ways to carry it out once the DINS is installed. Instead, "improved communication," specifying the nature of this communication and identifying its beneficiaries as clearly as possible, should be listed as an important DINS benefit. Its exact value would then be left to others considering acquisition of a DINS to assess against needs in their hospital.

Applying Cost/Effectiveness Analysis. Cost/effectiveness analysis is appropriate for assessing DINS functioning when:

- The function can be expressed in terms of a single, measurable objective

- The benefit of the function is not questioned

- All relevant costs in performing the function can be identified and estimated

- The function can be performed in at least two different ways (i.e., by the DINS and by other, more conventional methods)

Applying Cost/Benefit Analysis. Cost/benefit analysis is best suited to assessing DINS functioning when:

- The function performed by the DINS cannot be expressed as a single objective

- The function will confer benefits on a variety of professionals, non-professionals, or patients within the hospital or elsewhere however, these benefits are difficult or impossible to quantify in a precise, numerical way

- The function will confer benefits in some parts of the hospital but incur costs in others

- The function being examined is new, unique to the DINS, and therefore cannot be compared with existing functions

Determining Costs. Costs are often hard to measure. Alternative measures of cost in common use can be used to illustrate this point. For legitimate reasons, the "cost" of something can be measured in terms of one or more of the following:

- Its purchase price on the open market and overall operating expenses during day-to-day functioning, both allocated over an appropriate time period such as usable life for accounting purposes

- The proportion of its market price and operating expenses that is (or is not) reimbursable by third party payors

- The discounted present value of its dollar costs in normal operation over its useful life

- The loss of benefits associated with the best available alternative use of the resources used to obtain and support the DINS (e.g., the loss of benefits associated with the additional imaging or other equipment for the hospital that could have been purchased with the money spent on the DINS)

Each of these measures has its purposes. It often makes sense to use combinations of them. In the DINS project, the cost picture is clouded by at least three factors. First, the DINS is being funded for experimental prototyping purposes. The participating vendors and medical centers are contributing both time and other resources "free" or at reduced rates. Realistic market prices, a common measure of cost, do not prevail. Second, administrative formulas establishing the proportion of departmental or hospital costs attributable to the DINS for purposes of billing third party payors and for other accounting purposes have not yet been established. Finally, cost/accounting methods that appropriate a civilian hospital are not necessarily relevant to a military hospital where third party payors are non-existent. For these reasons, cost measures must be selected carefully.

Summary of Data Collection Requirements

Data collection will include, but not be limited to, the items summarized below.

Cost/Effectiveness Data. A few key functions performed by the two prototype DINS will be identified in the early stages of this study. They will be:

- Functions believed to be a significant advantage of the DINS in day-to-day operation as compared with existing methods for performing the function
- Functions that have been carried out in the past in each university hospital using conventional methods

For each such function, data collection will include, but not be limited to, the following:

- An operational definition of the function's objective (i.e., a definition specified in such a way as to allow an observer to determine whether it has been met)
- All reasonable dollar costs incurred in meeting this objective over a defined period of time (e.g., monthly). Dollar costs will include, but not be limited to:
  - Labor costs
  - Share of total facilities costs attributable to the function
  - Consumables
  - Overhead items

- All reasonable indirect costs incurred in meeting the same objective over the same time period. Indirect costs will include, but not be limited to:

  - The benefits foregone by devoting staff to performance of the function if these staff could be reassigned to other, more useful activities

Cost/Benefit Analysis. Several key functions will be identified for each of the DINS prototypes after the prototypes have been in operation at each university for a period of time. These functions will include, but not be limited to, functions that are:

- Regarded as significant strengths of the DINS in day-to-day operation

- Feasible only with the DINS

- Capable of conferring benefits on the radiology department and/or other related hospital departments

Of special interest will be the benefits listed in Section 1.5 of this document. For each function identified for cost/benefit analysis, data collection will include, but not necessarily be limited to, the following:

- All direct costs associated with performing the function

- All indirect costs associated with performing the function

- All benefits believed to result from the performance of the function (whether these benefits can be expressed in dollar terms or not) and the best available estimate of their magnitude. This will include, but not be limited to, benefits accruing to:

  - Radiologists

  - Technologists within the radiology department

  - Consulting physicians outside the radiology department

  - Patients

  - Management staff in the radiology department

  - Management staff elsewhere in the hospital

Deliverable Products

The results of this study will be documented as shown in Table 3-4.

3.4 Potential Impact of the DINS on Costs and Quality of Care

The Army is considering whether to implement a DINS on a pilot basis at one or more Army medical centers immediately after the current project concludes. In developing plans for such an implementation, the Army needs "first look" estimates concerning the impact such an implementation would have on these centers. This study is concerned with providing the necessary estimates for the Army's use on a timely basis.

Objectives

There are four objectives for this study. They are to:

- Provide data to the USAMRDC for use in preparation of the Program Development and Implementation (PDIP) package to be used in supporting a request for budget authority to carry out the pilot project installations

- Document the best available estimates of the role, costs and benefits of the DINS as implemented in peacetime Army medical centers, emphasizing quality of care improvements

- Document the best available estimates of the role, costs and benefits of the DINS as implemented in conjunction with combat casualty care facilities, showing how DINS could improve quality of care

- Provide cost estimates for DINS installation at Madigan Army Medical Center as required by Army Regulation (AR) 40-65

Summary of Approach

Most of this study will be complete before the DINS is implemented at the two university sites. Therefore, prototype project experience will not be available at the time the study's estimates are required by the Army (April 1988). Instead, this study will first review the available literature concerned with imaging networks in radiology. Second, it will gather the opinions of noted experts in the field by telephone, and it will draw upon the preliminary views of project team members who are well placed to register informed views on the subject. Third, these opinions and observations will be reviewed by MITRE staff in consultation with university staff and U.S. Army representatives for relevance and

TABLE 3-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR COST/EFFICACY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Cost-efficacy study results: University of Washington		X	
Cost-efficacy study results: Georgetown/George Washington Universities			X
Synthesis of cost-efficacy studies, including model of costs and benefits	X	X	X

usefulness to Army purposes. Finally, it will review the costs associated with the installation of the prototypes at each university site, summarizing these costs along the lines of AR 40-65 for use by the Medical Research and Development Command.

Summary of Data Collection Requirements

As noted above, at least two kinds of data will be collected, including:

- Reviews of available literature
- Expert opinion drawn from both project and non-project sources

Deliverable Products

The results of this study will be documented as shown in Table 3-5.

TABLE 3-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR IMPACT AND QUALITY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Data for PDIP	X		
Report on DINS potential value in U.S. Army fixed facilities	X		
Report on DINS potential value in combat casualty care	X		
Report on costs involved in DINS installation based on prototypes and university cost model	X	X	

4.0 STUDIES FOCUSSED ON DINS WORKSTATIONS

Workstations fall between personal computers (PCs) and larger minicomputer or mainframe systems, although the distinction is becoming increasingly blurry. A workstation differs from a PC in that it has greater power and sharper graphics. Workstations differ from conventional computer systems in providing each user with a guaranteed amount of processing power at all times. Conventional time-share computing systems can slow each user's processing if many users compete for resources at once. Workstations reveal their true power when linked into networks.

Figure 4-1 highlights the variety of workstations that can be connected to the DINS. These workstations can be classified into three broad categories in terms of their capability and intended use, including:

- Remote sending and receiving stations
- Hospital reviewing stations
- Radiology department reviewing stations

The remote station is located at a geographically remote health care facility. It has two essential functions. First, it is an input station, allowing the operator to place images in storage, to review them at a monitor, and to send them to a central facility for detailed review. Second, it is an electronic lightbox intended for general use in physician's offices, nursing stations, and examination rooms. The reviewing station is located inside the hospital but outside the radiology department. It is designed to support consultations among physicians in specialty areas other than radiology. The reporting station is located in the radiology department itself. It is designed to meet the needs of the staff radiologists during the review and generation of reports on each case. A single workstation can be designed to fulfill all three purposes, of course, though at somewhat higher cost per station.

Included in this section are proposed studies concerned with DINS workstations and the capabilities they should have. Summarized are studies that:

- Develop a normative model of the user interfaces with DINS workstations that can be used for evaluation purposes, and to investigate the capabilities of an advanced image processing station in connection with the DINS
- Investigate the effects of DINS workstation design, layout, and capabilities on radiologist viewing, on other physicians, on technicians, and on the practice of radiology within the hospital

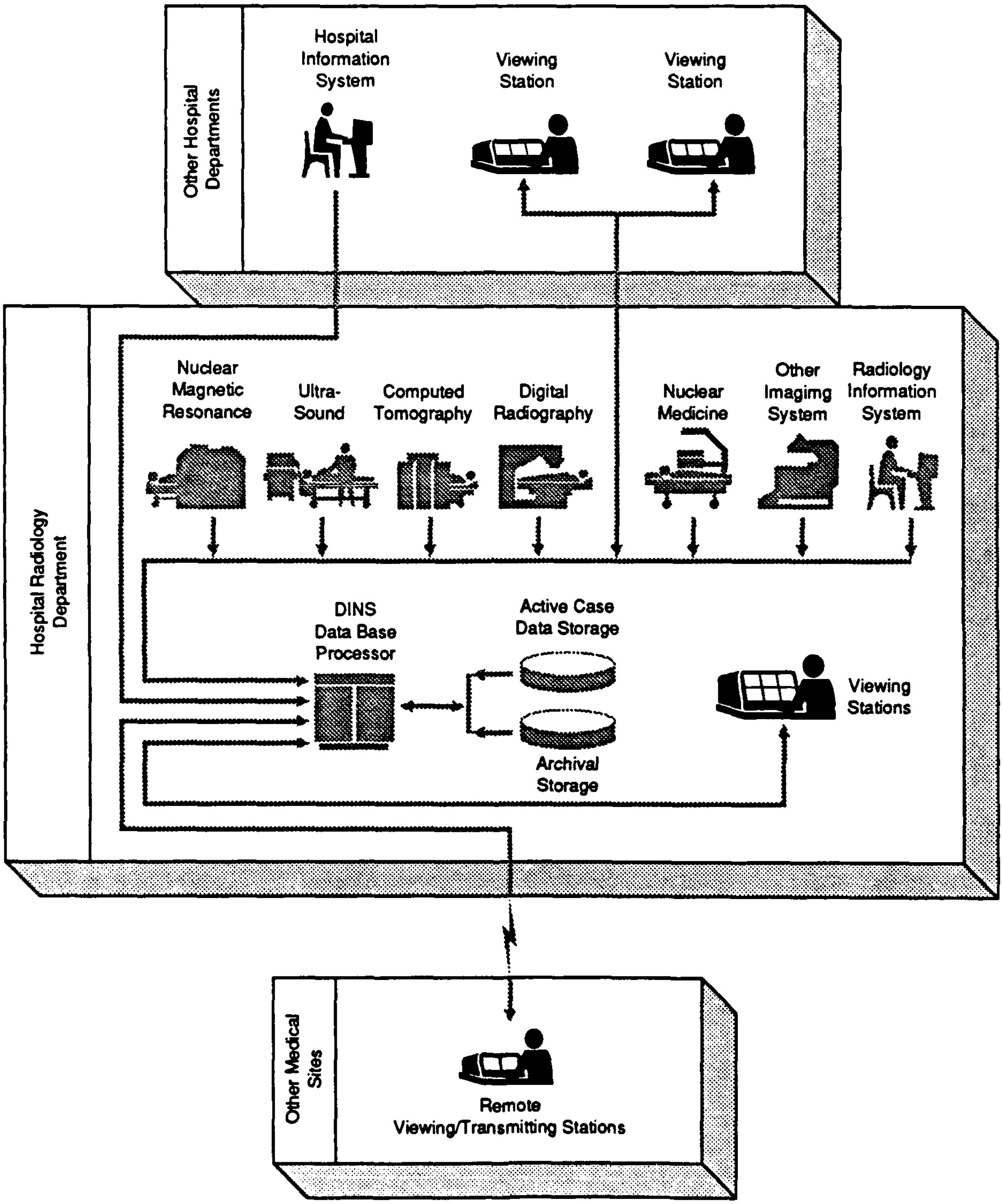

FIGURE 4-1
DIGITAL IMAGING NETWORK HIGHLIGHTING WORKSTATIONS

- Investigate the workstation's display requirements for contrast and spatial resolution

- Investigate the capabilities of PC-based workstations in connection with the DINS

- Investigate the diagnostic value and specifications for multi-modality image analysis

- Investigate the requirements for building a radiology-oriented decision support system suitable for making preliminary diagnoses or assisting the health care provider in other ways in combat casualty care and other emergency situations

Each of these studies is described in the following subsections.

4.1 Developing a Normative Model of the User Interface for a DINS Workstation and Investigating an Advanced Image Processing Station for DINS Applications

To evaluate DINS user interface issues, a normative framework is necessary. In critiquing the prototypes' human/machine interfaces, common metrics and criteria for comparison must be developed. A model of an abstract DINS workstation user interface would provide a framework for evaluation. Such a model can also be applied to the experimental workstation developed by Pixar Incorporated in order to evaluate user interface techniques not incorporated into existing prototype workstations.

The open architecture of the Pixar workstation offers an opportunity to evaluate techniques not incorporated in the prototypes. The model development effort will yield suggestions for advanced user interface technologies in future DINS. The feasibility and utility of some of these concepts can be evaluated through the Pixar.

The availability of medical images in digital form from the DINS will also allow testing of various image processing techniques. The usefulness of these techniques in the medical environment has yet to be determined. A state-of-the-art image processing workstation will be used to investigate the utility of these image processing techniques in the radiology department. The flexibility of the workstation will allow various human factor studies without the acquisition of special hardware.

Objectives

The five objectives of this study are to:

- Develop an evaluative model of DINS workstation user interfaces that takes typical prospective users into account

- Identify critical user interface issues to focus on when evaluating the prototype workstations

- Identify key ideas and technologies associated with the DINS user interface for experimentation using the Pixar

- Determine ways in which advanced interface concepts could be used in connection with future DINS

- Evaluate the utility and performance characteristics of current image enhancement methods

Summary of Approach

Communication between a user and the DINS is a conversation. The conversation includes inputs to the computer (outputs from the user), outputs from the DINS (inputs to the user), and the sequencing of those outputs and inputs. Viewing the user-computer interaction as a conversation implies a language model of dialogue. Conversation and dialogue should not be taken to imply verbiage. Rather, the dialogue model of communication consists of three levels: semantic, synatactic, and lexical. Communication can take such forms as pointing with a lightpen, keying in commands, or hearing a bell indicating an error.

As a first step, top-down methodology analogous to modern programming methodology will be used to develop the DINS workstation user interface model. Five steps are contemplated as follows:

- Task Analysis--A thorough and detailed analysis of each DINS user's tasks will generate a set of design constraints and objectives, a definition of user characteristics, and a set of functional requirements for the interface.

- Conceptual Design--Key concepts in the task will be analyzed to identify "objects" used in the system and possible actions upon those objects. Examples of objects are images, sections of images, and patient files. The conceptual design will identify and categorize these key concepts in terms of the user's view of the system.

- Semantic Design--The design will then be refined into units of meaning: a typical user to computer command specification might state that a request for a patient file can be keyed on the patient's identification (ID) number or name. The user's commands which operate on objects, directly or indirectly, will be designed, as well as the computer's responses.

- Syntactic Design--Next, the form in which these semantic units will be conveyed will be designed. From the user to the computer, this constitutes a command language grammar. From computer to user this includes positioning the information on various output devices and deciding on the form of the information (e.g., graphics or text).

- Lexical Design--Input devices will then be evaluated, including keyboards, voice recognizers, mice, etc. Output options such as line style, color, and text fonts will be assessed for their utility.

Second, during the model building effort, critical interface areas will be identified and several methods of handling them proposed. Some of these alternatives may be implemented in the prototypes, if feasible. In this case, they will be appraised. Other alternatives will be explored with the use of the Pixar. The overall model of the various DINS-user interfaces will be used to evaluate the system as a whole.

Third, volunteer radiologists who participated in the prototype evaluation studies will be asked to perform image manipulation and processing tasks similar to those performed in the earlier studies. Then they will be debriefed concerning their assessment of the usefulness of these innovations. The resultant data will be combined with error rates to make evaluations of the utility of the experimental procedures.

Fourth, a Pixar image processor will also be used in this study to test applications such as three-dimensional reconstruction of a series of two-dimensional, transaxial images. These will be evaluated with respect to their clinical utility. In addition to subjection evaluations of such techniques by radiologists, quantitative determination of radiologist performance will also be carried out using receiver operating curve (ROC) analysis.

Fifth, image enhancement methods will be investigated. Basically, there are two main categories of image enhancement techniques: spatial-domain and frequency-domain manipulation. The former category contains histogram equalization and direct histogram specification methods. The latter category contains techniques based on "filtering" the original image to obtain desired results. Other techniques include false-color and pseudo-color enhancement methods. Both categories of techniques appear to have potential in the DINS environment. Other somewhat less promising image processing methods can also be reviewed. These include picture segmentation, pattern recognition, feature extraction, interactive contrast reversal or enhancement and segmentation of the image into regions (each of which is homogeneous in a user-defined sense and distinct from its neighbors), edge detection and enhancement, and search for matching of pre-stored image shapes. This matching capability can be especially useful for comparisons between patients and between images taken at different times on a given patient. All these methods will be researched in the DINS environment.

George Washington University is developing an enhancement method based on histogram modification techniques to develop other image processing algorithms especially relevant to radiological images. As new algorithms become available, the DINS data base could be searched and evaluated for images with certain texture or shape properties.

Summary of Data Collection Requirements

Required data include a sample of radiographic images for evaluation, including sets of CT or NMRI data for three-dimensional reconstruction. Data collected will include structured user perceptions and results of controlled experiments.

Deliverable Products

The results of this study will be documented as shown in Table 4-1.

4.2 Investigating the Effects of Workstation Design on the Practice of Radiology

The basic requirement of the workstation is the display of clinical information (both images and text) to the user in an accessible, intuitively logical fashion. Since these data will be accessed by users of different needs and clinical interests, more than one type of workstation may be required. As mentioned, these workstations could vary with regard to user interface characteristics, resolution, the number of image displays, and the image processing features available. Choices among options are likely to be based upon the users of the particular workstation and its intended use. This study will investigate the communication of clinical radiology data to the referring physician.

Numerous image manipulation capabilities are offered the radiologist using digital imaging equipment. All are offered to improve the radiologists' ability to do their work. For the most part, none has been

TABLE 4-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES
FOR NORMATIVE MODEL STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report documenting proposed model of user interfaces			X
Report documenting results of experiments with the Pixar			X

evaluated for its actual use rate, and hence its probable value as perceived by radiologists. This study also collects and evaluates statistics on the actual usage of DINS features as a means to assess perceived value.

Objectives

The four objectives of this study are to investigate:

- The actual usage of various clinically-oriented, user-controlled capabilities for manipulating digital images on the DINS
- The clinical significance of various use rates from the users' viewpoint
- The specific usefulness of image processing and other data manipulation features at each type of workstation used with the DINS
- The overall acceptability of each type of workstation to its various users

Summary of Approach

The approach taken in the first step of this study depends basically on whether the workstations are open or closed. The optimum situation is an open workstation where a software monitor can be installed to keep a record of such items as user commands or options executed during a session, and types of images processed during a session. These data would be retrieved and analyzed for various time periods to determine trends as well as actual usage rates. In a closed workstation, the desired data could be extracted in a more indirect manner. For example, the keyboards from each workstation could be routed through custom-built, dedicated hardware or a PC. The monitoring device would pass each keystroke to the appropriate workstation while simultaneously decoding the function on the command line. The physical measurements will become challenging if a trackball, mouse, lightpen, or some other interactive scheme is employed to select processing options. However, a hardware approach can be used in decoding these interactive commands.

Second, interviews will be conducted with a structured sample of users to help determine the users' intent in using various capabilities (e.g., is a technique used frequently because it aids detection of a common pathology, because it is easy to use, or for other reasons?). At designated times during the project, the users of the DINS (e.g., technologists, radiologists, and referring physicians) will be surveyed concerning features they like about the particular workstation they use and additional features they would either require or desire. This survey will gather the subjective evaluation by the system's users of the appropriateness of the display digitization matrix (512 x 512 pixels versus 1024 x 1024 versus 2048 x 2048), image processing features, human-machine interface, the usefulness of user "help" features, and error reporting and recovery messages.

Third, the types of human-computer interface most commonly used (e.g., mnemonics, keyboards, menu-driven commands or track ball, voice recognition) will be evaluated in terms of the model developed in Study 4.1. This evaluation will yield information necessary for the design of the future workstations.

Fourth, a laboratory study of methods of human-computer interface will be performed. After an initial training session, volunteers (typically radiologists and referring physicians) will be asked to perform a series of computer-oriented image manipulation and processing tasks, using various interactive techniques such as keyboard mnemonics, menu-driven commands, mouse or track ball, touch screen, or voice recognition. The utility of user help features and quick reference guides will also be evaluated in this study. The time and error rates in performing these tasks will be noted. The error rates will be monitored for the user, given various fixed times to perform these tasks. The time between image acquisition and display at the workstation and time required per study at the workstation will be noted and the resultant values compared to those for the film-based workstation.

Summary of Data Collection Requirements

Four kinds of data will be collected:

- Usage rates and time delays for key user-controlled electronic functions of the workstation over time
- User perceptions and suggestions from structured interviews and surveys
- Results of controlled laboratory experiments
- Direct observation by research team members

Deliverable Products

The results of this study will be documented as shown in Table 4-2.

TABLE 4-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR WORKSTATION DESIGN EFFECTS STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of workstation study at University of Washington		X	
Results of workstation study at Georgetown/George Washington Universities			X
Report integrating results for U.S. Army use	X		

4.3 Investigating the Workstation's Display Requirements for Contrast Resolution and Spatial Resolution

The resolution of an image display can be described by two components: spatial and contrast resolution. Spatial resolution refers to the number of picture elements (pixels) vertically and horizontally that can be displayed. Common in digital radiology, for example, are 512 x 512 or 950 x 1100 pixel displays. For its part, each pixel may display various levels of gray. The total number of displayable gray levels or colors is the display's contrast resolution. This form of resolution is often characterized by the number of bits used. Thus, a pixel bit depth of 8, for example, indicates the ability to display 256 gray levels (i.e., 2 taken to the 8th power) of contrast. These two parameters should not be confused with the dynamic range and spatial resolution of a particular medical imaging modality. In fact, the spatial resolution and dynamic range of the imaging modality will define, in most cases, the spatial and contrast resolution necessary in the workstation that displays the images.

Various imaging and perceptual tasks also affect display requirements. For example, the small, high-contrast microcalcifications as well as low-contrast tumors common in mammography requires high spatial and high contrast resolution. Chest radiography requires the ability to localize lesions in bones, soft tissues, and in the lungs, implying high spatial resolution but lower contrast resolution. These two examples show how imaging tasks largely define resolution requirements.

There may also be a difference between the resolution of a digital image at acquisition and that of the workstation on which the image must be displayed. For example, a bone radiograph may be acquired and digitized in a 2000 x 2000 matrix that is 12 bits deep, while the workstation may only display 1000 x 1000 x 8 bits. Image manipulations such as continuous pan and zoom and window level could be used to obtain all available information of an image digitized at high resolution from its display at lower resolution.

Objectives

This study has three objectives, including investigations of the following subjects:

- The requirements for spatial and contrast display resolution for generically different types of medical images
- Whether lower resolution displays could be used with selected image manipulation techniques to view higher resolution images effectively

- The physical quantities that affect image quality on DINS workstation screens

Summary of Approach

As a first step in this study, a set of test films will be selected which are representative of the different image types to be used in conjunction with the DINS. These films will be digitized into 1024 x 1024 x 12, 1024 x 1024 x 8, 512 x 512 x 12, and 512 x 512 x 8 matrices. These images will be evaluated both with and without image manipulation capabilities (e.g., continuous pan and zoom, window and level). Phantom or computer-simulated image data will also be generated for an objective evaluation of observer performance as a function of these parameters.

Second, the determination of image quality will also involve experiments that can be done by collecting data using physical measurements. These experiments will center on verification of geometric image parameters and those related to image contrast. These tests will be conducted using tools such as straight edges, protractors, and light meters. Image geometric data will be collected to compare how one part of an image relates spatially to the corresponding part of the object that was imaged. This group of data can be divided up into those that affect the horizontal dimension on the image and those that affect the vertical dimension on the image. In each of the two directions named, geometric inaccuracies can be attributable to spacing non-uniformity and shape distortions. The vertical dimension is defined as the direction perpendicular to the direction of scan lines on a video monitor, regardless of how an object image is displayed on that monitor. The horizontal dimension is defined as the direction parallel to the direction of the video scan lines, regardless of the orientation of an object on a video display. Against this background, the study will investigate:

- Spatial Uniformity--Spatial uniformity refers to the ability to accurately portray objects composed of regularly spaced components. These components could be spaced in a linear fashion along any straight line, or they could be spaced at equal angular increments. This study will only address spacing uniformity in the horizontal and vertical directions. These two directions are chosen because any other spatial non-uniformity can be described as having a non-uniformity component in one or both of the directions chosen.

- Vertical Uniformity--Vertical uniformity is a test of the DINS ability to accurately reproduce spatial intervals between repeating structures in a test object in the vertical dimension. Such a test could be carried out by first imaging appropriate phantoms on various modalities. Then comparisons on physical measurements of images of the phantoms to the known spatial properties of the phantoms, accounting for any geometric scaling factors, should be done. The phantoms referenced could include physical objects or electronically generated objects.

- Horizontal Uniformity--Line space uniformity is a test of a DINS' ability to accurately render an object that contains regularly spaced objects in the horizontal dimension. This test could be done using techniques described above.

- Shape Distortions--For the purpose of the discussion to follow, shape distortions are defined to be any phenomenon which causes an image of an object to be rendered geometrically inaccurate when compared to the object itself. Such distortions will be quantified by taking physical measurements of images of test objects and comparing them to the test object. Efforts will be made to isolate which part or parts of the imaging chain that are responsible for causing any distortions found. Shape distortions possible include bowing (i.e., a distortion which causes a straight line to be rendered as an arc), angular displacement (i.e., a distortion that causes a straight line to be rendered as a straight line, but with the incorrect angular relationship to an object line), and curved distortions (i.e., a general class that is meant to encompass any distortion that is not included in the above categories). In general, the latter class of distortion is typified by object lines rendered as sections of arcs or lines with discontinuities or both.

Third, image contrast will be studied. Image contrast refers to a quantity that describes the difference in brightness between two components of an object. The actual brightness difference that these components exhibit may be based on the physical properties of the object components and/or the imaging modality used. Every effort will be made to isolate links in the imaging chain that degrade image contrast, investigating such subjects as the following:

- Contrast on one viewing station--Images, as viewed on a DINS viewing station, will be compared to the same image as viewed on the parent modality viewing station. A light meter will be used to measure the brightness from appropriate parts of images on a DINS viewing station and a parent modality viewing station. Also, the intrinsic contrast of any test object used will be calculated where possible. The two brightness measurements and the intrinsic contrast will be compared. If the DINS possesses the ability to alter the contrast of an image through image processing techniques, the above measurements should be done at the default settings of the DINS viewing station.

- Number of gray levels shown--This subject deals with how many levels of gray can be seen compared with how many are used to form the image. This determination could be done using both human observers and/or electronic light sensing equipment.

- Contrast resolution--Contrast resolution refers to the smallest increment between successive gray levels that can be visualized. This quantity may or may not be dependent on the absolute brightness of the two shades in question. This quantity will be assessed at various points on the gray scale dynamic range.

- Brightness uniformity--Brightness uniformity refers to a viewing station's ability to portray one shade of gray with the same brightness, independent of its position on the viewing screen.

- Focus uniformity--Focus uniformity refers to a viewing station's ability to portray an object line as a line of uniform width and line spread function accurately, independent of its position on the viewing screen. This measurement will be made using scanning light sensing equipment to determine measured line spread functions.

In a DINS, it is important that the image of an object of interest to be portrayed be identical in its presentation (i.e., spatial resolution, contrast resolution, lack of distortions, etc.) on any viewing station in the network. Image parameters that can vary from one workstation to the next, in addition to imaging parameters discussed earlier, include the brightness of the maximum white shade, the brightness of the minimum black shade, the incremental difference in brightness between any two shades, and the physical dimension of the image format.

Summary of Data Collection Requirements

Required data consists of a sample of digitized medical images that includes those acquired using several imaging modalities and from various parts of the body. Phantom or computer-simulated image data will also be generated. The image digitization and the image simulation will be performed using equipment at Georgetown University and in the MITRE laboratories.

Deliverable Products

The results of this study will be documented as shown in Table 4-3.

TABLE 4-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR IMAGE RESOLUTION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on results of image quality investigations	X	X	X
Report on methods for determining the quality of images and their comparative value	X		
Report integrating the results for use by the Army	X		

4.4 Investigating PC-Based Workstations for the DINS

There are several workstations commercially available that will meet the demanding, multi-faceted performance requirements characteristic of the DINS. However, for the most part, they are specialized workstations that are expensive and offer limited flexibility. Because of the closed nature of these workstations, it would be difficult to carry out many proposed studies needed for a complete DINS evaluation and for making recommendations for future systems.

Although PC-based imaging systems are currently available at a considerable cost savings, their performance is generally inadequate. They are basically suitable only for image display. They do not support satisfactorily such computationally intensive image processing algorithms as Region Of Interest (ROI) analysis, convolution, two-dimensional Fast Fourier Transform (2-D FFT), and geometric transformations.

To develop a low-cost image processing workstation, the University of Washington developed an IBM PC/AT-based image processing system for use as an experimental DINS workstation. The system resides entirely within the PC/AT. It uses the TMS 34010 Graphics Signal Processor (GSP) and TMS 32020 Digital Signal Processor (DSP) to implement the processing elements. A block diagram of the University of Washington Graphics Signal Processor (UWGSP) system is shown in Figure 4-2.

Physical features of the UWGSP system include four 512 x 512 x 8 bit frame buffers and a 512 x 512 x 4 bit graphics overlay memory. Hardware zoom, pan and scroll, and pseudo coloring are also supported. Images are displayed on a 60 Hz non-interlaced Red-Green-Blue (RGB) monitor.

Processing features supported in this workstation include the following:

- Point operations (e.g., lookup table manipulation)
- Arithmetic operations
- Geometric operations
- ROI analysis
- Filtering (convolution, 2-D FFT, median filtering)
- Edge enhancement and boundary detection
- Whole image or ROI quantitative image analysis
- Image segmentation and object detection

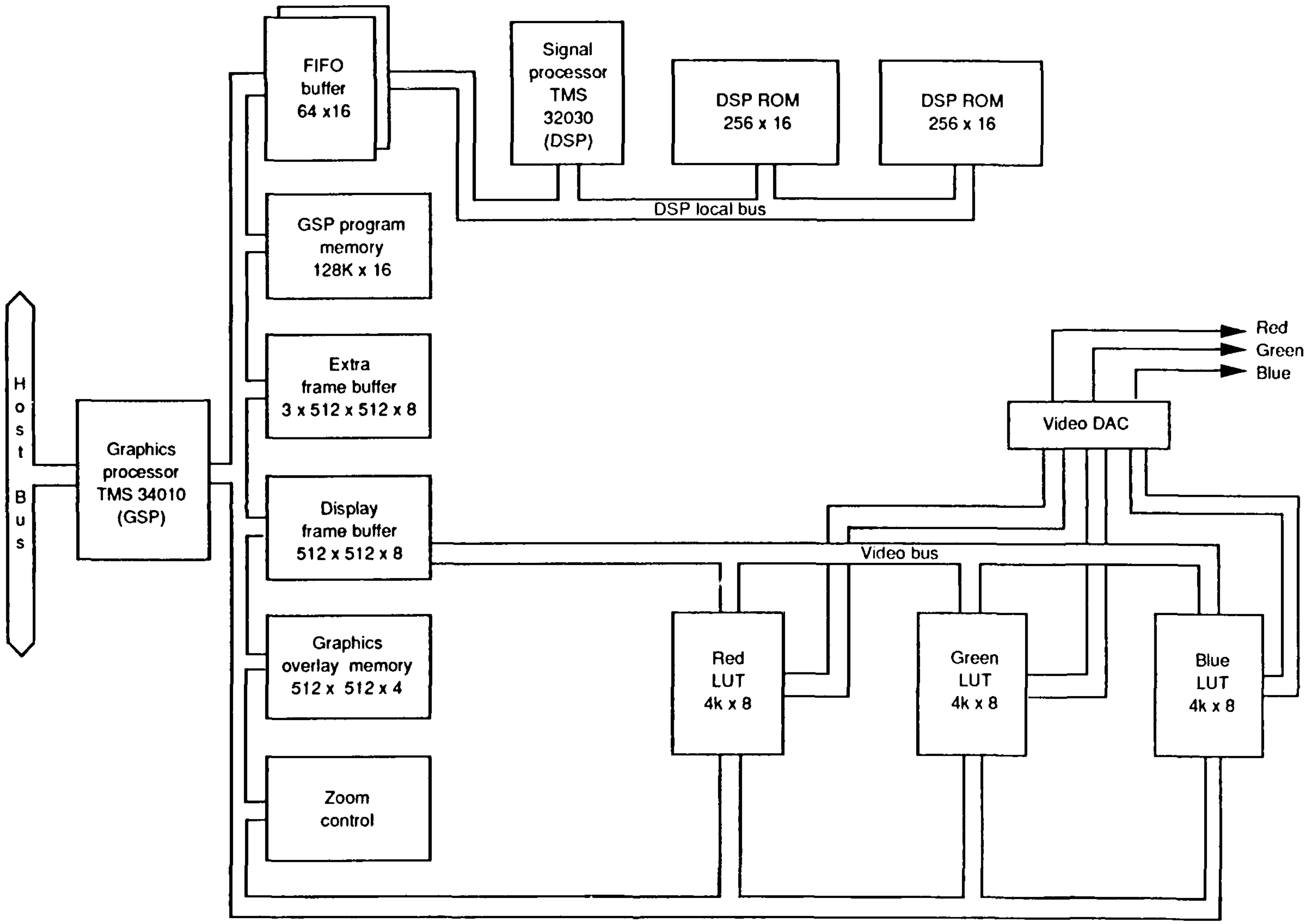

FIGURE 4-2
BLOCK DIAGRAM OF THE UNIVERSITY OF WASHINGTON'S GRAPHICS SIGNAL PROCESSOR

- Densitometry and morphometry
- Statistical texture analysis
- Interactive editing in graphics overlay memory

Because of their speed of operation, all these operations can be used in an interactive fashion. For example, arithmetic and logical operations between two 512 x 512 frame buffers require approximately 170 milli-seconds (ms). An 11 x 11 convolution, 2-D FFT based on the row-column method or a full screen geometric transformation (warping) on a 512 x 512 image can be finished in less than 10 seconds.

Objectives

The four objectives of this study are to:

- Implement user interface and processing features in an experimental mid-level PC-based DINS workstation
- Evaluate the workstation's man-machine interface and generate recommendations for improvement in future workstations
- Evaluate the usefulness of various image processing, manipulation, and analysis features either currently available or that will be implemented into the workstation
- Test and evaluate the image processing workstation in the DINS environment at the University of Washington and at MITRE

Summary of Approach

As a first step, working closely with radiologists and other potential users, necessary and desirable features of the workstation will be identified. These include image manipulation and processing functions as well as user interface functions.

Second, these features will be prioritized and features identified as most desirable by the users will be implemented at the University of Washington.

Third, the system will be initially offered to radiologists for use and evaluation as a stand-alone workstation. During this period, various processing algorithms (e.g., image compression, image enhancement, and image filtering) and user interface software will be tested and evaluated. Improvements will be installed in the system as needed.

Fourth, commercial hardware and software will be obtained and integrated into the UWGSP workstation to interface it to the IEEE 802.4 MAP network which will be used by the prototype DINS. Fifth, after this interface is complete, evaluation of the workstation performance will continue in the DINS environment. At MITRE, both the UWGSP board and several commercially available products will be evaluated on an Ethernet network.

Finally, prospective DINS users will be periodically surveyed to determine their overall perception of the system. Areas of interest in these surveys will include workstation features liked, features disliked, and features to implement or change. It is expected that as the users become more familiar with the system and its potentials, the initial monitoring of the system will expand. Monitoring the usage rate of various options and operating modes should enable the research team to develop trends and develop a quantitative measure of the value of various options. The technical capabilities of these devices will be evaluated at MITRE. Where possible, alterations to the system will be implemented in response to this feedback.

Summary of Data Collection Requirements

Data collection for this study will consist of surveys of radiological personnel and physical measurements of key workstation parameters. The surveys will be conducted both formally at periodic intervals using written questionnaires and informally in meetings with concerned personnel. Physical measurements will be taken by a monitor implanted in the UWGSP workstation software.

Deliverable Products

The results of this study will be documented as shown in Table 4-4.

4.5 Investigating the Diagnostic Value of and Specifications for Multi-Modality Image Comparison and Analysis

Each medical imaging modality is particularly well suited to highlighting specific structural and functional defects or diseases in human subjects. For example, ultrasound (US) clearly demonstrates tissue characteristics such as a solid mass versus a fluid-filled cyst. Sonography is particularly useful for demonstrating motion abnormalities as in echocardiography of the various heart valves. CT is especially well suited for the production of sequential, high resolution full-body cross-sectional images. MRI demonstrates detailed structure while at the same time indicating molecular make-up. Ultrasonic images are based on the body's properties with respect to high frequency sound wave

TABLE 4-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR PC-BASED WORKSTATION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on results of interface model of user interfaces		X	
Report on workstation evaluation results		X	
Report integrating the results for use by the Army	X		

transmission and are analogous to sonar. CT is based on the characteristics of X-ray transmission through the body. MRI determines structure based on atomic orientation via measurements of applied electromagnetic fields.

In specific instances, there appears to be tremendous diagnostic potential in collectively interpreting multi-modality images of specific human anatomy. Although each image can be interpreted on an individual basis as presently done, the need exists for a straightforward technique of performing comparative analyses. Ideally, the results of such an analysis could be summarized in a single image.

Objectives

The five objectives of this investigation are to:

- Determine if there is a consensus in the medical community that multi-modality image comparison would have significant diagnostic value, based on present techniques of image-based differential diagnosis
- Determine whether existing imaging devices provide sufficiently precise operator control over anatomical image location to permit multi-modality comparisons
- Determine if existing multi-spectral image analysis algorithms are applicable to medical multi-modality images
- Develop graphical/image processing techniques for comparing images and generating a summary image depicting the key features of diagnostic value
- Evaluate the feasibility and performance of multi-modality imaging from a clinical viewpoint

Summary of Approach

This study will poll a sample of radiologists and survey relevant literature to determine whether there is a consensus that multi-modality image analysis has diagnostic value and whether computer-assisted techniques for image analysis would be desirable.

The second step in this investigation will be to determine whether commonly used imaging modalities provide the operator with sufficiently precise control over an image plane to enable accurate inter-modality image comparisons. For example, in attempting to compare kidney images produced by two different techniques, it is essential that resultant images depict precisely the same anatomical structures. Unless a sufficient image base already exists to support a conclusive determination, sample images must be collected and evaluated. The use of a phantom test subject should produce the most quantitatively precise results.

The third step is to review multi-spectral image processing techniques such as those used in LANDSAT image processing to determine their applicability to multi-modal imaging in DINS. If it appears that these techniques are viable, experimental image processing software will be developed to illustrate some of the possibilities. This software will be installed on one of the DINS workstations for evaluation.

The fourth step will be to develop graphical/image processing techniques for feature extraction and image comparison. Presuming that multi-modality images of precisely identical anatomical structures are obtained, the images will probably not possess the same scale. A means must be developed to appropriately scale each image to achieve precise overlay registration. The ability to accurately overlay images will enable image comparison on a pixel by pixel basis. Should images possess varying degrees of distortion, techniques will be developed to allow for reasonably precise image overlay. This system must provide standard image processing capabilities and should allow for comparison of both processed and raw images.

This system must have manipulative capabilities for a straight visual analysis by the radiologist (such as transparent image overlay) and for mathematical analysis (such as algebraic addition or a Boolean combination of two images). The aim will be to produce a summary diagnostic image showing the features of interest as determined from both visual and computer-assisted analysis. Engineering and medical personnel will work closely together to ensure essential system capabilities.

Finally, this study will compare results as measured by radiologists' differential diagnoses based on conventional analysis techniques versus the use of this semi-automated system.

Summary of Data Collection Requirements

This study will require a literature review and a sampling of opinions of the radiologists associated with this project. Outside radiologist consultation may be obtained as deemed necessary.

Data for the second step of this investigation will consist of both human anatomic and phantom images to determine and verify positional image precision. Phantom image analysis should produce the most precise quantitative results, while comparison of anatomic images (unless from a cadaver) will produce results with less quantitative certainty.

During the third step of this study, results reported in the literature from implementation of and experimentation with LANDSAT techniques, will be examined.

In the fourth step of this study, the data will include sample raw and processed multi-modality images to assist in the development and evaluation of the required software and techniques, and composite images consisting of extracted features deemed of diagnostic value.

In the last step of this study, two sample groups of radiologists will be asked to make differential diagnoses based on sets of images they are given. One group will be asked to make diagnoses using multi-modality images in conventional formats. The other group will evaluate the same data using this semi-automated system. While accuracy of diagnosis is the ultimate measure of success, other factors such as speed of arriving at an accurate diagnosis will also be monitored.

Deliverable Products

The results of this study will be documented as shown in Table 4-5.

4.6 Investigating the Requirements for Building a Radiology-Oriented Decision Support System Suitable for Use in Combat Casualty Care Situations

Decision support systems are intended to supplement the skill of lesser trained individuals who must nonetheless make important decisions in situations where "experts" are not immediately available (e.g., in combat casualty care situations near the front). In such situations, decision support systems serve as a kind of automated consultant, posing questions, offering hypotheses, identifying key uncertainties, and suggesting plausible conclusions based on available evidence. In educational settings, they can serve a valuable role as a teaching device for students grappling with training cases. Decision support systems can also be used to "streamline" the performance of experts themselves (e.g., by anticipating requests based on past preferences and having appropriate information available upon request).

Several decision support and expert systems have been developed in medical care in recent years (e.g., MYCIN, CASNET, INTERNIST, IRIS). These systems codify knowledge that physicians apply to a diagnostic problem, making this knowledge available to non-expert diagnosticians in automated form. Existing medically-oriented decision support systems have achieved promising successes, but most rely on readily measured, comparatively unambiguous information on the patient such as history, presenting complaint, test results, signs, and symptoms.

TABLE 4-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR MULTI-MODALITY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of investigation and test effort	X		

In diagnostic imaging, information is primarily visual in nature. Patient history and presenting complaint provide useful information, but the principal task is interpreting images properly. As rapid improvements in imaging technology continue, the need for "diagnostic support assistance" will proliferate. This is particularly likely outside major medical centers and in casualty care situations.

A decision support system could be employed to step the health care provider through an interpretation session, automatically suggesting possible image enhancements based upon suspected pathology, anatomical area, and other pertinent information developed during the image reading process. For example, if a suspected soft tissue trauma is being displayed, the system could automatically suggest invoking window-width and level adjustments. Or, if a hairline fracture is suspected, edge detection could be automatically suggested. These automated prompts would provide the user with the best possible image display while relieving him of responsibility for tedious experimentation and the need to understand complex image enhancement algorithms.

Objectives

The five objectives of this project are to:

- Identify key information used in making a diagnosis from an important class of radiological images
- Identify and compare likely methods for developing a diagnostic decision support system suitable for radiological images
- Determine the image processing techniques likely to be especially useful in connection with common pathologies, concentrating on those likely in combat casualty care situations
- Develop, implement, and test a prototype DINS diagnostic decision support system for use in connection with an important class of radiological images
- Test this system on a sample of military health care providers and/or medical students

Summary of Approach

This project will proceed in five steps. The first step is to select a subset of plain film X-ray exams for analysis. This subset will be chosen to provide a range of diagnostic possibilities while being sufficiently narrow in scope to permit useful results. Cases which appear to meet these tests involve normal anatomic variants in bone and non-displaced bone fractures of the extremities, among others.

Second, working with an experienced Board-certified diagnostic radiologist with significant teaching responsibilities, the mental processes a diagnostician goes through to arrive at his findings will be codified. This codification will proceed on an iterative basis. Software/knowledge engineers will work with the diagnostician to codify diagnostic strategies on paper. These strategies will be reviewed for accuracy and completeness by the diagnostician/engineer team and subsequently refined. This process will be repeated until all concerned believe the correct, complete description of the diagnostic process has been developed.

Third, approaches to implementing a diagnostic decision support system will be compared in terms of their applicability to radiological diagnosis. At the same time, an assessment will be made of available hardware and software options to determine the combination best suited to the project's technical requirements. Appropriate image enhancement algorithms will be identified for incorporation into the system, based on the results of other tasks in this section.

Fourth, codified diagnostic knowledge will then be programmed, and tests performed using sample cases and medical students with appropriate levels of experience. These tests will:

- Teach the medical students how to use the system
- Present a sample of cases with known findings to the students that they are to diagnose with the help of the decision support system
- Document their experience on each case
- Assess the accuracy of results achieved by matched groups of users with and without the decision support system

Finally, the results will be used to evaluate the strengths and weaknesses of the test system, the lessons learned in the project, the potential applicability of the decision support systems approach to diagnostic imaging, particularly in combat casualty care situations, and the next steps to be taken.

Summary Data Collection Required

Indicated above.

Deliverable Products

The results of this study will be documented as shown in Table 4-6.

TABLE 4-6
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR EXPERT SYSTEM STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the results of the investigation	X		

5.0 STUDIES FOCUSSED ON THE NETWORK PERFORMANCE AND ARCHITECTURE OF THE DINS PROTOTYPES

This section describes proposed studies concerned with the capacity and performance of each prototype DINS from a communications network standpoint. The term "communications network" is defined broadly in this document. It includes all hardware, software, and data communications links involved in DINS operation in a fixed facility. It also includes the overall system architecture organizing these elements. Figure 5-1 highlights the communications network. Included in this section are studies with the following purposes:

- Assess the overall efficiency and effectiveness of the system architectures employed by the two prototype systems
- Investigate requirements for integrating the RIS or HIS with the DINS
- Model the DINS network under various operating conditions and assess the overall system efficiency of the two prototypes
- Examine the requirements for communications links between two or more DINS, and between a DINS and other non-DINS image processors
- Examine methods for linking a teleradiology system with the DINS
- Investigate the impact of image compression techniques on the DINS

Each of these studies is described in the following subsections.

5.1 Assessing the Overall Efficiency and Effectiveness of the System Architectures Employed by the DINS Prototypes

The DINS will store medical images from a variety of sources. The volume of data to be stored in an easily accessible manner will grow rapidly. This is particularly true if the DINS is installed in a large radiology department with full diagnostic imaging capabilities. The amount of data that can be processed and the speed that it can be handled are a function of network architecture in large measure. The term "network architecture" means the physical or hardware structure of computer-based networks and the attributes of the various components thereof, including how these components are interconnected.

Components usually considered in connection with a system's architecture are the storage system, processor units, input/output devices, and data communication devices. The DINS prototypes have

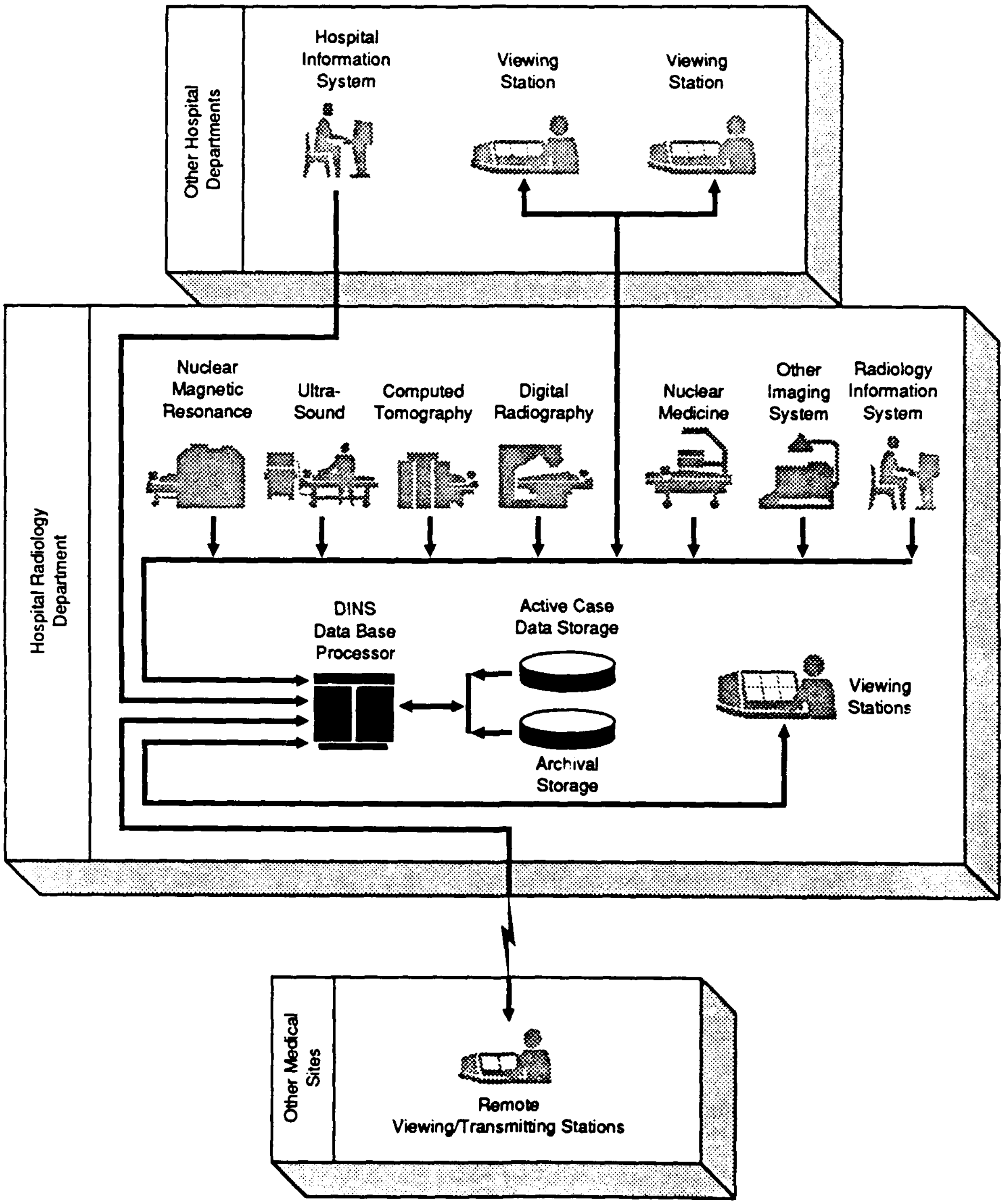

FIGURE 5-1
DIGITAL IMAGING NETWORK HIGHLIGHTING THE NETWORK

somewhat different network architectures. This affords an opportunity to evaluate the two architectures on a comparative basis with respect to overall efficiency and effectiveness.

Objectives

The seven objectives of this study are to:

- Assess each of the two prototype DINS network architectures from an efficiency and effectiveness viewpoint, given overall DINS objectives
- Determine the maximum reliable data throughput of each of the DINS prototypes under prescribed conditions
- Assess the adequacy of these throughputs for full-scale DINS implementation
- Compare this capacity with conventional archive methods for both films and digital images at each university site
- Forecast the probable growth in data storage requirements, based on project experience, and resulting architecture and capacity needs
- Develop system design recommendations for future DINS network architectures
- Determine the archival capacity of each prototype system in terms of storage volume and throughput in a busy hospital environment

Summary of Approach

A detailed analysis of the DINS network traffic will be performed at each site to determine maximum throughput, average workloads, and peak workloads. First, the image data volumes for each storage level will be estimated from the volume processed by the current film-based system. This actual storage volume will be incorporated into a network model used to determine the requirements of the full scale DINS. Second, the image data volume actually used in the fully operational DINS will be recorded. The image data volume distribution for each image generating modality will be recorded and studied. Third, the estimation model will be revised to reflect this data.

Fourth, experiments will be conducted with varying network loads and with varying loads across key network bridges. The results will be used to determine how close the prototypes come in practice to their theoretical maximum performance. Alternative architectures will also be modeled, if time and resources permit, to permit comparisons with the prototype systems. Test equipment provided by MITRE and the universities will be used to gather network traffic information.

Fifth, equipment and traffic management techniques not in use in the prototype DINS will also be studied to determine their appropriateness for a DINS. This study will incorporate the results of each of the other studies described in this section.

Sixth, testing scenarios will be developed to establish the limits of the ability of the prototype archive systems to store and retrieve images under various workloads. This will help determine the maximum number of disk drives that can be attached to the archive system bus, and thereby the maximum capacity of the DINS archive under specified conditions.

Finally, based on project experience and reviews of available literature, improvements to the DINS architecture or entirely new architectures will be hypothesized, modeled, simulated, and tested to develop higher throughput, higher capacity, higher reliability architectures for DINS. The proposed architectures will be derived from the results of this review and from those of the other archive studies.

Summary of Data Required

Data required for this study will be gathered during each of the other studies described in this section. In addition, all recent literature on image-based networks will be reviewed. Data describing the physical properties of the archive system components will be provided by the vendors. The baseline studies will provide data to aid in generating stress tests that are representative of the peak demands likely to be faced.

Deliverable Products

The results of this study will be documented as shown in Table 5-1.

5.2 Investigating the Requirements for Integrating a RIS or a HIS with the DINS

The information on patients normally carried by an automated RIS or HIS should be integrated with the patients' images so the two kinds of information can be viewed together by DINS users. The integration of an existing RIS or HIS with the DINS prototype at each site can pose system design and implementation issues of importance. The inclusion of digital

TABLE 5-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR SYSTEM ARCHITECTURE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of simulation models	X	X	X
Results of throughput studies		X	X
Recommendations for DINS architecture	X	X	X
Report synthesizing results for use by the Army	X		

image information in a medical record of a patient may require modifications to the interfaces between a RIS and its associated HIS and the RIS-RIS interface when patient information needs to be transferred among facilities (e.g., between a military and VA hospital).

This study identifies interface issues between RIS-DINS, RIS-RIS, and RIS-HIS. The relationship of these interfaces (or interface protocols) to the layers of the International Standards Organization (ISO) protocols and to various national standards (e.g., American College of Radiology/National Equipment Manufacturers Association (ACR/NEMA) standard) is also the subject of this investigation.

Objectives

The six objectives of this study are to:

- Determine the interfaces between the RIS and the DINS which should be automated from the user viewpoint
- Determine the necessary interfaces between a RIS at one site and a RIS at another site
- Determine the necessary interfaces between a RIS and a HIS in relation to the DINS
- Determine aspects of control which should reside with the RIS and aspects which should reside with the DINS to maximize system usability and efficiency
- Determine the security measures needed to ensure both appropriate system access and confidentiality of patient information
- Build and test the appropriate interfaces using the prototype DINS as a test bed

Summary of Approach

In the case of Georgetown University, the RIS system is an in-house developed system using the MUMPS dialect MIIS (Meditech, Inc.) and the DINS is designed and implemented by AT&T. At the University of Washington in Seattle, the RIS system is DECRAD from Digital Equipment Corporation (DEC) using ANSI MUMPS and the DINS is designed and developed by Philips/ Raytel. The communications linkage between the RIS and the DINS involves dedicated bidirectional lines (e.g., serial RS 232 full duplex lines). At least initially, these linkages may include a small computer (e.g., IBM PC) to provide protocol conversions. The following steps will be taken.

First, this study will explore issues related to the transfer of medical records information from one radiology department to another with special consideration to the transmission of digital image information. The study is limited to the exploration of issues, not the setting of standards. A survey of existing work in transmitting medical records information, ongoing efforts in the standardization of the medical record, perhaps even in related medical specialities (e.g, laboratory medicine) is contemplated. Since a VA hospital is a likely candidate for the receipt of medical records from a military hospital, the radiology system of the VA will be studied in some detail.

Second, the RIS-DINS interface will be invesigated. This interface is at the lowest level of integration difficulty. Its design and construction depends crucially on the mode of integration of the DINS with the RIS. If the DINS is tightly coupled with the RIS (i.e., the RIS and the DINS share the same computer system), the RIS and DINS communicate internally. Their interface resembles the intermodule communication of a RIS (e.g., scheduling, film library, reporting, billing, etc.), in that the interface protocol exists but is implicit in the software architecture of the RIS. Initially most DINS systems will probably be loosely coupled with a RIS, since the imaging and patient data management technologies are quite different and the two kinds of systems are usually implemented by different vendors. Vendors with expertise in imaging technology usually do not have the operational and clinical experience of RIS vendors. Conversely RIS vendors do not typically have the experience in imaging technologies.

The next step acknowledges that each RIS is (or soon will be) part of a HIS. The communications interface between the two systems depends on the type of HIS. In a centralized HIS, the communication will be with a mainframe computer system through which all information passes. In a decentralized HIS, the communication may take place among several HIS subsystems (e.g., laboratory, cardiology, pharmacy, library, etc.). The digital image information generated by the radiology department and its distribution to various users in the hospital will significantly impact the design of the communications system within the hospital. This study will identify areas of impact and the architectural consequences that digital image networks will force upon the next generation of hospital information systems.

Fourth, after the RIS has been interfaced with the DINS prototype at each site, communications traffic between the RIS and the DINS will be analyzed to determine the volume and nature of data transfers. Users of both systems will be queried about their experiences with the system, the problems they have experienced, and the solutions they recommend. Based on an analysis of these data, alternative strategies for integrating the

RIS with the DINS will be developed, highlighting the strengths and weaknesses of each strategy in representative hospital or combat casualty care contexts.

Finally, insofar as system security is concerned, it is presumed that the RIS will serve as a link between the DINS and the HIS. Thus, it will be necessary to evaluate overall system information flow and user requirements to determine appropriate system access and security mechanisms.

Summary of Data Collection Requirements

Four kinds of data will be collected for this study:

- Traffic statistics between the RIS and DINS
- Minimum and ideal data sets needed to link information systems
- User and administrator comments and recommendations based on their experiences and needs
- Ideas from the relevant professional literature

Deliverable Products

The results of this study will be documented as shown in Table 5-2.

5.3 Modeling DINS Networks

The DINS must feature high capacity communications media handling very large peak loads. This is particularly true in radiology where peak workload periods require the transmission of many patient "file folders" containing multiple image files.

The performance of the network (i.e., its speed and the amount of data it can process) is closely related to network architecture and protocols. Network architecture includes the physical components such as storage devices, processor units, the input/output portion of devices attached to the network, and data communications devices. Network protocols are the embedded rules that control the mechanics of data transfer. Permutations of alternative protocols and architecture can produce substantial differences in network performance.

The two prototypes currently being investigated have different network architectures. This offers an opportunity to explore network capacity issues and to evaluate the overall efficiency of both systems on a comparative basis. In addition, it is desirable to simulate a DINS

TABLE 5-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR RIS/HIS STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of interface investigation with AT&T prototype			X
Results of interface investigation with Philips prototype		X	
Summary of results for use by the Army	X		

network as a means of extending the analysis further than the capabilities of the two prototypes permit. Network simulation is the subject of this study.

Objectives

There are four objectives of this study:

- Determine key network parameters (e.g., data throughput, waiting time, error rates, etc.) for assessing network performance at various system loads
- Assess the performance of the two DINS prototypes against overall DINS requirements
- Develop analytical and simulation tools to conduct theoretical comparisons of alternative network architectures
- Estimate the implications for future DINS network architectures posed by combat casualty care

Summary of Approach

During the first step in this study, a detailed analysis of the DINS prototype will be conducted at each site. Its purpose will be to develop statistics concerning average and peak load error rates, queue times, and related statistics characterizing network performance. The statistics regarding network usage will be collected by network monitors installed in the prototype DIN systems. These statistics should be extensive and include but not be limited to error rates, service times, service request rates, and the like. It is expected that the network monitor will either be incorporated into the network controller or into PC-based monitors located on the network as appropriate.

Second, experiments will be conducted to determine the maximum throughput and to assess how closely actual network performance approaches theoretical performance.

Third, a network model will be developed to allow evaluation of alternative architectures and protocols. This network model will simulate network configurations deemed promising, and will permit sensitivity testing (i.e., determination of ways in which overall network performance varies as key network characteristics are varied).

Finally, the role and functioning of DINS in support of combat medical care will be simulated. The objectives of this effort will be to develop insight into the requirements that combat medical care will levy on the DINS network and to estimate the most promising architectures for meeting these requirements.

Summary of Data Required

Two types of data will be collected:

- Various network modeling methodologies (e.g., SLAM II) will be examined to determine their suitability
- A literature search will be conducted on various network protocols and architectures

Deliverable Products

The results of this study will be documented as shown in Table 5-3.

5.4 Investigating Internetworking Requirements among DINS and Non-DINS Networks

The attractiveness of a DINS to a hospital is enhanced if it can communicate electronically with other systems at geographically distant sites. This is especially true for large hospitals serving as a hub for a regional medical network, or for military hospitals which can expect to serve analogous functions in combat casualty care situations. Future DINS should be able to communicate with other DINS, sharing data with non-DINS networks. Such a capability should become more important as the field of digitally-based medical imagery grows. This study is concerned with identifying the requirements for internetworking.

Objective

The objective of this study is to determine the hardware, software, and network management requirements of links between the DINS and other digital imaging systems.

Summary of Approach

This study will investigate the above requirements in detail sufficient to provide design specifications for gateways, using the two prototypes as test cases. First, it will investigate the requirements for special protocols within the DINS (e.g., the ISO Internet Protocol, ISO Transport Protocol) that can simplify gateways. In the case of gateways employed by the two prototype systems, the study will analyze the effectiveness of their integration with the two DINS prototypes.

TABLE 5-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR NETWORK MODELING STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of simulation studies focussed on AT&T system architecture			X
Results of simulation studies focussed on Philips system architecture		X	
Results of simulation studies focused on DINS in support of combat medical care	X		
Results of architecture studies and recommendations for the future	X		

Second, the study will identify media access methods and protocols used in the two prototypes and in non-DINS networks that could either be used to convey inter-DINS traffic or to contain hosts that require DINS data. Appropriate literature will be reviewed. Finally, the activities of ACR/NEMA Working Group Eight, considering issues of relevance during the course of this project, will be monitored.

Summary of Data Collection Requirements

Data to be collected include:

- Results of literature reviews
- Simulation study results from Study 5.3
- Evaluation results from Studies 5.1 and 5.2

Deliverable Products

The results of this study will be documented as shown in Table 5-4.

5.5 Teleradiology and the DINS

Closely related to the prior investigation is a study of possible linkages between the DINS and remote locations using teleradiology. Such links would allow one or more remote medical care sites to draw upon the resources of a major DINS-equipped center, by sending case images to such centers, and receiving such images and related information from such centers.

Among the special requirements of this link is its ability to function in an "emergency" mode. In this mode, the emergency case (including images and patient data) being sent from the remote site to the central hospital for interpretation would automatically move to the head of a queue containing cases of lesser priority.

Objective

The objective of this study is to investigate techniques for transmitting and receiving images and supporting patient data to and from the DINS using teleradiology in a field environment.

Summary of Approach

At the University of Washington site, images will be transmitted from a remote site at Sitka, Alaska to the DINS at University Hospital. Using the DINS, the images will be stored in the archive and then retrieved by a radiologist at a workstation for diagnosis. To meet study objectives,

TABLE 5-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR INTERNETWORKING STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of internetworking investigations together with recommendations	X		

data on the speed and reliability of the teleradiology link will be gathered, including transmittal speed and degree of preservation of the diagnostic quality of an image. The ability of the teleradiology equipment to work in an integrated fashion with the rest of DINS, particularly in emergency mode, will also be evaluated.

Summary of Data Collection Requirements

This study will gather information on data transfer protocols, gateway specifications, and communication protocols allowing the DINS to receive and process information produced by equipment designed and/or manufactured by non-compatible teleradiology systems.

Deliverable Products

The results of this study will be documented as shown in Table 5-5.

5.6 Investigating the Impact of Image Compression Techniques for Radiological Images on the DINS Network

Data compression encodes a set of data such that a smaller set of data is obtained. The smaller data set represents the original and allows for the reconstruction of the original data. Since the quantities of image data are very large in the DIN environment, techniques for data compression to minimize the burdens of storage and transmission are important. A 1024 x 1024 x 8 digital image represents a megabyte of data, and the DINS requires transmitting, displaying, and storing many such images.

The size of typical radiological images in the DINS ranges from 256 Kbytes to in excess of 2 Mbytes. Since the bandwidth of a communications network in the DINS prototype is fixed, the maximum amount of data that can be sent over the channel is also fixed. This places a limit on the number of images that may be transmitted over the network in a given time. The effective channel bandwidth can be increased without changing the physical bandwidth by reducing the size of each image. This reduction can be achieved through image compression.

From a network perspective, compression techniques can greatly benefit the DINS through reduction of system response time. The response time of the system is the time required to extract an image from the data base, transmit it across the network, and perform the necessary decompression of the image for display. In order for DINS to be acceptable to radiologists, the response time of the system must be short enough to be interactive. By performing compression, the extraction and transmission times are reduced at the expense of increasing the

TABLE 5-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR TELERADIOLOGY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results on the network implications of teleradiology experimentation		X	

reconstruction time. Thus, an image compression scheme that has high compression ratios and short compression/reconstruction times is highly desired.

There are two main categories of image compression algorithms:

- Those that code the image data so that an exact reconstruction of the original image can be obtained (i.e., "lossless" or "noiseless" compression)

- Those that allow a mathematically imprecise reconstruction of the image such that visual degradation is possible (i.e., "lossy" or "noisy" compression)

The first group of algorithms permits no image degradation, but at the cost of offering comparatively little image compression. The second allows error in the compressed image, but offers greater compression. If an algorithm from the latter group is properly designed and "tuned" to the type of image to be compressed, compression errors may not be visible.

A term often used to describe the amount of compression that an algorithm can provide is the compression ratio (CR), expressed as:

$$CR = \frac{\text{Number of bytes in the original image}}{\text{Number of bytes in the compressed image}}$$

The higher the CR, the more compression. The more compression, the lower the communications bandwidth and storage space required. However, greater compression tends to increase processing time, which, in turn, affects the time required to retrieve, transmit, and display images. Additionally, as compression increases, the quality of the reconstructed image eventually becomes unacceptable. The most important consideration is the choice of encoding techniques which will reduce the data subject to the constraint that diagnostic information be preserved. The trade-offs among compression ratios, storage requirements, image quality, image content, display time, and communication bandwidth requirements are illustrated hypothetically in Figure 5-2.

Objectives

The three overall objectives of this study are to:

- Develop criteria for evaluating the performance of compression algorithms as applied in radiology

- Determine which algorithms are best suited to the different types of radiological images and what compression ratios are achievable by these algorithms

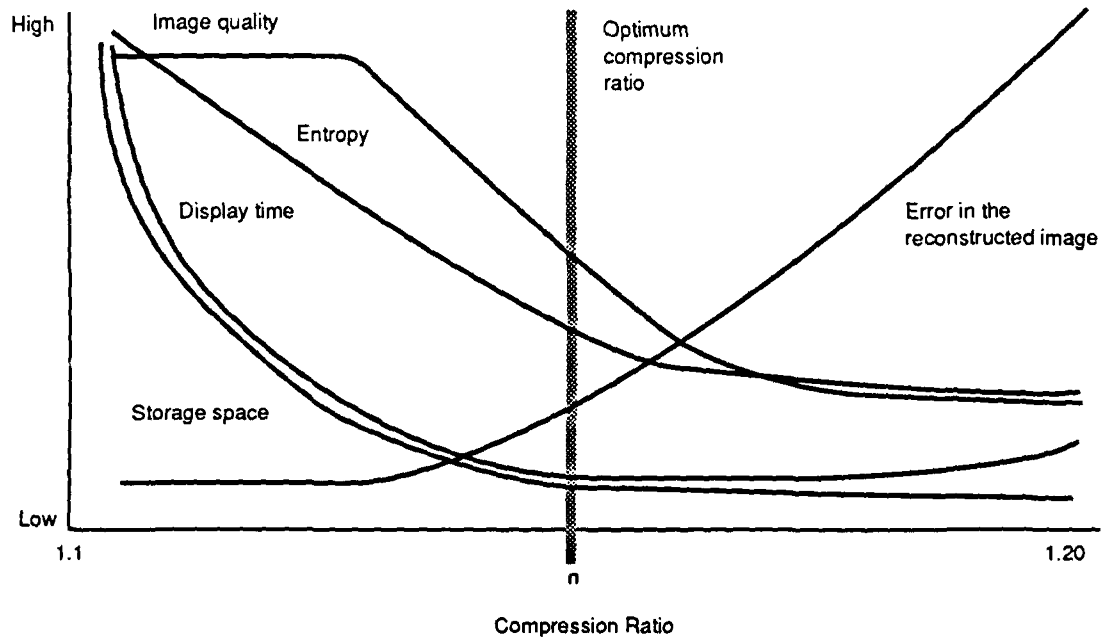

FIGURE 5-2
COMPARISON OF FACTORS INVOLVED
IN IMAGE COMPRESSION USING HYPOTHETICAL DATA

- Perform a comparative analysis of several compression algorithms, representative of the various types that exist in the literature and in industry

Summary of Approach

The data compression requirements for the DINS can be expected to vary, depending on the function. For example, one compression method might be used for image transmission, another for long-term archiving, and a third for medium-term storage. At the outset, this investigation will select representative images from different medical imaging modalities (e.g., plain films, CT, NMRI), and several types of images from a given modality (e.g., digitized X-ray films taken from different regions of the body). These images would be used as test cases for various lossless and lossy compression algorithms.

Second, to evaluate different compression algorithms using these test images, software will be generated to implement the algorithms (including both the image compression and reconstruction phases), to measure the error between the reconstructed and original images, and to measure key characteristics and properties of each type of image. There are many factors that are important in evaluating compression schemes. The following list will be used as a guideline for evaluating different methods for use in DINS environments:

- What is the expected average compression ratio? The higher the compression ratio, the lower the disk space required for storage and the time needed for transmission.

- Does the algorithm operate equally well on images from different imaging modalities? It may be necessary to encode images from different modalities and different clinical areas using different compression techniques.

- How susceptible is the method to errors in storage and transmission? Some compression techniques are extremely vulnerable to errors. A soft error is an error in reading or transmitting the image. If a soft error occurs, it should be detected and corrected by the network communication protocol. Of greater concern is the possibility of a hard error--a physical deterioration of the data on the storage media. These errors may be detected with a Cyclic Redundance Check Character(s) (CRC) or checksum, but not necessarily corrected. A robust compression algorithm should limit the damage caused by an uncorrectable hard error.

- How complex is implementation in hardware? Although software is an excellent way to evaluate the effectiveness of compression algorithms, it cannot achieve reasonable compression and decompression times. Since any implementation of image compression/decompression in the future has to be done in hardware, the hardware complexity should be evaluated.

- Can the scheme compress and reconstruct images at an acceptable speed? Speed is by far the most important factor and is dependent upon both the achievable compression ratio and the hardware complexity. An image is compressed once before archiving. Once it has been placed in the image data base system in compressed form, it will not need to be compressed again. Therefore, the response time of the system depends on the decompression time which is usually less than the original compression time.

Third, experiments will be conducted to determine the response time of the system under varying loads for both compressed and normal images. Results obtained from the installed DINS workstations can be used even if the system is closed by extrapolating the results to different image compression algorithms.

Fourth, image quality will be evaluated by compressing and then reconstructing images using several representative nonrecoverable algorithms (e.g., nonrecoverable DPCM and transform methods such as fast Fourier, discrete cosine, and Hadamard). The error between the reconstructed image and the original image will be measured using such techniques as normalized mean square error.

Finally, experiments will be conducted to determine DINS response times under varying loads when both compressed and normal images are on the system. Results obtained from the prototype DINS workstations can be used even if the system is closed by extrapolating the results to different image compression algorithms.

Summary of Data Collection Requirements

Data required include digital images in both compressed and uncompressed form generated on each DINS prototype and on laboratory equipment at MITRE and the universities. Clinical and phantom images will be used in connection with each DINS system for comparisons.

Deliverable Products

The results of this study will be documented as shown in Table 5-6.

TABLE 5-6
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR IMAGE COMPRESSION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Reports on the impact of data compression on network performance	X		X

6.0 EDUCATION, IMPLEMENTATION, AND TRAINING STUDIES

Three issues in DINS education, implementation, and training require investigation. The first issue concerns how best to develop a cadre of officials within the Army that is knowledgable concerning DINS. Included in this cadre would be key officials from the Army Surgeon General's office, the USAMRDC, and elsewhere within DoD as deemed appropriate. Also included would be clinicians and hospital administrators at each Army medical center slated for acquiring a DINS (e.g., Madigan Army Medical Center). The intent would be to convey the specific knowledge required to lay the groundwork for a successful implementation.

The second issue concerns ways to assure effective user training materials, particularly those oriented toward radiological technicians. The third issue concerns developing procedures for using the DINS as a pedagogical device for clinicians and other DINS users. Accordingly, proposed studies discussed in this section will investigate the following subjects:

- Methods for developing a cadre of knowledgable clinicians and administrators

- The overall effectiveness of DINS user training materials

- Ways to exploit the use of DINS as a teaching device for radiologists

Each of these studies is described in the following subsections.

6.1 Developing a Cadre of Knowledgable Clinicians and Administrators in a U.S. Army Medical Center to Promote Effective DINS Implementation

Current plans developed by the USAMRDC include the installation of operational DINS in a U.S. Army Medical Center as soon as feasible after completion of the current DINS prototype project. Because the technology underlying the DINS is both new and complex, the system's functioning must be well understood by those who must implement the DINS in their radiology departments. A staged learning process, in which key Army staff are exposed to DINS technology and functioning during the prototype project, is highly desirable. In this process, key research administrators, hospital managers, and clinicians would learn the capabilities, strengths, and weaknesses of the DINS in operation over a period of time. This approach will allow full understanding of DINS concepts and procedures by key personnel who will be responsible for both procurement and implementation.

As the DINS is discussed and demonstrated, it is expected that key staff from the Army hospitals and elsewhere will raise questions and issues resulting in improved DINS design and operation. In this way, the project team will draw upon the insights of potential DINS users at a point in the development and evaluation cycle when these insights can be used effectively. This study is concerned with maximizing the value of this structured, two-way communication process in smoothing the implementation of DINS.

Objectives

This study has the following three objectives:

- To develop a body of study materials, including a video tape for general audiences, for use in teaching DINS technology, functions, strengths, and weaknesses at a level appropriate to the needs of senior clinicians and radiology department administrators in U.S. Army medical centers

- To develop a curriculum and schedule for an appropriate mixture of tutorials and demonstrations of DINS prototypes in operation at Georgetown/George Washington Universities or the University of Washington that is suitable for the target audience

- To conduct the necessary educational programs at the appropriate site(s) over the course of the current prototype project

Summary of Approach

These objectives will be achieved in the following steps. First, each university site will designate a Coordinator of Education responsible for coordinating all educational activities involving key staff from the Army medical center nearest the university. Second, working with appropriate university staff, the Coordinator will assemble such tutorial materials as needed to provide an effective view of such subjects as the following:

- The overall objectives of DINS as an integrator of digital and non-digital imaging in medical care

- The technology underlying digital imaging networks

- The technical requisites for installation of a DINS in a moderate-sized hospital (e.g., location, floor space, cabling, electrical power links, maintenance, communications links)

- Strategies for implementation of a DINS
- The strengths and weaknesses of the DINS in operation and promising ways to capitalize on the former while minimizing the latter
- The organizational and professional changes that can be anticipated in connection with DINS installation

Third, the Coordinator will develop a draft curriculum combining tutorial materials and site visits for use in educating key military staff concerning DINS. Fourth, given approval by the Army of this curriculum, the Coordinator will assemble the staff needed to carry out the curriculum, develop a schedule for all necessary activities, and, in collaboration with appropriate staff at the Army medical center in question, carry out this schedule. Tutorials and site visits should be combined effectively so that the most efficient use of time is achieved.

Summary of Data Collection Requirements

Data collection will be in the form of published materials from appropriate professional journals, books, and vendor literature. It is also expected that the universities will draw upon selected faculty members who are participating in the DINS project and who have developed course materials in connection with their normal teaching responsibilities.

Deliverable Products

The results of this study will be documented as shown in Table 6-1.

6.2 Improving the Overall Effectiveness of User Training Materials for the DINS

The better the training materials available to users, the more likely the DINS will be used to its full capabilities. Good user manuals and other training materials are especially desirable for military use, where training time and resources are limited, where the user community is especially heterogeneous and geographically dispersed, and where self-training materials are especially valuable. This study is concerned with the quality of training materials developed by the two prototype system vendors, and with ways to improve these materials for use in military facilities.

TABLE 6-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR EDUCATIONAL STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Introductory curriculum for all interested Army personnel	X	X	X
Curriculum for U.S. Army staff at Fort Madigan		X	
Curriculum for U.S. Army staff at Walter Reed Army Medical Center			X
Support in teaching and demonstration	X		
Video tape concerning DINS	X		

Objectives

The two objectives of this study are:

- Determine the usefulness of vendor-supplied training materials provided for clinical and non-clinical users of the DINS at each site
- Develop recommendations for improvements in these materials for future operational systems, particularly those related to combat casualty care

Summary of Approach

This study will take place in five steps. The first step will formulate criteria by which user's manuals and other training materials will be evaluated for their value to intended users. Second, the materials made available by each vendor will be inspected, judging the materials against the criteria. Third, interviews of a subset of clinical and non-clinical users will be conducted to determine their assessments of the strengths and weaknesses of the materials. Fourth, an experiment will be performed on a sample of new users to test their ability to perform key DINS functions based on use of the training materials alone. Finally, from these results, conclusions and recommendations will be developed concerning the form, content, and subject matter of training materials for use by military personnel dealing with DINS equipment.

Summary of Data Collection Requirements

Data required for this study falls into three categories:

- Assessments by project staff of the vendor-supplied training materials
- Interview results
- Experimental results concerning user proficiency

Deliverable Products

The results of this study will be documented as shown in Table 6-2.

6.3 Developing Ways to Exploit the Use of the DINS as a Teaching Device for Radiologists and Radiological Technicians

One routine use of DINS workstations should be to assist in teaching interns, residents, and radiological technicians. Since the prototypes will be located at teaching universities during the project, an

TABLE 6-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR TRAINING MATERIALS STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on user training materials provided by Philips		X	
Report on user training materials provided by AT&T			X
Summary evaluation and recommendations for the Army	X		

opportunity exists to make practical use of the equipment in this capacity. The DINS is especially attractive as a teaching mechanism. It can draw upon a wide variety of case materials and display them in many useful ways, all in a rapid, convenient fashion. The distributed functionality of the DINS allows concurrent diagnosis and instruction, thereby allowing teaching without interruption of, or interference with, normal care giving.

Objective

The objective of this study is to investigate ways to use the DINS prototypes effectively as teaching devices in hospitals.

Summary of Approach

A cooperative effort between physicians and imaging specialists will result in the creation of several teaching files containing representative medical images. The initial set of images will be selected to provide training in image interpretation. This training will differ from traditional techniques in that the DINS will be used to obtain the image and present it in a video format rather than on film. A by-product of this approach will be that the student will have to acquire a basic understanding of DINS technology. As the medical community develops more advanced diagnostic techniques, as facilitated by the digital image processing capabilities of DINS, such techniques can be demonstrated to the students as well. In this fashion, the DINS can be used by interested students as a research tool to develop digital diagnostic aids. A by-product of this training will be graduating medical students who are familiar both with DINS operation and with digital imaging and diagnostic techniques.

Since radiologist acceptance of digital imaging seems to increase when it is part of the medical education process, the creation of several graded teaching files could demonstrate additional uses of the DINS, increasing its value and acceptance. Medical students currently being trained at the two university facilities could use these interactive teaching files to compare film-based and digital imaging technologies in an educational setting. Such a comparison will be valuable to the student who may, in the near term, find himself having to defend the use of digital technology to established practitioners less willing to give up the film media.

Methods for training radiological technicians in the best ways to acquire digital images could be developed. Finally, the prototype systems can be used to expose military medical personnel to DINS technology prior to selection and installation of operational DINS at military hospitals.

Summary of Data Collection Requirements

No additional data collections are required, but teaching files based on existing cases processed through the DINS at each site would be needed.

Deliverable Products

The results of this study will be documented as shown in Table 6-3.

TABLE 6-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR TEACHING DEVICE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on teaching mechanisms and strategies based on experience with the Philips prototype		X	
Report on teaching mechanisms and strategies based on experience with the AT&T prototype			X
Summary report for use by the Army	X		

7.0 CLINICAL STUDIES AT GEORGETOWN/GEORGE WASHINGTON UNIVERSITIES

The capabilities of DINS prototype equipment delivered in Phase I of the project will differ from that of Phase II at Georgetown/George Washington Universities (see Section 3.2 "AT&T Deliverables" of the Management Plan). For this reason, network functioning, teleradiology, and archiving capabilities should be evaluated in Phase I. Clinical impact and image quality issues should be addressed in Phase II after prototype workstations are installed in final configuration. Since a laser scanner will not be available until Phase II, the multi-modality, clinical impact studies in Phase I will be based on digital modalities (CT, NMRI, US) utilizing a video signal-based image.

This section proposes the following studies:

- The acceptance and impact of DINS upon radiology subspecialty services
- The acceptance and impact of DINS-assisted radiology service on other clinical services in the hospital
- The acceptance and impact of the DINS electronic image archive as an alternative to film archive
- The role of hard copies in the DINS environment
- The reliability of DINS in operation

Each of these studies is discussed in the following subsections.

7.1 Assessing the Acceptance and Impact of DINS on Medical Subspecialty Services

The impact of DINS may vary among radiological subspecialties in the hospital. The primary radiology services that will use DINS at Georgetown University follow:

- Ultrasound
- Body imaging
- Neuroradiology
- General and pulmonary

All of the ultrasound images will be placed on the DINS network during Phase I of the study, so ultrasound may be the first service that goes 100 percent digital at Georgetown University Hospital. For body imaging and neuroradiology service, CT and MRI images are to be placed on the network. In Phase II, with the high resolution laser film digitizer, all chest and portable chest images will be placed on the DINS network. It is also anticipated that all the images for pediatric service will be placed on the network. Currently, nuclear images or Digital Subtraction Angiography (DSA) images are not scheduled to go on the network during this project. This array of interconnections between the DINS and various subspecialty services affords an opportunity to study the impact of the former on the latter.

Objectives

In each of the radiology services listed above, the following six objectives will be addressed:

- Determine the daily workload of each subspecialty in case images as a means to estimate the local data storage requirements for review and reporting at each of the various services
- Determine the user acceptance of "soft images" from DINS as compared with film-based images
- Test advanced image processing and display methods using the Pixar system
- Determine the most convenient methods for reviewing images, including images from the previous studies, using DINS workstations
- Determine multi-modality image display requirements as viewed by clinicians
- Rank order features of the DINS for reviewing and reporting purposes in terms of usefulness to clinicians

Summary of Approach

These evaluations will be carried out using interviews, selected results from the baseline studies (see Sections 3.1 and 3.2), time motion studies, comparative readings, manual and automated monitoring, and use rate measurements. Active participation from the clinical side of the radiology department is essential for the success of this study. Fortunately this participation can be relied upon throughout the study's execution.

The study will proceed according to the following seven steps. First, daily workload in terms of number of images and data volume will be measured using the existing RIS information and by monitoring activities at DINS workstations at each subspecialty location.

Second, a number of comparative readings with selected set of "hard" (film) images and "soft" (digital) images will be carried out to determine the acceptance of the image quality in each of the image modalities. A rigorous ROC analysis is outside the scope of this project, however. Instead, a specially tailored "consumer acceptance" survey will be employed.

Third, image processing and handling requirements will be determined first by analyzing the activities of radiologists at the alternators, detailing work volume and flow. Then, on each workstation, a number of radiologists will be trained for routine use of DINS workstations.

Fourth, careful and comprehensive interviews are planned to obtain t'.e image processing and handling capabilities for reporting and reviewing that are needed for DINS. Necessary versus desired features as viewed by radiologists will be separated.

Fifth, the Pixar system will be used to develop and test various ideas for rapid image handling and processing for use in conjunction with DINS workstations.

Sixth, the use rate and profile in each subspecialty service will be monitored to determine the frequency and volume of previous images to be viewed at DINS workstations. Efficient means of presenting the summary data on the previous studies made on given patient will be developed.

Finally, careful interviews will be conducted with radiologists and referring physicians to determine their views on negative and positive features of DINS from the users viewpoint as evident in each radiological subspecialty.

Summary of Data Collection Requirements

This study will require the following three kinds of data:

- Structured expert opinion
- Structured observation
- Use rate data

Deliverable Products

The results of this study will be documented as shown in Table 7-1.

7.2 Assessing the Acceptance and Impact of DINS Upon the Provision of Radiology Service to Other Medical Services in the Hospital

As radiological images are made available instantaneously on DINS workstations at strategic locations in the hospital, professional interactions between referring physicians and radiologists may change. DINS may enhance the role of radiologists in patient management in some cases. In others, it could have a negative impact. This study will examine potential changes in radiologists' relationship with referring physicians that are attributable to DINS, wholly or in part.

Radiological images from the DINS will be made available to a number of medical services throughout Georgetown University Hospital, including:

- The emergency room (ER)
- The surgical intensive care unit (ICU)
- The neonatal ICU
- The nuclear medicine unit
- The radiation oncology department

These services have been selected, in part, to provide comprehensive data on how DINS affects non-radiology services. In this way, the extra-radiology impact of DINS can be fully tested in a realistic way and in a variety of situations.

Objectives

There are three objectives for this study. They are to:

- Estimate the impact of DINS upon professional interactions between radiologists and referring physicians
- Monitor changes in the consultation patterns between radiologists and other selected hospital physicians
- Determine the technical, operational requirements of the workstations used by referring physicians as these relate to promoting improved consultation

TABLE 7-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR CLINICAL ACCEPTANCE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on impact and user acceptability issues			X
Report on suggested system requirements			X

Summary of Approach

It is important to test DINS utility in cases where there are many competing users for clinical images. Other hospital services are good arenas for assessing the use of DINS for the continuous monitoring of surgical cases. For intensive care cases, for example, the demand for images is high and accurate tracking of images is difficult. Activities in intensive care and the emergency rooms will provide a good testing environment for the ability of DINS to support consultation.

This study will involve three overall steps. First, carefully planned interviews of physicians participating on selected cases will be undertaken. These interviews will be used to gather their views on the successes and failures of consultation using the DINS. Second, these cases will be subjected to activity monitoring as they are carried out. In this way, the behavior of clinicians can be observed, showing what consultation is actually done on the target cases. Third, clinician surveys will be used to collect data on the consultative process so that clinicians can describe how they viewed the DINS-supported consultative process after they have had time to reflect on it.

Summary of Data Collection Requirements

This study will require the following kinds of data:

- Structured observation
- Use rate data
- Surveys of clinician perceptions and attitudes

Deliverable Products

The results of this study will be documented as shown in Table 7-2.

7.3 Assessing the Clinical Acceptance and Impact of the DINS Electronic Archive

An electronic archive of radiological images rather than a film library is expected to have a significant impact on the process of making radiological images available to physicians. With an electronic archive, images can be viewed at various viewing stations in the hospital or at workstations within the radiology department. A number of operational issues can affect the use of electronic archive. For example, the electronic archive can have a potentially important impact on quality of care providing images quickly for review by referring physicians on demand, as well as by radiologists.

TABLE 7-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR OTHER-DEPARTMENT STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the impact DINS has on consultation patterns among radiologists and other clinicians from outside the radiology department			X

Objectives

This study has three objectives. They include:

- Determine the full range of operational characteristics of the AT&T electronic archive from the clinical user's viewpoint

- Determine user acceptance of the electronic archive in terms of desired response time, ease of use, and other characteristics of importance to clinical users

- Determine the technical and operational requirements for successful electronic archives as viewed by clinical users

Summary of Approach

This study will involve the following steps. First, objective data defining "archive use rates" will be identified. Second, the required data will be collected using both automated system monitoring and interviewing. Third, a questionnaire will be developed and structured interviews will be conducted using this questionnaire. Fourth, over the project period, selected images will be identified from the film library and from the electronic archive that are representative of the cases likely to be requested from the archive by clinicians. Finally, questions will be posed to users concerning reasons they prefer to use one archiving system over the other.

Summary of Data Collection Requirements

The following data on the use of the electronic archive will be collected:

- Types of users

- Purpose of use

- Frequency of use

- Time of day of use

- Type of images requested

- Number of images requested

- Mode of image reviews

- Waiting time for requested images
- Scheduled versus "on-demand" use of the archive
- General degree of satisfaction with archiving access

Deliverable Products

The results of this study will be documented as shown in Table 7-3.

7.4 Assessing the Appropriate Role of Hard Copy Images in DINS Environment

In the DINS-supported radiology environment, photographic "hard copy" images made from digital images may not be generated routinely. The use of hard copy will continue in many cases, however, especially for large hospitals and for surgical cases. It is not economically feasible to have as many high resolution viewing stations as desired in place of light boxes. Clinicians will no doubt wish to have hard copy images available for the foreseeable future. The type of hard copy images required may vary depending on clinical needs. This study is concerned with assessing hard copy requirements in DINS environment.

Objectives

This study has four objectives. They are to:

- Determine the number of hard copy images needed for typical clinical workloads
- Determine acceptable image quality for hard copy images based on clinical needs
- Determine the technical acceptability of dry silver or other such technologies for making hard copies
- Determine the user profile for various hard copy requests

Summary of Approach

The following steps will be taken. First, various types of hard copy devices will be identified and tested using a number of different kinds of images for user acceptability. The users/evaluators will be referring physicians, surgeons, radiologists, and other specialists. Second, a set of test images of various modalities will be made into hard copies for technical acceptance evaluation. Image resolution, dynamic range, size,

TABLE 7-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES
FOR ARCHIVE ACCEPTANCE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the comparative acceptability of the electronic archive among users			X

and user friendliness will be measured analytically. Third, the demand for hard copies will be assessed during the course of the project, together with the reasons for this demand.

Summary of Data Collection Requirements

The following kinds of data will be collected:

- Performance data of hard copy production devices
- Attitude surveys concerning image quality
- Survey data on usage patterns

Deliverable Products

The results of this study will be documented as shown in Table 7-4.

7.5 Assessing Factors Affecting DINS Reliability

Since user acceptance and satisfaction are typically inversely related to poor reliability, it is important to assess DINS reliability during the project. Reliability factors means those events that contribute to down time of a DINS, lengthening of user waiting times, and image-related information inaccuracies.

Objective

The objective of this section is to investigate three user-related subjects bearing on the reliability of a DINS. These include:

- Percent down time
- User waiting time delays
- Information inaccuracy

Summary of Approach

The approach to this study is to utilize user-invisible software to monitor DINS down time and user waiting times after a request for images and/or other information is made. Text information accuracy will be determined by doing software comparisons of text fields at various points in the network.

TABLE 7-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR HARD COPY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the use of hard copy devices for possible use in connection with the DINS			X

Percent down time is defined here as the amount of time a particular piece of equipment is unusable divided by the total possible amount of time available for its use. First, percent down time will be calculated for each piece of equipment delivered by the respective vendors. This will permit a detailed analysis of weak points in the DINS and also permit researchers to account for any cumulative effects in down time (e.g., if a remote display station is not functional, is it because the remote display is not working or is it because the link between it and the archive is not working?). This information could also be useful for those modeling the network configurations chosen. It could serve as a means of verifying the accuracy of a model's ability to predict the effects of equipment failure on the network as a whole. Following is a partial list of devices that may experience down time and therefore will be monitored: display stations, acquisition nodes, data management systems, network communications modules, optical disc drives, optical discs, magnetic disc drives, and magnetic discs.

Second, pathways in the DINS that present "bottlenecks" in the flow of information will be identified, as will the time dependent nature of information delay. This will be done as a function of the DINS workload and integrity. Two operations that could cause unacceptable waiting times, for example, are sequential image acquisition and image retrieval from the archive. User-invisible software will be used to monitor waiting times.

Third, the frequency with which false or incomplete text information is delivered with test images requested by users will be estimated. Also, if the DINS under study handles images separately from text, the frequency with which no text accompanies an image will be determined.

Finally, a study will be made of the ease that a DINS user corrects a text error once discovered. Such errors might include incorrect spelling of the patient name, ID number, and/or other demographic information.

Summary of Data Collected

This study will require the following three kinds of data:

- Percent down time
- Waiting times
- Text accuracy

Deliverable Products

The results of this study will be documented as shown in Table 7-5.

TABLE 7-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR RELIABILITY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the reliability of the DINS prototype developed by AT&T			X

8.0 CLINICAL STUDIES AT THE UNIVERSITY OF WASHINGTON

This section describes the clinical studies proposed by the University of Washington. Clinical studies evaluate the performance of an integrated system from the standpoint of the clinically-oriented user. Generally speaking, the clinical studies seek to examine how well the DINS works in a hospital radiology department and to identify the operational strengths and weaknesses of the system from the clinician's viewpoint. As such, clinical evaluation of a system tends to be particularly sensitive to the "weak link" of a system. For example, if the system is slow at performing certain functions, it is difficult or even impossible to evaluate the clinical utility of these functions accurately.

The DINS to be installed at the University of Washington will be phased in over a year or more, and at full installation will not support fully digital departments. Clinical studies, therefore, will focus on carefully selected subsets of departmental activity. The activity being tested must be supported as fully as possible during the test. This means that system resources will be allocated differently during different periods of the clinical evaluation. For example, one workstation will be dedicated to emergency room and intensive care unit images during the studies described in Section 8.5. Using the network simulation studies described in Section 5.0, the clinical requirements identified for individual areas in Section 8.0 will be extrapolated to performance requirements for the entire department.

The clinical role of the DINS and user understanding of it will evolve with experience. Therefore, the studies actually carried out may diverge somewhat from those described here. For example, the answers to some of the questions posed here may be obvious to experienced users quite soon, freeing resources for evaluation of system performance in other areas. Finally, the plans expressed in this section anticipate equipment and levels of performance that may differ markedly from the actual equipment installed and operated. As such, some flexibility must be sanctioned to deal with these contingencies. Studies in this section include the following:

- Initial clinically-oriented characterization of system functions and performance
- Identification of clinical requirements for a DINS
- Development of a clinical evaluation methodology
- Evaluation of the DINS from a department-wide perspective

- Evaluation of the impact of DINS on the ER/ICU
- Evaluation of the teleradiology link

Each of these studies is described in the following subsections.

8.1 Initial User-Oriented Characterization of System Functions and Performance

A first step in assessing any system from the user's viewpoint is to "exercise" the system to determine its capabilities and possible shortcomings. This is especially important when the system performs previously unfamiliar functions, as the DINS prototype will. This study "exercises" the DINS prototype in a structured fashion.

Objective

The single objective of this study is to obtain a description of the DINS from the health care provider's point of view.

Summary of Approach

This phase of the study will be carried out in conjunction with the studies in Section 5.0. In contrast to Section 5.0, however, the performance of DINS is described as the user from the health care community sees it, rather than breaking performance down into the performance of the individual system components. Both performance measures and the suitability of the user interface will be assessed.

System performance will be measured by trained users of the system equipped with stopwatches. Times will be expressed as mean times (+/- standard deviation) to perform each of the tasks described above. It is recognized that the time to perform certain tasks (for example, accessing the archive) may increase as the number of archived images grows and/or system traffic changes, and so appropriate performance measures will be repeated under different conditions of network, workstation loading, and different numbers of archived images.

The user interface will be evaluated through structured interviews. Interview design will be coordinated with Georgetown/George Washington Universities. Users will be classified according to level of present experience with digital image-viewing systems and some users may be interviewed twice, at the time of initial encounter with the system and after they have gained experience with it.

The evaluation will include both radiologists and non-radiologist physicians.

The user workstation interface will be evaluated with particular attention to the following:

- Ease that a particular study can be located using limited information (e.g., patient last name only) versus full information
- Ease that an inexperienced user can invoke basic workstation functions
- Ease that images can be selected for display on different screens
- Ease that a comparison of current radiological studies with old studies on the same patient can be made
- Ease that image processing functions can be invoked (including roam, zoom, edge enhance, video reversal, change level/contrast)
- Fault tolerance and ease of recovery from errors
- Quality of online help and the helpfulness of diagnostic messages

Network performance and integration will be clinically evaluated with emphasis on the following:

- Ease of entering images into the system
- "Transparency" to the user as far as the actual location of images (workstation, archive(s), date of entry stations, etc.) is concerned
- Ease of correlating RIS data and DINS images

These evaluations will be carried out separately for each of the workstations (e.g., remote monitor, diagnostic station) in the University of Washington system.

Summary of Data Collection Requirements

For each DINS workstation, the following performance data will be obtained:

- Spatial resolution, contrast resolution, refresh rate
- Time required to locate a study presentation in local storage and in the optical archive

- Time required to bring it to the screen as a function of image size, compression ratio, and the presence of other users--either on the network or at other monitors connected to the workstation

- Time required to change window/level, zoom

- Availability of specified types of image manipulation and time required to perform each

- Ability to rearrange images on the screen and the time required to do so

- Time required to locate examinations and reports using the RIS

- For the composing workstations, time required to fully enter images into the system, including interaction with RIS or other data base managers

Deliverable Products

The results of this study will be documented as shown in Table 8-1.

8.2 Identification of Clinical Requirements for a DINS

A second step in any acceptance evaluation is to poll the user concerning the usefulness of various system capabilities. This study conducts such a poll, determining the views of clinician/users concerning important DINS capabilities intended for radiologist use.

Objectives

The two objectives of this study are:

- To identify, by expert consensus, minimum standards for image quality in each of the major areas of radiology in preparation for the studies discussed subsequently in this section

- To estimate the need for multi-modality display and the number of images per study in each of the major areas

Summary of Approach

For the purposes of this section, the radiology department and the major clinical departments can be grouped into the following sections:

- Neuroradiology, neurology/neurosurgery/ear-nose-throat clinics

TABLE 8-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR USER-ORIENTED CHARACTERIZATION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Summary of DINS functions and performance as viewed by clinician/users		X	

- General radiology (plain film), pulmonary/cardiology/general medicine clinics
- Musculoskeletal radiology, orthopedics/rheumatology clinics
- Body CT/NMRI, radiation oncology, orthopaedics, rheumatology clinics
- Ultrasound, OB/GYN clinics
- GI/GU radiology, gastroenterology/urology/general surgery clinics
- Mammography
- Nuclear medicine
- ICU
- Teleradiology sites

For each of these sections, the study will define key requirements that the DINS must meet from the user's viewpoint. These will include, but not be limited to, the following:

- Average number of images required for a typical patient's study, including prior images
- Acceptable spatial resolution/compression/contrast resolution
- Perceived need for multi-modality display
- Required response time
- Perceived utility of available image manipulation techniques

These requirements will be developed with the help of experienced radiologists and other clinicians at the University of Washington. This study will also identify major system strengths/weaknesses so that the clinical studies described in Section 8.4 can be better planned. For example, certain clinical studies may be precluded or modified by the findings of this study. The goal is to attain a consensus on "acceptable" DINS capabilities (e.g, image quality, image manipulation tools) as judged by clinicians rather than to systematically vary resolution parameters in order to measure tradeoffs.

An expert user of the system will collect and enter appropriate test image sets into the archive and local workstations. In each area, 25 to 100 test images will be chosen to represent cases of both "typical" and "exceptional" difficulty. Images will be prepared with differing degrees of spatial/contrast resolution. Panels of experienced radiologists and clinicians will then view the images and their acceptance of the images will be recorded.

Generally, the radiologists participating in definition of requirements in a specific area will also be the radiologists evaluating system performance in Sections 8.4 through 8.6. As experience with the system accumulates, the requirements defined in this section may change. These studies will be repeated at the end of the evaluation period using the same sets of test images. Data on number of images per study will be obtained by a survey of current practices in each area. Evaluation methodologies will be developed in cooperation with appropriate staff at Georgetown/George Washington Universities. The final product will be a set of standards that define acceptable digital image quality in each major clinical area and an estimate of the number of images per study in each area.

Summary of Data Collection Requirements

This study will gather structured opinions from radiologists and other clinicians who must use the DINS. These opinions will deal with the items listed above.

Deliverable Products

The results of this study will be documented as shown in Table 8-2.

8.3 Development of an Evaluation Methodology

Objective

The objective of this study is to develop a "generic" set of evaluation tools that can be used in a variety of clinical settings to evaluate:

- Image acceptability/quality (compression, resolution, etc.)
- Utility and usage of available system functionalities
- User satisfaction with system performance in general
- Nature of deficiencies and suggestions for remedies

It is desirable for evaluation techniques to be as similar as feasible at the two sites. The breadth of this evaluation project requires the use of relatively simple evaluation tools, particularly

TABLE 8-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR CLINICAL REQUIREMENTS STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on perceived requirements for DINS operation as judged by clinician users		X	

questionnaires. These questionnaires should be as "universal" as possible, so that the same questions are asked in a variety of clinical settings. Finally, the questionnaires should be as similar as possible at the two sites, so they will be developed in concert with Georgetown/George Washington Universities.

A second set of evaluation tools to be developed is a set of images that represent both "routine" and "difficult" imaging problems in each of the clinical areas described in Section 8.2. Such images should include plain film images to be digitized, PCR images (University of Washington only), and digital images. These images will be selected by radiologists at the two sites. It is estimated that on the order of 100 studies will be selected per clinical area.

The performance benchmarks described in Section 8.2 form an additional set of tools that could be used at both sites to evaluate system performance. In concert with Georgetown/George Washington Universities, the University of Washington will:

- Define a "universal" questionnaire for user-oriented evaluation of the DINS which can be adapted to different clinical settings and different workstations
- Choose sets of test images
- Develop software for monitoring usage of workstation features for the independent workstation to be evaluated (Section 4.0)

Summary of Data Collection Requirements

This study will require two kinds of data, including:

- Structured professional opinions concerning evaluation objectives and methods
- Test images capable of meeting evaluation objectives

Deliverable Products

The results of this study will be documented as shown in Table 8-3.

8.4 Clinical Evaluation of the DINS Within the Radiology Department

The studies described in this section include all clinical studies performed within the radiology department. The duration of these studies is difficult to predict, since in many cases it may be apparent very quickly whether a particular clinical application is beneficial or not.

TABLE 8-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR EVALUATION METHODOLOGY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Evaluation methodology for clinical studies (collaborative)		X	X
Summary of methodology for use by the Army	X		

In addition, some system features have not yet been fully defined (particularly those of the digital image processing station); and these features may also affect the choice of the particular clinical studies to be performed. Depending on its exact capabilities, the digital image processing system (DIPS) may be used in applications where 12-bit contrast resolution is expected to be useful (limited in the planned system to PCR images) and for the clinical evaluation of vendor-supplied image processing techniques.

Objective

The overall objective is to evaluate the clinical usability of the DINS within the University of Washington department of radiology.

Summary of Approach

The tools for clinical evaluation developed in the study described in Section 8.2 will be applied to three areas:

- Image acceptability and system performance in selected clinical areas
- PCR image quality
- The RIS/DINS interface

Clinical evaluation of image acceptability and workstation performance will be studied using representative cases from each of the areas described in Section 8.2 after the initial training period is complete. In each area, at least one experiment in which image acquisition and case reporting is done through the DINS (possibly using the PCR) for a period of at least five (not necessarily consecutive) working days will be performed, provided the initial evaluation shows adequate image quality. Interviews will be conducted with the involved radiologists. Time-motion studies will be performed where appropriate and feasible. Additional labor costs required for DINS utilization will be estimated. In cases where image quality and/or system performance is judged not adequate to support an accurate clinical evaluation, this judgment will be documented. An estimate of the improvement required, or of the suitability of the DINS for less demanding applications, will be made.

To assess PCR image quality, representative films will be obtained in each of the plain-film areas described in Section 8.2. The image quality of each will be assessed on the DIPS (at 10 bits) and the 8-bit workstations. Attention will be paid to such things as the need for 2048 x 2048 resolution in selected cases, the utility of the increased dynamic range of the PCR in reducing retakes, and in revealing greater bone and soft tissue detail.

The ease of finding images is apt to be critical for user acceptability of the DINS. Interviews and time-motion studies will be obtained to assess the RIS/DINS interface and other methods for accessing the patient/image data base.

Summary of Data Collection Requirements

When the work described in Sections 8.1 through 8.3 is complete, a series of clinical studies will be defined covering the major clinical areas (Section 8.2). Using the techniques described in Section 8.3, the study will evaluate DINS performance in each area. In areas where major shortcomings are evident, consensus as to the required improvement in system capabilities will be obtained. This consensus will form the basis for the appropriate section of the evaluation report.

Deliverable Products

The results of this study will be documented as shown in Table 8-4.

8.5 Emergency Room and Intensive Care Unit Studies

A remote monitor connected to a workstation will be installed in the ER and in the Medical/Surgical ICU (5E) at University Hospital. For the duration of these experiments, the workstation will be dedicated to images from ER and ICU patients. Each day, patients discharged from the ER or ICU will have their images removed from local storage; new and continuing patients will have their images (and relevant old images) digitized. Instructions for the use of the DINS will be available at each of the two sites and help will be available at all times from the radiology resident on call.

Objective

The sole objective of this study is to evaluate the utility of the DINS at two sites inside the hospital, but outside the radiology department, where rapid access to images is important.

TABLE 8-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES
FOR CLINICAL EVALUATION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the results of clinical evaluations		X	

Summary of Approach

Evaluation of the system will be accomplished by periodic interviews of the participating clinicians. Unfortunately, no electronic means of monitoring system usage is available since image viewing will not generate any network transactions. The duration of these studies will be from one to three months.

Summary of Data Collection Requirements

Data to be collected will consist of:

- The reports of the interviews with participating clinicians
- Information on the volume of studies that were archived each day

Deliverable Products

The results of this study will be documented as shown in Table 8-5.

8.6 Teleradiology

A potential strength of the DINS in connection with teleradiology links is that the full capability of a digital radiology department can be made available to a small, remote clinical facility. This study is concerned with whether this potential can be tapped fully.

Objective

The objective of this study is to evaluate the utility of teleradiology as implemented with the University of Washington DINS in several different clinical situations:

- General radiology in a small hospital (Sitka, Alaska)
- Overreading of digital studies (Harborview, Connecticut)
- Trauma care in a busy ER (Harborview Trauma Center)

Summary of Approach

At present, film interpretation at Sitka, Alaska is based on mailing X-rays to radiologists for interpretation. For a period of time to be defined, images will be transmitted from Sitka to University Hospital, the studies read as they arrive, and the reports communicated back by telephone. After the initial intensive evaluation period, radiological consultation will be available for the next year, whenever requested by a

TABLE 8-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR EMERGENCY AND INTENSIVE CARE STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the results of employing DINS workstations in the ER and ICU		X	

Sitka physician. Diagnoses will be compared with interpretation based on the mailed films, that will continue to be sent as before. A log of all interpretations of these double-read images will be maintained.

The two Harborview studies are intended to study the use of portable workstations, which will be located at the duty station of the attending neuroradiologist or general radiologist. In the first study, sets of neuro-CT images (head, spine) will be reviewed by the attending neuro-radiologist(s) at this site for a period of one to three weeks. The vast majority of these studies relate to acute neurological events. If the initial test is satisfactory, it will be extended on an as-requested basis. Again, a log will be maintained for these cases.

The second Harborview study will involve the evaluation by the general radiology staff of emergency studies, again using a portable workstation. The ability of the workstation to enable a radiologist to provide consulting will be assessed in this environment.

Studies at the Seattle Veterans Administration Medical Center remain to be defined, depending on the final equipment configuration.

Summary of Data Collection Requirements

Data collected will consist of questionnaire/interviews and comparison between the DINS and conventional interpretations of the same films.

Deliverable Products

The results of this study will be documented as shown in Table 8-6.

TABLE 8-6
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR TELERADIOLOGY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on teleradiology link to Sitka, Alaska		X	
Report on teleradiology link to Harborview		X	

9.0 COMBAT CASUALTY CARE STUDIES

All studies described in the prior sections promote the development of improved military radiology, either directly or indirectly. In addition, five aspects of special interest to the Army from a combat casualty care standpoint will be studied in detail. They include the following:

- Standards for field-oriented electronic equipment in medical care
- Compatibility of equipment among various DoD echelons of treatment from a data interface standpoint
- Specifications for a field-deployable PC workstation, connected to the DINS, for use in short-term projects or in other special circumstances
- An investigation of the possibility of integrating and testing other DINS-compatible medical imaging equipment in conjunction with the DINS
- The ability of the DINS prototypes to perform under simulated disaster or combat casualty conditions

Each of these studies is described in the following subsections.

9.1 Standards for Field-Oriented DINS Electronic Equipment Used in Medical Care

Military and non-military standards that apply to the physical and operational aspects of electronically-based medical imaging equipment should be reviewed for their applicability to the DINS. A variety of standards may apply. These include ACR/NEMA standards for image formats and interfaces, all The Consultative Committee on International Telegraphy and Telephony (CCITT) standards regarding telecommunications, all military specifications standards for electronic equipment, the various computer-based graphics standards established in recent years, applicable Food and Drug Administration standards safeguarding the health and safety of people using electronic equipment, the IEEE 802 standards, DoD standards for the performance of electronic equipment in harsh environments, and others. If necessary, recommendations for new standards or for modifications to existing standards will be developed.

Optimal acquisition of images into a DINS means acquiring high quality images with minimum equipment complexity and minimum burden on technicians. This is particularly true in combat casualty care situations where time, urgency, distractions, harsh physical environments, and other demanding conditions work against the DINS user. The specifications for partially automated quality control mechanisms for image acquisition in combat casualty care and certain hospital circumstances require exploration.

Objectives

The seven objectives of this study follow:

- Assemble and analyze information on all standards that apply to the design, construction, deployment, operation, and maintenance of a DINS
- Determine the need, if any, for additions or modifications to any of the standards found to apply to the DINS
- Determine each of the key steps used by each prototype in digital image acquisition and the threats to high quality acquisition posed by poorly trained, hurried, or misinformed users at each step
- Investigate methods for improving the quality of digital image data acquired by the DINS at each acquisition step
- Investigate the feasibility of automating some or all these methods, to the extent feasible, to standardize image quality and reduce the procedural burden on DINS users
- Investigate user training requirements, concentrating on the image acquisition phase of DINS operation
- Develop appropriate recommendations for partially or fully automated film digitizers and supporting patient information systems to assure high quality images under all circumstances

Summary of Approach

This study will take the following steps. First, it will search all standards-based literature to develop a complete description of such standards, categorized by the way they apply to the DINS.

Second, since the two systems being installed at the university medical centers offer excellent opportunities to evaluate the various standards (or the need for such standards) in an operational setting, these interfaces will be tested. Testing will focus on the suitability of the relevant standards to the DINS.

Third, based upon evaluations of throughput, reliability and the like, recommendations will be made concerning ways these standards can be refined, if necessary.

Fourth, this investigation will study the image acquisition systems employed by each of the two prototype systems to determine their key image acquisition steps and to gauge their strengths and weaknesses against pre-determined performance criteria. Fifth, it will review literature on image acquisition systems to identify the most recent advances in the field and their potential applicability to the DINS, and it will review applicable standards published by the Joint Committee for the Accreditation of Hospitals (JCAH). Sixth, it will conduct laboratory tests concerned with image acquisition under hypothesized conditions to determine those steps crucial to high quality images, those that are error prone, and those that can be readily automated (e.g., choosing machine settings for lighting, contrast, focus, masking light-saturated areas extraneous to the patient's image, etc.). Finally, it will define specifications for the automation of those steps found to be suitable candidates.

Summary of Data Collection Requirements

This study will require four kinds of data:

- The results of document searches concerning applicable standards
- The results of reviews of industry publications and information provided by vendors associated with the DINS project
- Experimental studies involving these standards as implemented on the DINS prototype(s)
- The results of other experience with the two prototypes during the three-year DINS project

Deliverable Products

The results of this study will be documented as shown in Table 9-1.

9.2 Compatibility of Equipment among Various DoD Echelons of Treatment from a Data Interface Standpoint

All DINS equipment and protocols should be compatible among DoD echelons of care so that patients and their medically-related data can be moved easily from one echelon to another as treatment needs require (See Sections 1.3 through 1.4 for a review of the treatment echelons concept).

TABLE 9-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR STANDARDS-ORIENTED STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on standards applicable to a DINS deployed in support of military medical care	X		

It is unlikely that such compatibility will result if not made an explicit objective from the beginning of DINS development. This study explores ways to assure inter-echelon compatibility.

Objective

The two objectives of this study are:

- Investigate the requirements (both electronic and physical) for assuring DINS equipment compatibility among the four DoD echelons of treatment

- Investigate the requirements for assuring that all patient data successfully accompany patients on a timely basis as these patients move among care echelons

Summary of Approach

The following steps will be followed to achieve these objectives. First, the term "equipment compatibility" will be defined in operational terms (i.e., in terms of electronic interfaces and data compatibilities). Second, the typical flow of patients and their associated data among the Army's four echelons of care will be defined in consultation with knowledgeable Army health care planners and administrators. Next, this flow will be analyzed to determine points at which key interfaces among the various echelons can take place and the threats that may exist to their smooth functioning. Fourth, interfaces that would eliminate these threats will be developed and specified. Finally, an investigation will be conducted of laser card technology as a means for storing a patient's medical records in a hardened form for transport along with casualties in combat evacuations.

Summary of Data Collection Requirements

Three kinds of data are needed for this study. They include:

- A review of the available literature on the subject

- The results of engineering studies conducted during this project that focus on equipment interoperability

- Interviews with appropriate, knowledgeable DoD health care system experts specializing in electronically-based radiology systems or combat casualty care

Deliverable Products

The results of this study will be documented as shown in Table 9-2.

9.3 Investigating Requirements for a Field-Deployable PC Connected to the DINS for Use in Combat Casualty Care Situations

It may be desirable to connect a PC to a DINS over landlines or some other long distance communications medium to carry out certain radiological functions on a short-term basis drawing upon the resources of a DINS. Some examples of possible uses for this PC/DINS link include examining dental records at disaster sites, querying a patient's records when processing personnel for mass evacuation, and performing limited diagnostic functions in certain combat casualty care situations. Other applications may emerge through study of PC-based capabilities. This study investigates the use of a PC in such applications.

Objectives

The three objectives of this study include determining the following:

- Plausible uses of a PC link with the DINS from remote locations in both peacetime and wartime

- Data communications links that are available under plausible peacetime and wartime circumstances, their technical requirements, and their likely availability

- Engineering and managerial requirements for the effective deployment and use of a PC/DINS link in operational situations

Summary of Approach

The study's first objective will be pursued in two ways. First, the potential capabilities of PCs in image display and manipulation will be explored to determine possible applications for which the PC is suited from an engineering viewpoint. At the same time, knowledgable sources within the military medical community will be surveyed to obtain their ideas concerning possible uses for a remote link that would have high value if it were available. These ideas will then be brought together to determine potentially high value applications that are technically feasible.

TABLE 9-2
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR COMPATIBILITY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on the requirements for equipment compatibility in military medical care	X		
Report on laser card technology and its potential in combat casualty care	X		

The second and third objectives will be pursued analytically. High value applications will be examined to determine their technical requirements under intended conditions (e.g., peacetime disaster vs. wartime casualty care), and to determine the extent that these requirements can be met within the design and operational constraints imposed by the overall DINS.

Summary of Data Collection Requirements

Three kinds of data are required for this study:

- Reviews of relevant literature on the emerging capabilities of PCs, concentrating on their image display capabilities.
- Results of interviews with knowledgable military health care officials and providers
- Engineering studies in the laboratory on the subject of data communications and image quality in the extra-DINS environment

Deliverable Products

The results of this study will be documented as shown in Table 9-3.

9.4 Integration and Test of Military DINS-Compatible Medical Imaging Equipment

It is currently expected that one or more diagnostic devices currently under development by the military will be available in testable form during the three-year DINS project. The battlefield filmless radiology system, the individually-carried laser card medical record, and the portable ultrasound imaging unit currently being developed are examples. The flexibility and utility of both the DINS and these new medical imaging systems will be enhanced if they can be interconnected in effective ways. This study is concerned with this subject.

Objectives

The four objectives of this study are:

- Maintain technical liaison with developers of military medical imaging equipment that has the potential for useful interconnection with the DINS
- Determine which equipment will be at a stage of development sufficiently advanced to permit investigation of the potential for interfacing with the DINS

TABLE 9-3
DELIVERABLE PRODUCTS AND RESPONSIBILITIES
FOR FIELD-DEPLOYABLE PC STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on potential PC applications in connection with the DINS	X		

- Investigate the issues involved in establishing effective interfaces between the DINS and the other system(s)

- Develop the necessary draft specifications for such interfaces

Summary of Approach

During the course of the DINS project, MITRE will stay in close touch with the Project Officer from the USAMRDC. For purposes of this study, the objective of this first step will be to stay abreast of developments in medical imaging being carried out under Army sponsorship and elsewhere by military agencies. As the progress and purposes of these developmental efforts warrant, these systems will be evaluated for their potential value as elements on a DINS network.

Second, if the potential value warrants, these systems will be assessed from data communications and systems engineering perspectives to determine the work needed to establish interfaces with the DINS. Third, in the event that one or more such systems is sufficiently well developed during the DINS project, and it is otherwise desirable, MITRE will develop a link between the system and the DINS. The purpose will be to establish "proof of concept," and to determine the specifications for building the capability for such links into DINS of the future.

Summary of Data Collection Requirements

This study will require four kinds of data:

- Summary descriptions of candidate medical imaging systems, together with estimates of their developmental schedules and descriptions of their proposed missions

- For promising candidate systems, complete descriptions of their imaging capabilities and interface capabilities

- Expert opinion concerning the probable benefits in linking the candidate systems with the DINS

- Data concerning interface capabilities

Deliverable Products

The results of this study will be documented as shown in Table 9-4.

TABLE 9-4
DELIVERABLE PRODUCTS AND RESPONSIBILITIES
FOR DINS COMPATIBILITY STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on candidate systems for DINS application	X		

9.5 Simulation of DINS Performance Under Disaster or Mass Casualty Conditions

An important potential strength of the DINS in operation would be its ability to function smoothly and effectively in a casualty care situation of significant size. In such a situation, there would be the need to move images and patient data among several geographically remote facilities in order to follow patients physically transported among these sites, and to seek professional opinions on the patient's condition from the best available sources. A simulated exercise of the DINS from this viewpoint could be especially valuable in developing specifications for future systems.

Objectives

The two objectives of this study are the following:

- Plan and conduct a simulation of a large scale casualty care situation, drawing upon the resources of the two prototype systems

- Evaluate the results of this simulation with a view to developing recommendations concerning improved ways of handling disaster or mass casualty situations for future DINS military use

Summary of Approach

Near the conclusion of the DINS project, the universities, MITRE and the Army will conduct a disaster or combat casualty simulation exercise. This exercise will simulate the ability of the DINS to transport patient images and supporting data among sites as might be required by a combat casualty care situation. In this exercise, George Washington University could play the role of a third echelon hospital, Georgetown University a fourth echelon hospital, and the University of Washington a continental U.S. hospital.

First, as a part of this exercise, the DINS' ability to archive and store radiographs will be tested (including dental records and medical documents) on an optical digital archive. Fast access to records for identification purposes is typically needed, so access times will be an important consideration. Second, a requirement at one site for several hundred records to be obtained from the DINS at another site will be included as part of the exercise for this purpose. The results will then be evaluated to determine improvements needed in the concept or operation of future DINS.

Finally, this study will also examine how crisis situations can be managed in order to provide continuous care in the event of partial DINS system failure (e.g., as a result of military action). Part of this study will be devoted to developing crisis management plans depending on the level of the DINS failure. These plans will then be worked into educational and training material as deliverables to the project sponsors. Below is a list of situations that could result in a crisis situation:

- Central archive failure
- Network communications failure
- Single communication link failure
- Acquisition node failure
- Viewing station failure

Summary of Data Collection Requirements

Specific data requirements would depend upon the nature of the exercise decided upon, but would include data characterizing the ability of the DINS to move images and patient data to the proper geographic locations, quickly, conveniently, with minimum loss or inaccuracy, and with a minimum of special arrangements.

Deliverable Products

The results of this study will be documented as shown in Table 9-5.

TABLE 9-5
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR FIELD SIMULATION STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Results of mass casualty simulation at University of Washington		X	
Results of mass casualty simulation at Georgetown/ George Washington Universities			X
Synthesis of results	X		

10.0 TRENDS IN THE DEVELOPMENT OF MAJOR DINS ELEMENTS

The elements that compose a DINS are subject to substantial evolution over the next several years. The field of radiology is changing rapidly due to advances in medical imaging, evolution in the way the practice of radiology is organized, the introduction of new modes of medical diagnosis, and other factors. The electronically-based technologies that compose the DINS are also evolving at a rapid rate, typically characterized by increases in capability accompanied by decreases in cost. A project concerned with developing specifications for future DINS should attempt to take relevant trends into account.

10.1 Objectives

The two objectives of this study are to:

- Determine the major DINS elements--medical, organizational, and electronic--that are likely to change in significant ways over the next five years

- Forecast this evolution as accurately as possible so that these trends can be taken into account when developing plans and specifications for future DINS

10.2 Summary of Approach

Four major steps will be taken during this study. First, literature reviews will be conducted on the trends that affect the practice of radiology, concentrating on those aspects that affect digital radiography in major medical centers. Second, similar reviews will be conducted concerning the hardware, software, and data communications technologies that comprise the DINS, concentrating on those likely to change rapidly over the next few years. Third, the combined MITRE/university project team will identify the elements of the DINS that are most significant for future purposes, based on experience with the two prototype systems. Those elements most likely to change will be identified. Finally, trends in these elements will be forecast based on expert opinion (perhaps employing Delphi or related techniques), based on the DINS prototype project experience and based on estimates appearing in relevant professional literature.

10.3 Summary of Data Collection Requirements

Data to be collected in this study include:

- Information from professional literature on trends and developments in relevant fields

- Results of the evaluations of the prototype systems conducted during this project

- Expert opinions concerning relevant trends as revealed in Delphi style or other forecasting exercises

Many of these subjects already have been investigated indirectly as part of other studies described in this document. This study will focus on forecasting aspects alone. Subjects of particular interest will include:

- Practice patterns in radiology, concentrating on uses of digital imaging and their effects on these patterns

- Planned practice patterns in combat casualty care

- The organization and structure of large hospitals, particularly in the military health care system, concentrating on radiology services

- Digital imaging used in diagnosis

- Computer system capabilities and associated costs

- Digital network capabilities and associated costs

- Standards and protocols applicable to large-scale digital information networks, their current status, development efforts underway, and their likely result

10.4 Deliverable Products

The results of this study will be documented as shown in Table 10-1.

TABLE 10-1
DELIVERABLE PRODUCTS AND RESPONSIBILITIES FOR TRENDS STUDIES

PRODUCTS	MITRE	UNIVERSITY OF WASHINGTON	GEORGETOWN/ GEORGE WASHINGTON UNIVERSITIES
Report on relevant trends in DINS technology, organization, and practice	X		

GLOSSARY*

Acronyms

ACR/NEMA	American College of Radiology/National Equipment Manufacturers Association
ACU	Automatic Calling Unit
ANSI	American National Standards Institute
AR	Army Regulation
ARPANET	Advanced Research Projects Agency Network
ARR	Automatic Request for Repetition
ASCII	American Standard Code for Information Interchange
bpi	Bits per inch
bps	Bits per second
CCITT	The Consultative Committee on International Telegraphy and Telephony
CDRH	Center for Devices and Radiological Health
COMMZ	Communications Zone
CPU	Central Processing Unit
CR	Compression Ratio
CRC	Cyclic Redundancy Check Character(s)
CRT	Cathode Ray Tube
CT	Computed Tomography
db	Decibel
DCE	Data Communication Equipment
DEC	Digital Equipment Corporation
DEPMEDS	Deployable Medical Systems (U.S. Army)
DINS	Digital Imaging Network System
DIPS	Digital Image Processing Station
DoD	Department of Defense
DSA	Digital Subtraction Angiography
DSP	Digital Signal Processor
DSR	Data Set Ready
DTMF	Dual Tone Multiple Frequency
DTR	Data Terminal Read
EIA	Electronics Industry Association
EM	End of Medium
EOA	End of Address
EOM	End of Message
EOT	End of Text or End of Transmission

***Not all acronyms listed in this glossary appear in the text of this document**

GLOSSARY (Continued)

Acronyms

ER	Emergency Room
ETB	End of Transmission Block
ENQ	Enquiry
FEBA	Foward Edge of the Battle Area
FDM	Frequency Division Multiplexing
FDX	Full Duplex
GSP	Graphics Signal Processor
HD or HDX	Half-Duplex Circuit
HICAP	High Capacity
HIS	Hospital Information System
ICU	Intensive Care Unit
ID	Identification
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Standards Organization
ITU	International Telecommunications Union
IRG	Inter-Record Gap
IPS	Inches Per Second
JCAH	Joint Committee for the Accreditation of Hospitals
Kb	Kilobyte
LAN	Local Area Network
LOCAP	Low Capacity
LRC	Longitudinal Redundancy Check
MASH	Mobile Army Surgical Hospital
Mb	Megabyte
MHz	MegaHertz
MICR	Magnetic Ink Character Reader
MRI or NMR	Magnetic Resonance Imaging (also called NMR imaging)
ms	Milli-seconds
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
NAK	Negative Acknowledge
NMRI	Nuclear Magnetic Resonance Imaging (also called MRI)
OCR	Optical Character Recognition

Acronyms

PACS	Picture Archiving and Communication System
PAX	Exchange, Private Automatic
PABX	Exchange, Private Automatic Branch
PBX	Exchange, Private Branch
PC	Personal Compter
PCM	Pulse-Code Modulation
PDIP	Program Development and Implementation Package
PDM	Pulse-Duration Modulation
PPM	Pulse-Position Modulation
PROM	Programmable Read-Only Memory
RGB	Red-Green-Blue
RIS	Radiology Information System
ROC	Receive Operating Curve
ROI	Region of Interest
RTS	Request to Send
UPS	Uninterruptible Power Source
US	Ultrasound
USAMRDC	U.S. Army Medical Research and Development Command
USUHS	Uniformed Services University of the Health Sciences
UWGSP	University of Washington Graphics Signal Processor
VA	Veterans Administration
WWL	Window Width and Level

Terms

Access	The manner by which files or data sets are obtained from storage by human users or by the computer. Access methods can be selected to provide data security for sensitive information.
Access Time	The amount of time required to retrieve data from a computer or storage device.
Acoustic Coupler	A device that converts digital signals into audible tones for transmission or reception using a telephone handset.
Acquisition, Image	Production of an image by a radiological device. The acquired image is digitized, if necessary, and is available for capture by the DIN system.

GLOSSARY (Continued)

Address	The identification of a particular location in a computer memory or data source.
Algorithm	An unambiguous series of steps by which a given problem may be solved (e.g., a diagnostic algorithm is a series of clinical decision steps). A "soft tissue" algorithm increases the resolution in those cases where resolution is limited by pixel size.
Allocation	The allotment of available main memory and file storage to accommodate programs and data.
Alphanumeric	A contraction of alphabetic-numeric. A character set consisting of letters, numbers, and special graphic characters/symbols.
Alternate Routing	An alternative communications path used if the normal one is not available.
Alternator	A machine for viewing X-ray films that employs a series of translucent panels that mechanically move in front of fluorescent lights. Films are mounted on the panels. In this manner a large number of films can be viewed at one location.
Amplitude	The extreme point in the range of a fluctuating quantity (e.g., the high and low points in the range of luminance of a video signal).
Amplitude Distortion	Distortion in the amplitude of a wave form due to attenuation, noise, cross-talk, and other factors.
Amplitude Modulation (AM)	Modulation of a signal in which the amplitude of its wave form is varied by the amplitude of another signal.
Analog	A measurement which varies in a continuous fashion, such as voltage, brightness, temperature, etc.
Analog Data	Data expressed in the form of continuously variable quantities such as sine waves. (Compare with Digital Data.)
Analog Image	An image produced by a continuously variable physical process (e.g., exposure of film).

GLOSSARY (Continued)

Analog to Digital Converter (A/D)	A device which converts analog data to a digital form.
Analog Transmission	Transmission of a continuously variable signal as opposed to a discretely variable signal. The normal way of transmitting a voice signal over telephone lines has been analog, but digital encoding is coming into widespread use.
Anteroposterior (AD)	In radiology denotes that the direction of the X-ray beam is from the front to the back.
Application Program	The working programs in a computer system may be classified as application programs and supervisory programs. Application programs are the main data processing programs that perform the functions of the application. They contain no input-output coding except in the form of macroinstructions that transfer control to the supervisory programs. They are usually unique to one type of application, whereas supervisory programs could be used for a variety of applications.
Arithmetic/Logic Unit	Performs the various arithmetic and logical operations within the computer.
Array Processor	A digital circuit (device) which is capable of rapidly performing various arithmetic operations on large collections (arrays) of numbers simultaneously.
Artifact	A structure or object appearing on a medical image produced by the imaging system but not actually present in the tissue being imaged (e.g., motions, streaks on CT images or static discharge marks on X-ray films).
Aspect Ratio	The proportionate size of an image, expressed as the horizontal dimension divided by the vertical dimension.
Assemble	(1) To convert a program written in nonmachine language into machine instructions and to assign memory storage for those instructions; (2) To accumulate in main or auxiliary memory a portion of an incoming long message.

Asynchronous Transmission	Transmission in which each character, word, or small block is individually transmitted without clocking or timing information. The beginning and ending of messages are defined by the use of start and stop elements. The gap between each character or word is not of a necessarily fixed length. (Compare with Synchronous Transmission.) Asynchronous transmission is also called start-stop transmission.
Attenuation	Decrease in magnitude (amplitude) of current, voltage, or power of a signal during transmission between two or more points.
Audio Frequencies	Generally frequencies that can be heard by the human ear (usually 30 to 20,000 cycles per second). In telecommunications, the frequency range is 300 or 3300 cycles per second.
Audio Response Unit	Used in "voice answer back" applications, an Audio Response Unit is digitally controlled to produce synthetic syllable and word responses to persons entering keyboard data.
Automatic Error Correction	A technique, usually requiring the use of special codes and/or automatic retransmission, which detects and corrects errors occurring in transmission. The degree of correction depends upon coding and equipment configuration.
Automation	(1) The implementation of processes by automatic means; (2) The theory, art, or technique of making a process more automatic; (3) The investigation, design, development, and application of methods of rendering processes automatic, self-moving, or self-controlling.
Automonitor	Making an electronic computer prepare a record of its own data processing operations, or a program or routine for this purpose.
Autopolling	Performing the polling function automatically to reduce the data communication tasks of the host computer. Autopolling can be performed by communication preprocessors, multiplexers, data concentrators, and other devices.

GLOSSARY (Continued)

Auto-Restart	The capability of a device or system computer to perform automatically the initialization functions necessary to resume operation following an equipment or power failure.
Auxiliary Storage	Device which is normally capable of holding a larger amount of information than the main memory of the computer but with slower access.
Axial	A plane perpendicular to the longitudinal axis of the body. An axial plane shows a cross section of the body in the head-to-toe direction.
Band	In data communications, the frequency spectrum between two defined limits.
Bandpass Filter	A filter which permits free passage to frequencies within a specific range and which bars passage to frequencies outside of that range.
Bandwidth	The difference, expressed in Hertz (Hz), between the two limiting frequencies of a band. The bandwidth is one factor in determining how much information a transmission medium (e.g., a cable) can carry. See data transmission rate, throughput.
Baud	A unit of data transmission speed equal to the number of discrete conditions per second. In a system where one discrete condition represents one bit, it is the number of bits per second (bps).
Baudot Code	A code for the transmission of data in which five equal-length bits represent one character. This code is used in most teletypewriter machines.
Bias Distortion or Asymmetrical Distortion	Distortion affecting a two-condition (or binary) modulation (or restitution) in which all the significant conditions have longer or shorter durations than the corresponding theoretical durations.

Bidirectional Broadband Amplifier	An assemblage of amplifiers and filters which amplifies and re-equalizes in the forward direction all signals received in the higher frequency portion of the broadband spectrum, and simultaneously amplifies and re-equalizes in the reverse direction all signals received in the lower frequency portion of the broadband spectrum (IEEE Standard 802.4 definition).
Binary	A computer-oriented numbering system that uses two symbols (usually 0 or 1) to represent data.
Binary Digit	A numeral in the binary scale of notation. This digit may be zero (0) or one (1). It may be equivalent to an on or off condition, a yes, or a no. Often abbreviated as bit.
Binary Signalling	A communications mode in which information is passed by the presence and absence, or plus and minus variation of one parameter of the signalling medium only.
Binary Stream	Serial flow of binary digits (bits).
Bi-Stable	The capability of assuming either of two stable states, method of storing one bit of information.
Bit	Contraction of "binary digit", the smallest unit of data in a computer (usually 0 or 1).
Bit Rate	The speed at which bits are transmitted, usually expressed in bits per second. (Compare with Baud.)
Blanking	The suppression of video information forcing the electron gun of the display monitor to display black at the edges of the screen.
Block	A group of characters, bytes, or words communicated as a unit.
Block-by-Block Transmission Mode	A transmission mode in which a block is not transmitted until proper acknowledgment is received for the preceding block.

Block Diagram	A diagram of a system, instrument, computer, or program in which selected portions are represented by annotated boxes and interconnecting lines.
Boolean Algebra	A process of reasoning, or a deductive system of theorems using a symbolic logic, and dealing with classes propositions, or on-off circuit elements. It employs symbols to represent operators such as AND, OR, NOT, EXCEPT, IF THEN to permit mathematical calculations. Named after George Boole.
Break	In machine telegraphy, a prolonged spacing impulse, exceeding the duration of one character. This may be introduced deliberately or may be caused by a line fault. A break is frequently used by the receiving terminal to interrupt the transmitting terminal.
Brightness	Perceived luminance.
Broadband	A communication channel having a bandwidth greater than a voice-grade channel. (A voice-grade channel suitable for speech, digital, or analog data, generally has a frequency range of 300 to 3000 Hz.) A broadband channel is capable of higher-speed data transmission.
Broadband Coaxial System	A system whereby information is encoded, modulated onto a carrier, and band-pass filtered or otherwise constrained to occupy only a limited frequency spectrum on the coaxial transmission medium. Many information signals can be present on the medium at the same time without disruption provided that they all occupy nonoverlapping frequency regions within the cable system's range of frequency transport (IEEE Standard 802.4 definition).
Broadband Signalling	Transmission of a signal employing modulation of a carrier by the signal.
Broadcast	Simultaneous transmission of data to a number of receiving nodes.
Buffer	An area of storage that is reserved for use in performing an input/output operation, into which data are written or from which data are read.

Buffer Storage	(1) A synchronizing element between two different forms of storage, usually between internal and external; (2) An input device in which information is assembled from external or secondary storage and stored ready for transfer to internal storage; (3) An output device into which information is copied from internal storage and held for transfer to secondary or external storage; (4) Any device which stores information temporarily during data transfers. Computation continues while transfers between buffer storage and secondary or internal storage or vice versa take place.
Bug	A mistake in a program or system.
Burst	In data communications, a sequence of signals counted as one unit in accordance with some specific criterion or measure (e.g., to display an image requires a large burst of data and thus high data transmission rates).
Bus	One or more conductors used for transmitting signals or power. The bus, as used in a computer bus or local area network, normally has a "tree" topology.
Busy Condition	A condition in which communications lines or trunks are unavailable for use.
Byte	A group of binary characters operated upon as a unit and usually shorter than a computer word. In most systems, a byte is a sequence of 8 adjacent bits.
Cable	One or more conductors within an enveloping protective sheath constructed to permit the use of conductors separately or in groups.
Called Station	Station to which a message is routed or a transmission is directed.
Calling Device	An apparatus which generates the pulses required for establishing connections in an automatic telephone switching system.
Candela	The luminous intensity of one sixteenth of one square centimeter of projected area of a black body at the freezing point of platinum.

GLOSSARY (Continued)

Capacitance	The ratio of the electric charge transferred from one to another of a pair of conductors to the resulting potential difference between them.
Capture	The function by which a digital image is incorporated into a DIN system. See acquisition.
Card Dialer	Automatic dialer and regular telephone combined in one desk-top unit. Phone numbers coded on plastic cards are inserted in the dialer slot for fast, accurate dialing.
Carrier	A continuous frequency capable of being modulated or impressed with a second information carrying signal.
Carrier, Common	A company regulated by the Federal Communications Commission or a public utilities commission, and required to supply communication service to all users at published rates.
Carrier, Data	A single frequency or tone which is modulated by voice or data to communicate information.
Carrier System	A means of establishing a number of channels over a single path by modulating each channel on a different carrier frequency and demodulating at the receiving point to restore the signals to their original form.
Carrier Wave	The basic frequency or pulse repetition rate of a signal, bearing no intrinsic information until it is modulated by another signal which does bear information. A carrier may be amplitude, phase, frequency modulated, or a combination of these modulation schemes.
Centralized System	A system in which data processing, storage, and control functions are performed at one location. Data may be input and output at other locations. See distributed system.
Channel	In data communications, a pathway for information transmission.

Channel, Analog	A channel on which the information transmitted can take any value between the upper and lower limits defined by the channel. Most voice channels are analog channels.
Channel, Voice-Grade	A channel suitable for transmission of speech, digital, analog, or facsimile data, generally with a frequency range of about 300 to 3400 cycles per second.
Character	Letter, figure, number, punctuation, or other sign contained in a message. Besides such characters, there may be characters for special symbols and some control functions.
Character Density	The number of characters that can be stored per unit of length.
Character Interval	The total number of unit intervals (including synchronizing, intelligence, error checking, or control bits) required to transmit any given character in any given communication system. Extra bits which are not associated with individual characters are not included.
Character Reader	A specialized device which can convert data represented by one of the typing formats or handwritten script directly into machine language. Such a reader may operate optically. If the characters are printed in magnetic ink, the device may operate magnetically or optically.
Characteristic Distortion	Distortion caused by transients which, as a result of the modulation of a signal, or present in the transmission channel and depend on its transmission qualities.
Check Character (or Digit)	One or more characters (or digits) carried in a symbol, word, or block, and coded, depending on the remaining elements, in such a way that if an error occurs it will be detected (excluding compensating errors).
Check Number	A number composed of one or more digits used to detect equipment malfunctions in data transfer operations. If a check number consists of only one digit, it is synonymous with check digit.

Circuit	(1) Communications line or electrical transmission facility; (2) Connection between terminals or terminals and computer; (3) A communications link between two or ore points.
Circuit Capacity	The number of communications channels which can be handled by a given circuit at the same time.
Circuit, Four-Wire	A communication path in which four separately insulated wires (two for each direction of transmission) are present.
Circuit, Twisted Pairs Shielded	Circuit formed of two separately insulated wires that have been twisted around each other for better coupling. Noise reduction is achieved by shielding the twisted wires with a metallic conductor, usually grounded.
Circuit, Two-Wire	A circuit formed by two conductors insulated from each other. It is possible to use the two conductors as either a one-way transmission path, a half-duplex path, or a duplex path.
Clear to Send	An EIA RS-232 designation used by a terminal or computer to detect that its modem is ready to send data.
Clock	A device for timing events. In data communications, a clock is required to control the timing of bits sent in a data stream, and to control the timing of the sampling of bits received in a data stream.
Clock Rate	The rate at which pulses are emitted from the clock.
Clocking	The process of timing and synchronizing the transmission and reception of data at a clock rate.
Coaxial Cable	A cable consisting of one conductor, usually a small copper tube or wire, within and insulated from another conductor of larger diameter, usually copper tubing or copper braid.
Code	A system of symbols and rules for use in representing information.

Code Conversion — The process by which a code of some predetermined bit structure and representation (for example, 5, 7, 14 bits per character interval) is converted to a second code with more or less bits per character interval. In certain cases, such as the conversion from start/stop telegraph equipment to synchronous equipment, a code conversion process may only consist of discarding the stop and start elements and adding a sixth element to indicate the stop and start condition. In other cases, it may consist of addition or deletion of control and/or parity bits.

Code Level — The number of bits used to represent a character (e.g., the five-bit Baudot code is a "five-level code").

Code Set — A pattern of bits in groups used to represent characters. A different pattern is used to represent each individual character of a particular Code Set.

Coder/Decoder (CODEC) — Device used to digitize analog signals using pulse-code modulation techniques. Often found on a single chip.

Command Processing — Reading, analyzing, and performing commands issued via keyboard entry, voice, touch-sensitive screen or other user interface.

Communication Line — Any physical link, such as a wire or a telephone circuit; synonym for data transmission line.

Communications Channel — A path for flow of information, particularly digits or characters.

Communications Failure — When a message is transmitted correctly but is not received correctly.

Communications Network — A complex of data communications equipment, data links, and channels. See LAN.

Communications Port — The provision in a computer to accommodate a data communication device.

Communications Preprocessor — A special purpose computer connected between a general-purpose processor and communication channels to perform communications functions more efficiently than would be possible if the general-purpose processor performed both communications and general-purpose functions.

Communications Processor	A computer dedicated to the performance of complete communications function such as message switching.
Communications System	Series of interconnected communications networks, circuits, stations, and facilities for fulfilling communications needs on a broad scale.
Community Information Utility	A computer network that allows wide public usage.
Compatibility	The property of systems that allows them to be run in concert with each other.
Compile	To produce a sequentially ordered machine language program from a series of symbolic operation codes or statements. A special compiling program is used to perform this transformation from non-machine to machine language.
Compiler	A program that translates high-level language statements into machine language instruction. Generally, there is more than one machine language instruction for one high-level language statement.
Computer Code Checking	A means of determining if errors have occurred. There are three types: character parity check, block parity check, and cyclic parity check.
Computer Utility	(1) A service which provides computational services; (2) A "time-shared" computer system. Programs as well as data may be made available to the user. The user also may have his own programs immediately available in the central processor, may have them on call at the computer utility or he may load them by transmitting them to the computer prior to using them. Certain data and programs are shared by all users of the service; other data and programs because of proprietary nature have restricted access. Computer utilities are generally accessed by means of data communications subsystems.

Conditioning	The addition of equipment to a leased voice-grade channel to provide at least the minimum line characteristics required for accurate data transmission at higher than voice-grade speeds.
Conduit	A plastic or metal tube through which communications cable travels.
Console	A portion of the computer used to control the machine manually, correct errors, determine the status of storage, and manually revise the contents of storage.
Contention	A condition arising when two or more data stations (nodes) attempt to transmit at the same time over a shared channel or access the same peripheral device (disk, printer, etc.).
Continuous Tone	A term describing a photographic print where brightnesses appears consistent and uninterrupted.
Continuous Transmission Mode	A transmission mode in which line blocks are sent without any pause between them as long as no more than one completely transmitted block is unacknowledged. Receipt of acknowledgment for a line block is expected during the transmission of the succeeding line block.
Contrast	A measure of relative intensity difference in an image. Excessive contrast implies mainly dark black and bright white content; high or medium contrast implies a good distribution of intensities from black to white; low contrast implies a distribution of intensities consisting primarily of shades of gray. High contrast often means, loosely, excessive contrast.
Contrast Enhancement	Any operation serving to increase or decrease the contrast of an image in order to bring out definition not clearly visible in the original.
Control Character	A character whose occurrence in a particular context initiates, modifies, or stops a control operation (e.g., a character to control carriage return).

Control Mode	The state that all terminals on a line must be in to allow line control actions or terminal selection to occur. When all terminals on a line are in the control mode, characters on the line are viewed as control characters performing line discipline tasks, such as polling or addressing.
Control Program	The program responsible for handling input/output for both terminals and file storage, establishing processing priorities, maintaining waiting lists of work in process, activating operational programs, and performing other supervisory functions in a real-time system. Words sometimes used synonymously to designate such a program include driver, executive, monitor, supervisor.
Control Unit	A computer internal unit responsible for directing and coordinating the entire computer system.
Controller Device	Converts bits or bytes into words, converts (translates) data code, matches the speed of the device to the speed of the memory, and controls the device.
Conversational Mode	A procedural mode for communication between a terminal and the computer in which each entry from the terminal requires a response from the computer and vice versa.
Convert	(1) To change numerical information from one number base to another; (2) To transfer information from one recorded medium to another.
Core (Memory)	Where program instructions, addresses, modifiers, device addresses, tables, data, and constants are stored.
Coronal	A plane which passes vertically through the body dividing it into anterior and posterior portions.
Couplings	The connecting of two or more devices in such a manner that information or energy is transferred from one to the other.

Cross-Talk	The unwanted signals in a channel which originate from one or more other channels in the same communication system.
Cursor	A position indicator employed in a video display terminal to indicate the position where character data will be entered or corrected.
Cycle	A term applied to alternating current. Specifically, the time required for an electric current to start at zero, go through some positive value, through zero, then through some negative value and return to zero. The frequency of cycle repetition is expressed in hertz, named after Heinrich Herz, and is equivalent to cycles per second.
Data	Any representations such as characters or analog quantities to which meaning might be assigned by humans.
Data Access Arrangement	An electronic unit used to connect customer-owned equipment to the telephone-type facilities.
Data Bandwidth	The maximum speed of data, defined in bits per second, that a device or channel can handle. See data transmission rate.
Data Block	The accumulation of a specific number of characters into a group or block of information.
Data Circuit	Communication facility permitting transmission of information in digital form.
Data Compression	A method of reducing data storage capacity required by storing data in encoded form. Various encoding methods are used to shorten the length of records by eliminating gaps, empty fields, and redundancies.
Data Message	Information in a form and format which is to be machine processed.
Data Modem	A MOdulation/DEModulation device that enables computers and terminals to communicate over telephone circuits by converting digital signals into a modulated carrier.

Data Modem Clocking	The derivation of synchronous clocking signals from the modem rather than from the terminal or computer.
Data Origination	The earliest stage at which the source material is first put into machine readable form or directly into electrical signals.
Data Processing	Any operation or combination of operations on data.
Data Set	Converts terminal/computer digital signals to modulated common carrier signals. Also provides for other control signals.
Data Set Adapter	An interconnection device located in the terminal or computer equipment. It provides various controls and features, and interfaces the Data Set. It may, in some cases, replace the Data Set.
Data Set Ready (DSR)	An EIA RS-232 designation applied to a sense circuit used by a terminal or computer to detect that power is applied to its modem, and that the modem is connected to a communication circuit.
Data Sink	A port in a network that can receive data.
Data Source	A port in a network that can transmit data.
Data Terminal	Equipment employed at an end of a transmission circuit for the transmission and receipt of data.
Data Terminal Read (DTR)	An EIA RS-232 designation applied to a control circuit used by a terminal or computer to tell its modem that the terminal or computer is ready for operation. In some applications this circuit is used to enable the modem to answer or terminate calls.
Data Transmission Rate	The amount of data actually transmitted between nodes or over a communications medium in a time interval, expressed in bits per second (bps). The data transmission rate is one factor affecting the response time of the system. This data transmission rate cannot exceed the data bandwidth of the slowest node or communications medium.

Debugging	The process of determining the correctness of a computer routine and taking action to correct any errors. Also the detection and correction of malfunctions in the computer itself.
Decode	(1) To apply a code so as to reverse previous encoding; (2) To determine the meaning of individual characters or groups of characters in a message; (3) To determine the meaning of an instruction from the set of pulses which describes the instruction, command, or operation to be performed.
Degradation	A condition in which the system continues to operate, but provides a reduced level of service.
Delay Distortion	Distortion resulting from nonuniform speed of transmission of the various frequency components of a signal through a transmission medium.
Delphi	A forecasting technique which relies on the use of structured expert opinion employed on an iterative basis
Demodulation	The process of retrieving data from a modulated carrier wave; the reverse of modulation.
Device Address	Required for input/output instructions. Required by a computer in order to access the devices connected to the associated device channels.
Diagnostic Programs	Used in a computer system to check equipment malfunctions and to pin-point faulty components. May be used by the computer engineer or may be called in by the computer's supervisory programs automatically.
Diagnostic Routine	A routine used to locate a malfunction in a computer, or to aid in locating mistakes in a computer program. Thus, in general, any routine specifically designed to aid in debugging or troubleshooting.
Diagnostics System	Means for identifying overall malfunctions in a computer system. Rather than checking one individual component, system diagnostics utilize the whole system in a manner similar to its normal operation. Programs

	resembling the operational programs are used rather than programs that run logical patterns. These normally detect overall system malfunctions but do not necessarily isolate faulty components.
Diagnostics Unit	Used on a computer to detect faults in various system units. Separate unit diagnostics check such items as arithmetic circuitry, transfer instructions, and each input-output uni..
Dial Switching Equipment	An automatic telephone system, whereby one user can establish, through electro-mechanical or electronic equipment, a connection to another telephone user without the assistance of the attendant.
Dial-Up	The use of a dial or pushbutton telephone to initiate a station-to-station telephone cail or to establish a data transmission link.
Dibit	A group of two bits. In four-phase modulation, each possible dibit is encoded as one of four unique carrier phase shifts. The four possible states for a dibit are 00, 01, 10, 11.
Differential Pulse Code Modulation (DPCM)	An image data compression technique relying on the coding of adjacent pixel luminance differences rather than their absolute luminance.
Digital	The representation of data or physical quantities in the form of discrete codes, such as numerical characters, rather than in a continuous stream. Each discrete step of quantized data can be represented by a different code.
Digital Data	Information represented by a code consisting of a sequence of discrete binary data elements, such as zero and one. (Compare with Analog Data.)
Digital Image	An image composed of discrete pixels each of which is characterized by a digitally represented luminance level. The screen size for a digital image might be a 1024 x 1024 matrix of pixels x 8 bits (representing 256 luminance levels) per pixel.

GLOSSARY (Continued)

Digital Signal	A discrete or discontinuous signal; one whose various states are discrete intervals apart. (Compare with Analog Transmission.)
Digital to Analog Converter (D/A)	A device that serves to convert each binary quantity sample, such as a pixel, to the equivalent analog level, such as a voltage level, for display.
Digitize	To obtain a digital representation of the magnitude of a physical quantity from an analog representation of that magnitude (e.g., to use a digitizer to scan a film image and create digital data representing that image).
DIN Report	Functional Requirements for a Hospital-Based Digital Imaging Network and Picture Archiving and Communication Prototype System, 30 April 1985, The MITRE Corporation.
Diode	A device used to permit current flow in one direction in a circuit and to inhibit current flow in the other. In computers, these are primarily germanium or silicon crystals.
Disk	A flat circular plate with a special surface used as a data storage medium (e.g., hard disk, floppy disk, optical laser disk).
Disk Storage	The storage of data on the surface of disks coated with fine magnetic material that can be polarized.
Display	The presentation of data for viewing or the device used to present data. A video monitor is a typical display device.
Display Unit	A device which provides a visual representation of data.
Distortion	The unwanted change in a waveform that occurs between two points in a transmission system.
Distributed Data Processing	Loosely speaking, a network wherein processing capabilities are distributed geographically rather than concentrated in a single computer.

Distributed System	A system in which data processing, storage, and control functions, in addition to input/output functions, are distributed among a number of locations. See centralized system for comparison.
Double Parity	A system using both vertical and horizontal parity schemes.
Download	To transmit data from central or distributed data base locations to local storage at a workstation or other satellite facility such as a personal computer.
Downtime	The period during which a computer or communication channel is malfunctioning or not operating correctly due to mechanical or electronic failure, as opposed to available time, idle time, or standby time, during which the computer is functional. Contrasted with uptime.
Drop Cable	The smaller diameter flexible coaxial cable of the broadband medium which connects to a station.
Drum Storage	A storage device that uses magnetic recording on a rotating cylinder.
Dual-Cable	A broadband coaxial cable system in which separate coaxial cables are used for the forward and reverse directions of signal transmission. Connection of a dual-cable system to a station requires dual F-connectors at the station--one for transmission and one for reception.
Dual Tone Multiple Frequency (DTMF)	A system used by subscriber telephone sets to signal the calling number digits to the Central Office. Uses two of four frequency tones for each digit. Synonymous to Touch Tone.
Duplex, (Full)	In data communications, simultaneous two-way independent transmission in both directions.
Duplex, (Half)	In data communications, alternate, one way at a time, independent transmission. This is the type of transmission supported by baseband coaxial cable.

Duplex Channel	A communication channel with the capability of simultaneous two-way communication, equivalent to full duplex.
Duplex Transmission	Simultaneous two-way independent signal transmission in both directions. (Compare with Half Duplex Transmission.) Also called full-duplex transmission.
Duplexing	The use of duplicate computers, files, or circuitry, so that in the event one component fails, the alternate enables the system to carry on its work.
Dynamic Range	The range of data values found in a set of values (e.g., in an image, high dynamic range implies a wide spread of gray values whereas low dynamic range indicates a small spread and, therefore, low contrast).
Echo Check	A method of checking data transmission accuracy whereby the received data are returned to the sending end of the link for comparison with the original data.
Echo Suppressor	A line device used to prevent energy from being reflected back (echoed) to the transmitter. It attenuates the transmission path in one direction while signals are transmitted in the other direction.
Edge Enhancement	Any operation that accentuates edge details within an image. Such operations include the shift and difference, gradient, and Laplacian enhancements.
Efficacy, Cost	Ability to produce desired effect(s) at reasonable cost. In economic analysis, cost/efficacy usually incorporates elements of both cost/effectiveness and cost/benefit analysis.
Electronic Mail	The use of computer devices to transmit information into some other user's file in a local or remote computer so it can be retrieved by only that user at a later time. It is an alternative to the use of conventional paper media.
Encode	To apply a code, frequently one consisting of binary numbers, to represent individual characters or groups of characters in a message.

GLOSSARY (Continued)

Entrance Facility	The facility between the customer's premises and the Telephone Company Central Office or the customer-provided inter-exchange facilities.
Entropy	A measure of the uncertainty that a particular event will occur in an experiment. The greater the entropy associated with a certain event, the greater the amount of information that is obtained when that event occurs. This is a term that is used in many disciplines to describe the amount of disorder that exists in a system.
Envelope Delay	Characteristics of a circuit which result in some frequencies arriving ahead of others, even though they were transmitted together.
Equalizer	Any combination of inductors, capacitors, or resistors inserted in transmission line or amplifier circuit to improve its frequency response.
Equalizer Delay	A corrective network which is designed to make the phase delay or envelope delay of a circuit or system substantially constant over a desired frequency range.
Equivalent Bandwidth	Given a measure of the frequency spectrum of a signal (image), such as the magnitudes of the frequency components of the signal, the range of frequency components that when added together (actually the sum of the squares) yield, say, 99 percent of the energy of the original signal spectrum. This range of components determines the equivalent bandwidth of the signal. This term has particular meaning in digital signal processing where arrays of numbers are processed by FFT routines and the number of frequency domain coefficients is determined by the size of the array used and not all of those coefficients are necessary to retain the signal (image) description.
Equivalent Four-Wire System	A transmission system using frequency division multiplexing to obtain full-duplex operation over only one pair of wires.
Erasable Storage	A device for storing data that can be modified.

Error	Any discrepancy between a computer, observed, or measured quantity, and the true, specified, or theoretically correct value or condition.
Error Control	A plan, implemented by hardware, software, or procedures to detect and/or correct errors introduced into a data communications system.
Error-Correcting Code	An error-detecting code incorporating sufficient additional signaling elements to identify the nature of some or all of the errors in the message and to correct them entirely at the receiving end.
Error Corrections	System which detects and provides correction for errors by transmission equipment or facilities.
Error-Detecting Code	A code in which each signal conforms to specific rules of construction, so that departures from this construction in the received signals can be automatically detected at the receiving end of the link.
Error Transmission	A change in data resulting from the transmission process. The change in data may be the result of outside interference wit the normal transmission.
Even Parity Check	Test whether the number of digits in a group of binary digits is even in order to discover possible transmission errors.
Exchange Service	A service permitting interconnection of any two customers' stations through the use of the exchange system.
Executive Routine	A routine which controls loading and reloading of computer routines and in some cases makes use of instructions which are unknown to the general programmer.
External Clocking	In synchronous communication, a terminal or computer is externally clocked when the bit-timing signal is provided by the modem.
External Storage	The storage of data on a device which is not an integral part of a computer, but is for use by the computer.

GLOSSARY (Continued)

F-connector — A 75 L F-series coaxial cable connector (of the kind commonly found on consumer television and video equipment).

Fail Softly — Failure of a piece of equipment in which the system's programs let the system fall back to a degraded mode of operation rather than let it fail catastrophically, giving no response to its users.

Fall-Back Procedures — When the equipment develops a fault, the programs operate in such a way as to circumvent this fault. Procedures necessary for fall-back may include switching over to an alternative computer or file, changing file addresses, sending output to a typewriter instead of a printer, using different communication lines, or bypassing a faulty terminal.

Fault Tolerant — Pertaining to a system in which failed components do not cause the system to fail. Fault tolerant systems provide backup components that are automatically activated when the primary component fails. A distributed system which may not have backup for certain components could be considered to be fault tolerant.

Feedback Control — A type of system control obtained when a portion of the output signal is operated upon and is fed back as input in order to obtain a desired effect.

Fiber Optics — The branch of optical technology concerned with the transmission of radiant power through one or more fibers of glass or plastic that are enclosed by material of lower index of refraction. Each fiber transmits light throughout its length by internal reflections. A bundle of spatially aligned fibers can relay an image optically. A simple fiber can be used as a signal transmission material.

Field — The set of horizontal scan lines in one vertical scan of an image. In an interlaced video display as defined by the standard video format, one field will contain the even numbered lines, and the next field will contain the odd numbered lines. See frame.

File, Patient	A set of films of a single patient. Radiologic procedure reports are typically included along with the films in the patient file. This set of films typically represents a record of all procedures performed in the radiology department for that patient and is an official record in a radiology department.
File Gap	An interval of space or time associated with a file to indicate or signal the end of a file.
File Maintenance	The processing of a file to effect changes in the file; for example, updating a master file.
Filter	A network designed to transmit frequencies within one or more frequency bands and to attenuate or block other frequencies.
Flag	(1) A bit of information attached to a character or word to indicate the boundary of a field; (2) An indicator used to tell some later part of a program that some condition occurred earlier; (3) An indicator used to identify the members of several sets which are intermixed.
Floppy Disk	A magnetic storage medium based on a flexible plastic disc contained in a square protective cover, generally used when storage capacity requirements are low (less than 1 megabyte).
Flowchart	A method of diagrammatically representing the steps involved in solving a problem. Flowcharts are used to guide the writing of program instruction sequences.
Fluoro	Fluoroscopy.
Foreground Processing	High-priority processing, usually resulting from real-time entries, given precedence by means of interrupts over lower priority "background" processing.
Format	A contraction meaning the FORM of MATERIAL, designating the way in which information is organized.

Fortuitous Distortion	Distortion resulting from causes generally subject to random laws such as accidental irregularities in the operation of the apparatus and of the moving parts, disturbances affecting the transmission channel, and thermal noise.
Forward	The direction of transmission originating at the head-end of a broadband cable system and relayed "outbound" by the system's bidirectional broadband amplifiers to the system's "subscribers." Transmission on the higher-frequency channels is supported in this direction.
Forward Error Correction	Error correction without retransmission that uses error correcting codes.
Four-Wire Circuit	A circuit using two pairs of conductors, one pair as the "go" channel and another pair as the "return" channel.
Four-Wire Terminating Set	Hybrid arrangement by which four-wire circuits are terminated on a two-wire bases for interconnections with two-wire circuits.
Frame	All the horizontal scan lines in an image, which consists of two fields in an interlaced video display.
Frame Buffer	A temporary storage which contains all the pixels for a complete image.
Frame Rate	The frequency at which an image is completely updated on the display monitor. This is half the field rate in an interlaced video display.
Frequency	The rate of recurrence of some cyclic or repetitive event, such as the rate or repetition of a sine-wave electrical current, usually expressed in cycles per second, or hertz.
Frequency-Derived Channel	Any of the channels obtained from multiplexing a channel by frequency division.

Frequency Modulation	One of three ways of modifying a sine wave signal to make it "carry" information. The sine wave "carrier" has its frequency modified in accordance with the information to be transmitted.
Frequency Transform (Fourier Transform)	An operation that breaks down an image into its fundamental frequency components for subsequent analysis or filtering.
Front End Processor	The communication controller connected to the host processor through which various computer terminals and other devices are attached.
Function Switch	A circuit having a fixed number of inputs and outputs designed such that the output informations is a function of the input information, each expressed in a certain code, signal configuration, or pattern.
Gate	A circuit which yields an output signal that is dependent on some function of its present or past input signals.
Geometric Manipulation	Any operation that alters the spatial geometry of an image. Examples include scaling, rotation, translation, and rubber sheet transformation.
Giga	A prefix meaning ten to the ninth power, one billion, as in Gbps (billion bits per second).
Gray Level	The luminance value assigned to a pixel. A value may range from black, through grays, to white (e.g., an eight bit system accommodates 256 (2^8) levels).
Gray Scale	(1) The luminances available as valid gray levels for a given image processing system. The gray scale represents the discrete gray levels defined in a system--for instance, an 8-bit system accommodates 256 levels; (2) A scale of brightness displayed and photographed with an image.
Group Address	An address assigned to a group of terminals, which may or may not share a single communication channel.
Halon	Trade name for a fire extinguishing chemical commonly used in computer centers.

GLOSSARY (Continued)

Hamming Code	One of the forward error correction code systems named after the inventor.
Handshaking	A preliminary procedure performed by two communicating devices to verify that communication has been established.
Hardcopy	A medium (e.g. film, paper) on which a permanent, usually non-electronic representation of images or text is stored.
Hardware	Physical equipment such as CPU, memory device, interface, etc., used in data processing, as opposed to computer programs, procedures, rules, and associated documentation.
Hardwired	Pertaining to a physical connection for, or characteristic of, a device; for example, the address of a console or I/O device.
Head	The assembly which reads, records, or erases information on a storage device.
Head-End Remodulator	The unit located at the head-end of a broadband bus local area network which receives in a <u>reverse</u> channel the signals transmitted by other network stations, and rebroadcasts those signals back to those other stations in a corresponding <u>forward</u> channel.
Hertz (Hz)	A unit of frequency expressed in cycles per second, where 1 Hz equals 1 cycle/second.
Hexadecimal	A numbering system with a base of 16 represented by the symbols 0 through 9 and A through F.
High-Speed Printer	A printer which operates at a speed more compatible with the speed of computation and data processing so that it may operate on-line.
High-Speed Reader	A reading device capable of being connected to a computer so as to operate on-line without seriously holding up the computer.

High-Split	The broadband system configuration, as determined by the system's bidirectional amplifiers, in which signaling in the spectrum from 5 MHz to 174 MHz is relayed in the reverse direction and signaling in the spectrum from 234 MHz up is relayed in the forward direction.
Histogram	The representation of a frequency distribution by means of rectangles whose widths represent class intervals and whose areas are proportional to the corresponding frequencies. When used to show the gray-scale occupancy of an image, the horizontal axis represents gray level, and the vertical axis represents the number of pixels. This histogram presents an easy-to-read indication of image contrast and luminance dynamic range.
Hit	(1) An isolated electrical noise impulse of sufficient strength to mutilate data; (2) An item from a data base which meets certain search criteria.
Holding Time	The length of time a communication channel is in use for each transmission. Includes both message time and operating time.
Home Loop	A system whose parts, including remote terminals, are all situated in one building or localized area. Also used for communication systems spanning several buildings and sometimes covering a large distance, but using no common carrier facilities.
Horizontal Integration	A method of organizing data files in distributed systems so that users at the same organizational level can share data pertinent to that level's operation, avoiding duplication.
Host Computer	The primary or controlling computer in a data communications system.
Image Analysis	Any operation intended to manipulate or numerically tabulate some aspects of an image.
Image Operation	Any algorithm for effecting a quality enhancement, analysis, or coding of an image.

Image Quality Enhancement	Any image operation serving to bring out some aspect which is either not visible or poorly seen on the original.
Image Store	The memory array within an image processing system that stores an image for subsequent display and processing.
Initialize	To set counters, switches, addresses, or contents of storage to starting values at the beginning of a computer routine.
Intensity	In image interpretation, the gray level of a given pixel.
Interface	A shared boundary or a device to allow data to be passed across such a boundary. An interface might be a hardware component to link two devices or it might be a portion of storage or registers accessed by two or more computer programs. A data transmission interface is a shared boundary defined by common physical interconnection characteristics, signal characteristics, and functional characteristics of the interchange circuits. The standardization of these characteristics makes the interfaces possible.
Interlace	The technique used in the standard video format whereby the field of odd image lines is displayed alternately with the field of even lines. Interlacing is used to reduce noticeable flickering in an image display.
Internal Storage	Storage facilities forming an integral physical part of a computing device from which instructions may be executed.
Interoffice Trunk	A direct trunk link between local central offices.
Interpolation	The insertion of estimated values between known values. This technique might be used with geometric operations when the output pixel coordinates do not land exactly on a defined pixel grid point. Interpolation divides the transformed pixel's brightness and distributes portions to the four surrounding valid pixel locations.

GLOSSARY (Continued)

Interrupt	A break in the normal flow of a system or routine such that the flow can be resumed from that point at a later time. An interrupt is usually caused by a signal from an external source.
Intertoll Trunk	A trunk between toll offices in different telephone exchanges.
Job Stream	A series of jobs (application programs) that are processed one after the other by the computer.
Joint User	A person, firm, or corporation who is designated by the customer as a user of a private line service of that customer and to whom a portion of the charge for the service will be billed.
Key Set	A desk-top telephone set, sometimes called a pushbutton telephone, wherein the buttons are used for intercom, holding, signalling, and/or pick-up of additional telephone lines.
Keyboard	An arrangement of keys for manual operation similar to a typewriter keyboard.
Keyboard Devices	Teleprinters, word processors, CRTs, and other devices that use a keyboard for manual entry of information.
Keyboard Inquiry	Interrogation of the contents of a computer's storage initiated at the keyboard.
Kilo	A prefix meaning thousand.
Laser Disk	See optical (laser) disk.
Lateral	Denotes the side of a patient (away from the midline). A lateral view is an X-ray projection obtained by passing the X-ray beam through the patient from one side to the other.
Leased Line	A communication channel leased for exclusive use from a common carrier and frequently referred to as a Private Line.
Leased Line Network	Generally a telephone network leased from the telephone company.

Levels	The rows of recorded information on magnetic tape. Also used to designate the storage devices of various speeds within a computer.
Light Box	Same as view box.
Line	Communication channel or telephone circuit. Sometimes called a facility.
Line Adapter	A communications interface between the bit-parallel format of a computer and the bit-serial format of a communication channel.
Line Address	A character or set of characters designating a specific communication channel.
Line Dropout	A large, monetary change in the transmission characteristics of a telephone circuit.
Line Feed	Teletypewriter function code which rotates the platen of a page machine to a position to accept the next printed line, keeping the printing mechanism at the same character printer position.
Line Loading	The use of resistors, capacitors, and inductors to compensate for the frequency distortion and delay distortion characteristics of telephone lines.
Line Printer	A device which prints one line of characters across a page at a time.
Line Segment Enhancement	Any image operation that accentuates line segment details within an image. With a 3x3 kernel size, line segments in the vertical, horizontal, or either diagonal may be enhanced.
Line Switching	Switching in which a circuit path is set up between incoming and outgoing lines. Contrast with message switching, in which no physical path is establish.
Line Turnaround	In half duplex communication, the switching of modems and communication channel from transmission in one direction to transmission in the opposite direction.

Link	A transmission facility to transfer data between communications ports.
Link Communication	The physical means of connecting one location to another for the purpose of transmitting and receiving information.
Listening Mode	In data communications, a mode in which a node does not send or receive messages, but monitors messages on the line.
Loading	Adding inductance (load coils) to a transmission line to minimize amplitude distortion.
Local Area Network (LAN)	A data communications network designed to send and receive data from devices over intermediate distances, in the 1-10 kilometer range.
Local Channel	A channel connecting a communications subscriber to minimize amplitude distortion.
Local Exchange or Local Central Office	An exchange in which telephone subscribers' lines terminate.
Local Line or Local Loop	A channel connecting the subscriber's equipment to the line terminating equipment in the central office exchange.
Local Terminal	A terminal connected to a computer by cable rather than a communications link.
Location	A place in the main memory or auxiliary storage where a unit of data may be stored or retrieved. Synonymous with address.
Logical Diagram	In logical design, a diagram representing the logical elements and their interconnections without necessarily expressing construction or engineering details.
Long-Space Disconnect	A feature of some modems which causes the modem to terminate a telephone call in response to the receipt of a space signal for an extended period of time.

Look-Up Table (LUT)	In digital imaging, the means for implementing a point process. The look-up table is a memory device loaded with map values for a given point process. Each input pixel value acts as an address to the memory, whose output, or map value, is subsequently used as the output pixel value. See Map.
Loop	(1) In computers, a coding technique whereby the same group of instructions is reused with modification of the data being manipulated; (2) In communications, normally the circuit between the subscribed and central office.
Loop Checking, Message Feedback, or Information Feedback	Terms for a method of checking the accuracy of transmission of data in which the received data are returned to the sending end for comparison with the originally transmitted data.
Loop Signalling	A method of signalling between two communicating devices by the repetitive interruption of a DC current carrying loop circuit.
Lossless Compression	A compression process that involves no loss of information from the original image.
Lossy Compression	A compression process that allows image error to occur through the compression/reconstruction process so a greater amount of compression can be realized than in a lossless algorithm for the same image. The amount of error can be made significantly small if the statistics of the image are known and the right algorithm is used for an image.
Luminance	The total lumens actually leaving a surface per unit area. Luminance is usually measured in candelas per square meter.
Luminance Resolution	The precision with which the luminance of a pixel can be measured, or quantized (e.g., a resolution of eight bits represents 256 possible gray values or luminance levels).

Mach-Band Effect (Mach Effect) A visual illusion, created by the response characteristics of the eye, in which there is a perceived edge accentuation when viewing sharp black to white transitions.

Machine Language The only language a computer understands. All programs are either written in or converted to machine language prior to operation in the computer.

Macro Instruction A symbolic program language statement that produces several machine instructions.

Magnetic Core A magnetic substance capable of assuming and remaining in one of two conditions of magnetization.

Magnetic Core Storage A storage device in which binary data are represented by the direction of magnetization in each unit of an array of magnetic core.

Magnetic Disc A flat circular plate with a magnetizable surface layer on which data can be stored by magnetic recording. Disc storage provides random access to stored data.

Magnetic Disk Storage A storage device or system consisting of magnetically coated disks on the surface of which information is stored in the form of magnetic spots arranged to represent binary data. These data are arranged in concentric circular tracks on the disk surfaces and are accessible to reading and writing heads on an arm which can be moved mechanically to the desired disk and then to the desired track.

Magnetic Drum A cylinder having a surface coating of magnetic material, which stores binary information by the orientation of magnetic dipoles near or on its surface. Since the drum is rotated at a uniform rate, the information stored is available periodically as a given portion of the surface moves past one or more flux detecting devices called heads located near the surface of the drum.

Magnetic Head A transducer for converting electric variations into magnetic variations for storage on magnetic media, or for reconverting energy so stored into electric energy. It may also be used for erasing such stored energy.

Magnetic Tape	A tape whose surface layer can be divided into discrete units each of which can be charged positively or negatively. Magnetic charge can be altered so that the information stored on the magnetic tape can be modified. Tape storage does not provide random access to stored data; it must be searched sequentially.
Magnetic Tape Storage	A storage device in which data are stored in the form of magnetic spots on metal or coated plastic tape. Binary data are stored as small magnetized spots arranged in column form across the width of the tape. A read-write head is usually associated with each row of magnetized spots so that one column can be read or written at a time as the tape traverses the head.
Mainframe	Host and communications port functions combined in the same system.
Main Storage	Usually the fastest storage device of a computer and the one from which instructions are executed.
Map	A graphic representation of the mapping function used in a point process. The map graphically defines how input pixel luminances are transformed to resultant output luminances. See Look-up table.
Mapping Function	A mathematical equation defining a point process. A mapping function is the formula that calculates resultant output pixel luminances from input luminances.
Mark	Presence of signal. The state of a communication channel corresponding to the transmission of a binary one.
Mark-Hold	The normal no-traffic line condition whereby a steady mark is transmitted. (Compare with Space-Hold.)
Mark-to-Space Transition	The transition or switching from a marking state to a spacing state.
Masking	A technique for sensing specific binary conditions and ignoring others. Typically accomplished by placing zeros in bit positions of no interest, and ones in bit positions to be sensed.

Master File	A main reference file.
Master Station	(1) The main station in a group of stations that controls the transmission of all the stations; (2) A unit having control of all other terminals on a multipoint circuit for purposes of polling and/or selection of next transmitter.
Matrix	(1) An array of quantities in a prescribed form, usually capable of being subject to a mathematical operation by means of an operator or another matrix according to prescribed rules; (2) An array of coupled circuit elements (e.g., diodes, wires, magnetic cores, and relays) that are capable of performing a specific function such as the conversion from one numerical system to another.
Mean Time to Repair	The average time taken to correct a system fault once identified.
Median Filter	An image spatial filtering operation based on an input pixel and its eight neighbors. The resultant value is the median of the nine pixel luminances such that an equal number of values are greater than and less than the resulting median output value.
Mega	A prefix meaning million.
Memory	(1) An organization of storage elements, primarily for the retrieval of information; (2) The rapid-access storage elements on which instructions are executed and data operated on.
Memory Cycle	Any one of a variety of sequences used to transfer data in or out of a memory device such as the image store.
Memory Cycle Time	The time necessary to complete a memory cycle.
Memory Data Register	The interface between the input, output, memory, and Central Processing Unit. Normally, information can only get out of or into the memory via the memory data register.
Memory Dump	A listing of the contents of storage devices.

Memory Protection	A means of assuring, with special hardware, that the contents of main memory will not be destroyed or altered. Memory protection devices help guard a real-time system against the effects of equipment malfunctions and program bugs.
Message	A communication prepared for information interchange in a form suitable for passage through the interchange medium. It includes: (1) all portions of the communication, such as machine sensible controls; (2) an indication of the start of the message and the end of the message.
Message Format	Rules for the placement of such portions of a message as message heading, address, text, and end of message.
Message Heading	Part of a message containing all components preceding the text.
Message Numbering	The identification of each message within a communications system by the assignment of a sequential number.
Message Reference Block	When more than one message in the system is being processed in parallel, an area of storage is allocated to each message and remains uniquely associated with that message for the duration of its stay in the computer. This message reference block will normally contain both the message and data associated with it that are required for its processing.
Message Retrieval	The capability to retrieve a message after it has entered an information system.
Message Routing	The function performed at a central message processor of selecting the route, or alternate route if required, by which a message will proceed to the next point in reaching its destination.
Message Switching	The technique of receiving a message, storing it until the proper outgoing line is available, and then retransmitting to its addressee. No direct connection between the incoming and outgoing lines is set up as in line switching.

Metallic Circuit	A telephone circuit providing a direct-current connection between terminating points, without intervening transformers, amplifiers, etc.
Microcommand	A command specifying an elementary machine operation to be performed.
Microsecond	One-millionth of a second.
Microwave	Any electromagnetic wave in the radio-frequency spectrum above 890 megacycles per second.
Mid-split	The broadband system configuration, as determined by the system's bidirectional amplifiers, in which signaling in the spectrum from 5 MHz to 108 MHz is relayed in the reverse direction and signaling in the spectrum from 162 MHz up is relayed in the forward direction.
Millisecond	One-thousandth of a second.
Mnemonic	A symbolic designator consisting of alphabetic, numeric, or combinations of alphabetic and numeric characters.
Mode	A style or method of operation characterized by the use of specific facilities in a specific way.
Model, Mathematical	A collection of equations that represent mathematically what goes on in a process. A mathematical description of a process.
Modem	(Modulation/demodulation unit), a hardware unit which converts the binary signals of user equipment to audio analog signals for transmission on a communication circuit.
Modulation	The process by which some characteristic of one wave is varied in accordance with another wave or signal. This technique is used in data sets and modems to make computer and other machine signals compatible with communications links over which they must travel.

Modulation, Amplitude	A method of transmission whereby the signal wave voltage is impressed upon a higher frequency carrier wave whose amplitude is varied in accordance with amplitude variations of the signal wave.
Module	(1) An interchangeable plug-in item containing components; (2) An incremental block of storage or other building block for expanding computer capacity.
Monochrome	A term pertaining to an image represented by a single color. Generally, a monochrome image is presented as black and white.
Multidrop Circuit	A circuit interconnecting several stations.
Multidrop Line	A line or circuit interconnecting several stations
Multiplexing	A method for achieving shared use of a communication channel by the division of a transmission facility into two or more channels either by splitting the frequency band transmitted by the channel into narrower bands, each of which is used to constitute a distinct channel (frequency-division multiplexing), or by allotting this common channel to several different information channels, one at a time (time-division multiplexing).
Multiplexer	A device which uses several communication channels at the same time, and transmits and receives messages and controls the communication lines.
Multiprocessor	A computer with multiple arithmetic and logic units for simultaneous use.
Multiprogramming	The concurrent execution of more than one program on a single computer.
Multistation	Any network of stations capable of communication with each other, whether on one circuit or through a switching center.
MUX	Contraction of the word multiplexer.
Nanosecond	One-thousandth of millionth of a second.

Narrowband	A communications channel with a bandwidth less than that of a voice grade channel.
Negative Acknowledge (NAK)	A communication control character transmitted by a receiver as a negative response to the sender.
Network	(1) A series of points interconnected by communications channels; (2) The switched telephone network of telephone lines normally used for dialed telephone calls; (3) A private line network of communications channels confined to the use by one customer.
Node	In a data network, a point where one or more functional units interconnect data transmission lines, especially such a point on a local area network (LAN).
Noise	Random electrical signals, introduced by circuit components or natural disturbances, which degrade the performance of a communications channel.
Nonerasable Storage	Read-only storage (i.e., storage into which data once entered cannot be modified).
Nyquist Criterion	The theoretical requirement used to define sampling rate in an image acquisition system. The sampling rate must be at least twice that of the highest spatial frequency to be resolved in the reconstructed image.
Object Program	The machine language version of a high-level or assembly language program which the computer can understand.
Odd Parity Check	A check which tests whether the number of digits in a group of binary digits is odd in order to discover possible transmission errors.
Offline	Not controlled directly by the host computer operating system.
Online	Being controlled directly by or in direct communication with a host computer.

Online Computer System	One in which the input data enter the computer directly from their point of origin and/or output data are transmitted directly to where they are used. The intermediate stages such as keying data into diskettes, writing magnetic tape, or offline printing are largely avoided.
One-Way Channel (Simplex)	A channel which permits transmission in one direction only.
Open-Ended	Organized so the addition of new terms, subject headings, or classifications does not disturb preexisting system.
Open-Wire	Overhead telephone line having each physical wire separately supported by insulators.
Open Systems Interconnection Reference Model (ISO/OSI)	The International Standards Organization's Open Systems Interconnections reference model is the standard for local area network (LAN) architecture. The model consists of seven hierarchical layers: physical, data link, network, transport, session, presentation, and application. These layers address LAN design from the specification of the physical transmission medium to the capabilities of user interaction with LAN services. LAN manufacturers may or may not develop all the software necessary to address each layer of the model.
Operand Register	Holds the addresses of the memory location being serviced.
Operating System	Software that controls the execution of computer programs and that may provide scheduling, debugging, input/output control, accounting, compilation, storage assignment, data management, and related services.
Operating Time	The time required for seizing the line, dialing the call, waiting for the connection to be established, and coordinating the forthcoming transaction with the personnel or equipment at the receiving end.

Operator Console — The console used for performing imaging procedures. This is the only console where the scan program can be used.

Optical (Laser) Disk — A storage disk using a laser to retrieve digital data. Optical disks provide significantly greater storage capacity than magnetic disks. Although the state of the art does not include optical disks with erasable memory, this advance is anticipated.

Originating Station — The telecommunications station from which the message is first transmitted.

Originator — The composer of the message.

Output — (1) Data that has been processed; (2) The state or sequence of states occurring on a specified output channel; (3) The device or collective set of devices used for taking data out of a device; (4) A channel for expressing a state of a device or logic element; (5) The process of transferring data from internal storage to an external storage device.

Output Block — (1) A block of computer words considered as a unit and intended to be transferred from an internal storage medium to an external destination; (2) A section of internal storage reserved for storing data which are to be transferred out of the computer; (3) A block used as an output buffer.

Output Circuit — The communications link between the computer and the output station for transmission of characters by the computer to the output station.

Output Devices — Devices used to receive the information from the computer and make it available to human users.

Output Station — The telecommunications station to which the computer transmits characters. Also known as "receive station."

Overlay — A technique for bringing routines into high-speed storage from some other form of storage during processing, so that several routines will occupy the same storage locations at different times. Overlay is used when the total storage requirements for instructions exceed the available main storage.

Packing Density — The number of characters or units of useful information contained within a given linear dimension (e.g., on tapes or disks).

Pad Character — A character inserted to fill a blank time slot in synchronous transmission, or inserted to fulfill a character-count requirement in transmissions of fixed block lengths.

Padding — A technique used to fill out a block of information with dummy records.

Parallel Access — The process of obtaining information from or placing information into storage where the time required for such access is dependent on the simultaneous transfer of all elements of word from a given storage location.

Parallel Computer — A computer in which the digits or data lines are handled concurrently by separate units of the computer. The units may be interconnected in different ways as determined by the computation to operate in parallel or serially. Mixed serial and parallel machines are frequently called serial or parallel according to the way arithmetic processes are performed. An example of a parallel computer is one which handles decimal digits in parallel although it might handle the bits which comprise a digit either serially or in parallel.

Parallel Operation — The performance of several actions, usually of a similar nature, simultaneously through provision of individual, similar, or identical devices for each such action. Parallel operation is performed to save time over serial operation. Parallel operation requires more equipment.

Parallel Transmission — (1) Simultaneous transmission of the bits making up a character or byte, either over separate channels or on different carrier frequencies on the channel; (2) The simultaneous transmission of a certain number of signal elements constituting the same data signal.

Parity (Parity Bit)	A method of error detection using an extra bit to make the total number of bits in a character either odd or even. If a character is sent with odd parity, it should be received with odd parity if no errors are introduced by the communication process.
Parity Check	Addition of non-data bits to the data in a message, making the number of ones in a grouping of bits either always even or always odd. This permits detection of bit groupings that contain single errors. Parity checks may be applied to characters, blocks, or any convenient bit grouping to help detect errors of transmission.
Parity Check, Vertical	A parity check applied to all bits in one character. (Also called vertical redundancy check.)
Password	An alphanumeric symbol known only to a specific authorized user and to the system. It is used to protect against unauthorized access to the computer system.
Phase Equalizer or Delay Equalizer	A corrective method applied in a network which is designed to make the phase delay or envelope delay of a circuit substantially constant over a desired frequency range.
Phase Modulation	One of three ways of modifying a sine wave signal to make it "carry" information. The sine wave "carrier" has it phase changed in accordance with the information to be transmitted.
Photometric Correction	An image operation that corrects image sensor response and spatial distortion.
Pilot Model	A model of a computer-based system used for program testing purposes which is less complex than the complete system (e.g., the files used on a pilot model may contain a smaller number of records than the operational files; there may be fewer lines and fewer terminals per line).
Pixar	An experimental workstation developed by Pixar Incorporated with advanced image processing capabilities.

Pixel	The fundamental picture element of a digital image, (e.g., display screens present a 1024 x 1024 pixel matrix). Each pixel can be thought of as a dot of luminance. When a large number of them with varying luminance are placed adjacent to each other a picture is formed.
Plant	Equipment and line facilities providing communications by electronic means.
Point Process	An image process used to evoke contrast and luminance alterations upon an image, in which each input pixel luminance is transformed through a mapping function creating an output pixel luminance value. See look-up table.
Point-to-Point	Communication between two terminal points only, as opposed to Multipoint and Multidrop.
Polar Operation	Circuit and operation in which mark and space transitions are represented by a current reversal.
Poll	A flexible systematic method, centrally controlled, for permitting stations on a multipoint circuit to transmit without contending for the line.
Polling	A means of controlling data transfer on a communication line or ascertaining the status of devices in a system. An alternative to contention.
Polling List	A list for each channel which tells the sequence in which the terminals are to be polled by the network's controller.
Port	An entry point into a computer or data communications system.
Posteroanterior (PA)	In radiology, denotes that the direction of the X-ray beam producing an X-ray film was from the back to the front.
Power Splitter	A small module which electrically and mechanically couples one large diameter trunk cable to other large diameter trunk cables, providing a branching topology for the broadband trunk. A power splitter splits the

	signal energy received in the forward direction among the outgoing trunks, and combines any signal energy received in the reverse direction. It passes low-frequency (less than 1 kHz) ac power between the trunk cables. It contains only passive electrical components (R, L, C).
Precedence (Priority)	Designation assigned to a message to indicate the relative order of handling.
Preventive Maintenance	The maintenance of a computer system, which is necessary to keep equipment in top operating condition and to preclude failures during production runs.
Primary Storage	The principal memory of the computer.
Private Line	The channel and channel equipment furnished to a customer for his exclusive use, not requiring interexchange switching arrangements.
Procedure	An action performed on a patient for the purpose of acquiring data. The data usually will be in the form of images when the procedure is performed in the radiology department. The term <u>procedure</u> is sometimes used interchangeably with <u>study</u>.
Process, Active	A process whose existence is recognized by the computer system.
Processing, In-Line	Processing transactions as they occur, with no preliminary editing or sorting before they enter the system.
Program	(1) A collection of instructions to perform certain tasks; (2) A logical sequence of instructions which the computer must execute to solve a problem or perform a task.
Program Flow-charting	A series of detailed pictorial functional representation defining a logical solution to a problem. Used to guide the actual coding of computer language.
Prone	Horizontal position of the body, lying face down.

Propagation Delay — The time necessary for a signal to travel from one point on a circuit to another.

Protocol — An operating convention consisting of a sequence of rules or instructions. An example would be the sequencing rules for requests and responses by which nodes in a communications network coordinate and control data transfer operations and other operations. Networks produced by different manufacturers use different proprietary protocols, which sometimes makes interfacing components of different systems impossible.

Pulse — A unit of energy characterized in terms of duration and amplitude. When representing information, it can be regarded as a bit; when not representing information, it can be regarded as noise.

Pulse Modulation — Transmission of information by modulation of a pulsed or intermittent carrier. Pulse width, count, position, phase, or amplitude may be varied to encode the information.

Pulse Repetition Rate — The number of electric pulses per unit of time experienced by a point in a computer, usually the maximum, normal, or standard pulse rate.

QTA — A communications term indicating that a message has been interrupted, but will be repeated in its entirety without further action on the part of the station receiving the QTA notice.

QTB — A communications term indicating that a message has been interrupted while being relayed and cannot be automatically furnished in complete form. It is the responsibility of the station receiving a QTB notice to contact the station that originally prepared the message and request that it be repeated.

Quantization — The act of converting an analog signal, such as pixel luminance, to one of a specific number of distinct levels. The resulting level can then be represented digitally.

Queue	Waiting line resulting from temporary delays in providing service.
Queuing	Arranging into a sequence for processing.
Query Message	A message directed back to the originator to check correctness of the text received by the addressee.
Random Access	The capability to obtain data from a storage device in such a way that the process depends only on the location of the data and not on a reference to data previously accessed. Disk storage provides random access memory; tape storage does not. Random access memory is necessary to support rapid system response times.
Random Access Memory (RAM)	A memory device allowing direct access (for reading or writing of data) to any memory location or address.
Read	To transfer information from any input device to main memory or auxiliary storage.
Read-Write Head	Used for reading, recording, or erasing polarized spots which represent information on magnetic tape, disk, or drum.
Real-Time	Capable of affecting the immediate environment. A real-time computer system affects its environment by receiving, processing, and returning data to its users quickly enough to affect the users' functioning in the environment at that time.
Real-Time Clock	A clock which indicates the passage of actual time, in contrast to a fictitious time set up by a computer program.
Real-Time Communication	Information transmitted, received, and processed concerning an event currently taking place.
Reasonableness Checks	Tests made on information being transmitted to ensure that the data lie within a given "reasonable" range.

Reconstruction	The process of reformulating an analog or digital image for display from digitally stored image data. In medical imaging, reconstruction means the processing of a set of projection data into transverse slices via an algorithm such as filtered back projection.
Record	A group of related facts or field of information treated as a unit.
Recovery From Fall-Back	When the system has switched to a fall-back mode of operation and the cause of the fall-back has been removed, the system is restored to its former condition. The recovery process may involve updating information in the files to produce two duplicate copies of the file.
Redundancy	A repetition of information, or the insertion of information which is not new, and therefore redundant. The use of check bits and check characters in data communication is a form of redundancy, hence the terms cyclic redundancy, longitudinal redundancy, vertical redundancy.
Redundancy Check	An automatic check on data based on the systematic insertion of duplicate components or characters used solely for error checking purposes.
Referring Physician	A doctor who sends patients to the radiology department for a study.
Regional Center	A control center connecting sectional centers of the telephone system together. Every pair of regional centers in the United States has a direct circuit group running from one center to the other.
Regional Image Statistics	Measurements of the mean and variance, for example, of the gray level values in neighborhood areas of interest in an image.
Relay	(1) Transmission forwarded through an intermediate station; (2) Electrically operated switch, usually comprised of an electromagnet, and armature, and a number of contact springs; (3) Device in which a small

	current or power flow can be made to control a larger current or power flow in a secondary circuit by opening or closing contacts.
Reliability	A measure of the ability to function without failure.
Remedial Maintenance	The maintenance performed following equipment failure, therefore, performed on an unscheduled basis.
Remote	Physically distant from a local computer, terminal, or multiplexer.
Remote Access	An arrangement whereby distant terminals have access to a central computer via communications channels.
Remote Terminal	A terminal attached to a computer system through a telecommunications link.
Repeater	(1) A device whereby currents received over one circuit are automatically repeated and sent along another circuit or circuits, generally in an amplified and/or reshaped form; (2) A device used to restore signals which have been distorted because of attenuation to their original shape and transmission level. Commonly used in digital networks.
Repeater Station	An intermediate point in a transmission system where line signals are received, amplified or reshaped, and retransmitted.
Report Generator	A technique for producing complete data processing reports giving only a description of the desired content and format of the output reports, and certain information concerning the input file.
Report, Radiological	The radiologist's interpretation of a radiologic study. In addition to patient data, the report usually contains a description of the findings and a conclusion or impression based on these findings.
Residual Error Rate or Undetected Error Rate	The ratio of the number of bits, unit elements, characters, or blocks incorrectly received but undetected or uncorrected by the error-control equipment, to the total number of bits, unit elements, characters, or blocks sent.

Response Time	The time the system takes to react to a given input. For example, if a message is keyed into a terminal by an operator and the reply from the computer is typed at the same terminal, response time is the time interval between the operator pressing the last key and the terminal typing the first letter of the reply.
Reverse	The direction of transmission originating at the "subscribers" of a broadband cable system, terminating at the head-end and relayed "inbound" by the system's bidirectional broadband amplifiers. Transmission on the lower-frequency channels is supported in this direction.
Reverse Channel	A capability for signalling in a direction opposite to the main flow of data, usually only a fraction of the bandwidth or bit rate of the main channel. Sometimes called a supervisory channel, the reverse channel is frequently applied to acknowledging the correct receipt of data.
Ring	In a data communications network, a structure which involves two or more nodes connected in a closed loop with each node connected on a point-to-point data flow basis to two adjacent nodes.
Ring Indicator (RI)	An EIA RS-232 designation applied to a sense circuit used by a terminal or computer to detect the presence of ringing current on the communication circuit, and hence predict an incoming call.
Routine	A sequence of machine instructions that carry out a well-defined function.
Routing	The assignment of the communications path by which a message or telephone call will reach its destination.
Routing, Alternate	Assignment of a secondary communications path to a destination when the primary path is unavailable.
Routing Indicator	An address or group of characters in the heading of a message defining the final circuit or terminal to which the message is to be delivered.

GLOSSARY (Continued)

RS-232	A technical specification published by the Electronic Industries Association establishing the interface requirements among modems, terminals, and computers.
Rubber Sheet Transformation	A geometric image operation used to contort an image through the use of specified control points.
Run-Length Coding	An image data compression technique relying on the coding of strings of pixels of identical luminance rather than absolute luminance.
Sagittal	A plane which divides the body from front to back into right and left portions.
Sample	A segment of an analog signal usually collected over a fixed time interval which is much shorter than the total duration of the analog signal. The sample may be subsequently digitized.
Sampling	The subdivision of the (analog) signal into discrete segments but not including the digitization process.
Satellite Computer	A processor connected locally or remotely to a larger central processor and performing certain processing tasks--sometimes independent of the central processor, sometimes subordinate to the central processor.
Saturation Testing	Program testing with many messages. Intended to debug those errors which occur infrequently and which may be triggered by rare coincidences associated with high volumes of traffic, such as two different messages arriving at the same time.
Scaling	A geometric image operation used to enlarge or shrink an image.
Scan	(1) To examine stored information for a specific purpose such as content or arrangement; (2) To examine the status of communication lines or other input/output channels.

Seek	A mechanical movement involved in locating a record in a random-access file. This may be the movement of an arm and head mechanism that is necessary before a read instruction can be given to read data in a certain location on the file.
Selective Calling	The ability of the transmitting station to specify which of several stations on the same line is to receive a message.
Self-Checking Code	Uses expressions such that one or more errors in a code expression produces a forbidden combination. A parity check makes use of self-checking code exploring binary digits in which the total number of 1's (or 0's) in each permissible code expression is always even or always odd. A check may be made for either even parity or odd parity. A redundancy check employs a self-checking code which makes use of redundant digits called check digits.
Self-Checking Numbers	Numbers which contain redundant information so that an error in them, caused, for example, by noise on a transmission line, may be detected.
Semiconductor	A solid element with an electrical conductivity that lies between the high conductivity of metals and the low conductivity of insulators and which can be selectively controlled. Semiconductor circuit elements include crystal diodes and transistors. Used extensively in computer manufacture.
Sense	(1) To examine, particularly relative to a criterion; (2) To determine the present arrangement of some element of hardware, especially a manually-set switch; (3) To read punched holes or other marks.
Sensitivity	In system performance analysis, a measure of the change in system performance per unit of change in a specific independent variable.
Sequential/Serial Access	Obtaining information from or placing information into storage where the time required for such access is dependent on waiting while nondesired storage locations are processed in turn.

Serial Operation	The transmission of the bits of a character in sequence, one at a time.
Serial Transmission	Used to identify a system wherein the bits of a character occur serially in time (implies a single transmission channel).
Service (by Carriers)	(1) The function performed by the common carriers in supplying the communication needs of the subscribers; (2) The quality of the service supplied by the common carrier.
Service Bureau	An installation where the user can lease processing time on a central processor and peripheral equipment. The user supplies the program, and the center will load both program and data to be processed, process the data, and deliver the results to the user. Data communications may be used between the user and the center to move the information electrically. The service bureau may also provide such services as keypunching the data and preparing it for processing.
Service Message	A message originated between relevant switching centers and/or communications stations concerning such matters as the transmission of previous messages; reports of garbling, nondelivery, or misdirection; communications discrepancies and incidents of equipment or circuit difficulties.
Service Routine	Routines for assisting in maintenance and operation of the computer as well as the solution of production problems. Includes monitoring or supervisory routines, assemblers, compilers, diagnostics for computer malfunctions, simulation of peripheral equipment, general diagnostics, and input data. Service routines are generally standardized so as to meet the servicing needs at a particular installation, independent of any specific production type routines requiring such services.
Shift-and-Difference Edge Enhancement	An edge enhancement operation by which an image is skewed by one pixel either up or to the left and then subtracted from the original generating horizontal or vertical edge enhancements. The process is known for its ease of implementation.

Shift-In (SI)	A control character indicating that the code combinations which follow shall be interpreted according to the standard code table.
Shift-Out (SO)	A control character indicating that the code combinations which follow shall be interpreted as outside of the character set of the standard code table (nonprintable) until a Shift-In character is reached.
Sideband	The frequency band on either the upper or lower side of the carrier frequency within which fall the frequencies produced by the process of modulation.
Signal Attenuation	The reduction in the strength of electrical signals.
Signal Element	That part of a signal which occupies the shortest interval of the signalling code. Considered to be of unit duration in building up signal combinations.
Signal-to-Noise Ratio (SNR or S/N)	Used to describe the relative contributions to a detected signal of the true signal and random superimposed signals ("noise"). One common method to improve (increase) the SNR is to average several measurements of the signal on the expectation that random contributions will tend to cancel out.
Simplex	Communication in only one direction.
Simplex Circuit	A circuit permitting the transmission of signals in one direction only.
Simplex Mode	Operation of a communication channel in one direction only, with no capability for reversing.
Simultaneous Contrast	A visual illusion created by the response characteristics of the eye. The effect is to make a region of an image appear brighter or darker depending upon the surrounding brightness.
Simulation	(1) Simulation for design and monitoring. This is a technique whereby a model of the working system can be built in the form of a computer program. Special computer languages are available for producing this model. A complete system may be described by a

	succession of different models. These models can then be adjusted easily, and the system that is being designed or monitored can be experimented with to test the effect of any proposed changes. The simulation model is a program that is run on a computer separate from the system that is being designed; (2) Simulation of input devices. This is a program testing aid. For various reasons it is undesirable to use actual lines and terminals for some of the program testing. Therefore, magnetic tape or other media may be used and read in by a special program which makes the data appear as if they came from actual lines and terminals. Simulation in this sense is the replacement of one set of equipment by another set of equipment by another set of equipment and programs, so that the behavior is similar; (3) Simulation of supervisory programs. This is used for program testing purposes when the actual supervisory programs are not yet available. A comparatively simple program to bridge the gap is used instead. This type of simulation is the replacement of one set of programs by another set which imitates it.
Single-Addressed Message	A message to be delivered to only one destination.
Single Sideband	Carrier system in which one sideband is transmitted and the other is suppressed.
Skip Code	A function code which directs a machine to omit certain fields of information.
Software	Computer programs, procedures, and rules governing the operation of a computer system.
Source Data Automation	The many methods of recording information in coded forms on paper tapes, punched cards, or tags that can be used over and over again to produce many other records without rewriting.
Source Programs	Programs written by the programmer and requiring translation to object programs to operate the computer.

Space	(1) Absence of a signal. The state of a communication channel corresponding to the transmission of a binary 0; (2) A character code which causes a printer mechanism to leave a character width with no printed symbol.
Space-Hold	The normal no-traffic line condition whereby a steady space is transmitted. (Compare with Mark-Hold.)
Space-to-Mark Transition	The transition from a spacing state to a marking state in a circuit.
Spatial Filtering	The set of image operations allowing the attenuation or accentuation of spatial frequencies within an image. Such operations include low and high pass filtering and are generally carried out by a group process.
Spatial Frequency	Spatial rate of change in an image. The concept dealing with the spatial rate of luminance change in an image. Luminance fluctuations occurring in close proximity to one another represent high spatial frequencies, whereas regions of relatively constant luminance represent low spatial frequencies.
Spatial Resolution	Property of distinguishing two equal sized adjacent objects in the same plane.
Spectrum	(1) A continuous range of frequencies, usually wide, within which waves have some specific common characteristic; (2) A graphical representation of the distribution of the amplitude (and sometimes phase) of the components of a wave as a function of frequency. A spectrum may be continuous or contain only points corresponding to certain discrete values.
Spiral Parity	A system whereby the check character is developed by making diagonal rows, either odd or even.
Splitter	A smaller version of the power splitter used to couple drop cables together. It does not pass low-frequency ac power between the drop cables.

Stand-Alone Capability	Designed to function independent of a host computer, either all of the time or some of the time.
Standard Video Format	The RS-170 timing and voltage level specifications dictating the qualities of the United States black-and-white commercial television signal.
Star	In a data communications network, a structure which involves one or more nodes connected on a point-to-point data flow basis to a central node, but not to each other.
Start Bit	A bit used in asynchronous transmission to precede the first bit of a data character transmitted serially, signalling the start of the character.
Start of Header (SOH)	Synonymous with the Start of Message.
Start of Message (SOM)	One or more characters used to identify the start of message. This character or characters is optionally permitted depending on the type of code in any other sections of a message and thus has the meaning of SOM only the first time that it appears in a given message (i.e., after the previous EOM).
Start of Text (STX)	One or more specific characters that indicate the beginning of text.
Start-Stop System	A system in which each group of code elements is preceded by a start signal which prepares the receiving mechanism for the reception and registration of a character, and is followed by a stop signal which brings the receiving mechanism to rest in preparation for the reception of the next character. (Contrast with Synchronous System.) Start-stop transmission is also referred to as asynchronous transmission.
Station	One of the input or output points of a communications system (e.g., a terminal, the telephone set in the telephone system, or the point where the computer interfaces the channel on a leased line).

Status Maps	Tables which give the status of various programs, devices, input/output operations, or the status of the communication lines.
Status Reports	A term used to describe the automatic reports generated by a system generally covering service conditions such as circuits and stations out of service and back in service.
Step-by-Step Switch	A switch that moves in synchronism with a pulse device such as a rotary telephone dial. Each digit dialed causes the movement or successive selector switches to carry the connection forward until the desired line is reached. Also called stepper switch. (Compare with Line Switching.)
Stop Bit	A bit (or bits) used in asynchronous transmission to succeed the last bit of a data character transmitted serially, and representing the quiescent state in which the line will remain until the next start bit begins.
Stop Element	The last element of a character in asynchronous serial transmissions used to ensure recognition of the next start element.
Storage	A general term for any device capable of retaining information.
Store-and-Forward	The interruption of data flow from the originating terminal to the receiver by storing the information enroute and forwarding it at a later time.
Store-and-Forward Message Switching	A facility for accepting messages as rapidly as they are received from originating terminals, storing the messages, and forwarding them at a rate acceptable to the receiver.
Study	The set of images and other data acquired during a radiological procedure.

Sub-Split	The broadband system configuration, as determined by the system's bidirectional amplifiers, in which signaling in the spectrum from 5 MHz to 30 MHz is relayed in the reverse direction and signaling in the spectrum from 54 MHz up is relayed in the forward direction. (This configuration is commonly found in community residential cable TV systems.)
Subvoice-Grade Channel	A channel of bandwidth narrower than that of voice-grade channels, usually subchannels of a voice-grade line.
Supervisory Control	A control system which furnishes intelligence, usually to a centralized location, to be used by an operator to supervise the control of a process or operation. May be used to prepare and transmit supervisory control messages to the Switching Center computer.
Supervisory Programs	Programs designed to coordinate service and augment the machine components of the system, and coordinate and service application programs. They handle work scheduling, input-output operations, error actions, and other functions.
Supervisory Signals	Signals used to indicate the various operating states of a circuit.
Supervisory System	The complete set of supervisory programs used on a computer system.
Supine	Horizontal position of the body, lying flat on back.
Support Programs	Programs to install the system, including diagnostics, testing aids, data generator programs, and terminal simulators.
Switched Line	A telephone line connected to the switched telephone network.
Switching Center	Equipment at a central location at which multiple circuits terminate, capable of interconnecting circuits or transferring traffic among circuits.

Switchover	When a failure occurs in the equipment, switching to an alternative component. This may be an alternative file unit, an alternative communication line, or an alternative computer. The switchover process may be automatic or manual.
Sync (Synchronous Idle)	A communication control character used by a synchronous transmission system in the absence of any other character to provide a signal from which synchronism may be achieved or retained. Start and stop bits are not required when this mode of operation is used.
Sync Character	A character transmitted to establish character synchronization in synchronous communication. When the receiving station recognizes the Sync Character, the receiving station must synchronize its receiving clock to that of the transmitting station, and communication can begin.
Synchronization	(1) The process of achieving synchronous operation of a transmitting and receiving station; (2) The process of first transmitting a series of synchronizing characters prior to the characters being transmitted. This synchronizes the transmitter and receiver. Synchronizing characters may be interspersed among the data characters to maintain synchronization. Start and stop bits are not required.
Synchronous Computer	A computer in which all operations and events are controlled by equally spaced pulses from a clock.
Synchronous System	A system in which the sending and receiving instruments are operating continuously at substantially the same frequency and are maintained, by means of correction, if necessary, in a desired phase relationship. (Contrast with Start-Stop System.) Timing information is sent with the user's message data in synchronous systems.

Synchronous Transmission	(1) The transmission of data bits in step with a synchronizing clock; (2) A transmission process such that the bits of one character are followed immediately by those of the next, with no pauses and no start or stop bits. (Contrast with Asynchronous or Start-Stop Transmission.)
System	A collection of people, machines, programs, and methods organized to accomplish a prescribed set of functions.
System Planning	The establishment of the general requirements and form of a communication system.
Systems Flow-charting	Represents a series of recurring, planned events in a logical order. Not as detailed as program flowcharting.
Table Look Up	(1) To obtain a value corresponding to an argument, stated or implied, from a table of values stored in the computer; (2) The operation of obtaining a value from a table.
Tap	The physical means of connecting a device (node) of a communications network with the transmission medium (i.e., cabling).
Tap (Impendance-Matching)	A small module which electrically and mechanically couples the large diameter trunk cable to smaller diameter drop cables, passes low-frequency (less than 1 kHz) ac power between input and output trunk cable sections, and isolates the power from drop cable sections. It splits the signal energy received in the forward direction very asymmetrically, with the bulk of that signal energy passed to the outgoing trunk cable and only a small percentage going to the drop cables, and combines with similar asymmetry any signal energy received in the reverse direction. It contains only passive electrical components (R, L, C).
Tape Transport	Term generally used to describe a magnetic-tape handler. The device is usually equipped as follows: (a) reels to wind and unwind the tape in either direction; (b) heads designed to read and/or write in

	magnetic pulses; (c) power units to operate the wind and rewind reels and to pass the tape through the read-write heads; and (d) electronic circuits to provide read-write capability.
Telecommunications	The transmission of information over long distances using electronic media such as radio, telephone lines, microwave, or television.
Telecommunications Access Method	IBM term which refers to the use of macro instructions to create message control programs and application programs.
Teleprocessing	A form of information handling in which an automated data processing system utilizes electronic communication facilities.
Teleradiology	The electronic transmission of radiologic images from a radiology department to an off-site viewing station where interpretations are made.
Tera	A prefix meaning ten to the power twelve, one trillion, as in Tbytes (one trillion bytes).
Terminal	A device with which a human may communicate with a host computer.
Terminal Address	An identifying character (or group of characters) used to direct a message to a specific terminal within a group of terminals connected to a multidrop or multipoint communication circuit.
Text	The information portion of a message, as contrasted with the header, check characters, and end-of-text characters.
Thermal Noise	The continuing background of random noise that occurs in all electronic circuitry due to the vibration of atoms composing the circuitry. This vibration sends out electromagnetic waves in a random jumble, increasingly so as heat rises, interfering with communications.

GLOSSARY (Continued)

Throughput	A measure of the amount of work performed over a given period of time. In discussions of communications networks, this term is used synonymously with data transmission rate, expressed in bits per second.
Throughput Time	The total length of time needed to complete an entire operation. May be referred to as Response Time.
Tie Line	A private-line communications channel of the type provided by communications common carriers for linking two or more points together.
Time-Division Multiplex	A system in which a channel is established by connecting intermittently, generally at regular intervals, its terminal equipment to a common channel. At times when these connections are not established, the section of the common channel between the distributors can be utilized to establish other similar channels.
Time-Sharing	A method of using a single computer system in which several users execute their programs concurrently.
Trackball	Device used to manually move a cursor on a video screen.
Tracks	The longitudinal channels on a magnetic tape or a magnetic drum where information bits are recorded.
Traffic	A term used to identify messages being switched, transmitted, or received.
Traffic Analysis	Obtaining information from a study of communications traffic. It includes statistical study of message headings, receipts, acknowledgments, relays, routings, and services; tabulation of the volume, types, and directional flow at each point, noting departure from established instructions (operating routine).

Trail, Audit	A system of providing a means for tracing items of data from processing step to step, particularly from a machine produced report or other machine output back to the original source data.
Transceiver	A terminal that can transmit and receive traffic.
Translation	A geometric image operation used to move an image from one physical location to another on a display screen.
Translator	A device that converts information from one system of representation into equivalent information in another system.
Translator Program	A computer program capable of analyzing high-level and assembly language instructions and substituting the machine language version.
Transmission Speed	The number of information elements sent per unit time, usually expressed as bits, characters, word groups, or records per second or per minute.
Transparency	(1) A data communication mode which enables the equipment to send and receive bit patterns of any form, without regard to their possible interpretation as control characters; (2) Activities carried out by the system that are invisible ("transparent") to the user.
Troubleshoot	To search for the cause of a malfunction or erroneous program behavior in order to correct the malfunction.
Trunk	A major link in a communication system, usually between two telephone switching centers.
Trunk Cable	The main (larger-diameter) semirigid coaxial cable of a broadband coaxial cable system. Both ac power and rf signaling are carried on the cable.
Trunk Group	Those trunks between two points which are both switching centers and/or individual message distribution points, and which employ the same multiplex terminal equipment.

GLOSSARY (Continued)

Turnaround Time	The time required for line turnaround in half-duplex communication systems.
Unattended Operation	The automatic features of a station's operation permit the transmission and reception of messages on an unattended basis.
Undersampling	The sampling of an analog video signal at a rate less than that required by the Nyquist Criterion to resolve a given spatial frequency.
Unsharp Masking	An image operation used to produce a enhancement-sharpened version of an image.
Usage Count	Count indicating the number of time a circuit or piece of equipment is used during a certain period.
Vertical Integration	A method of organizing data files in distributed systems so that users of data pertinent to different levels of the organization can share a common data base, avoiding unnecessary duplication. (Compare with Horizontal Integration.)
Video	Pertaining to the analog form of image transmission.
View Box	A translucent panel mounted in front of fluorescent lights on which films are placed for viewing by radiologists.
Voice-Frequency or Telephone Frequency	Any frequency within that part of the audio-frequency range used for the transmission of speech of commercial quality (i.e., 300-3400 cycles per second).
Voice Grade Channel	A channel suitable for transmission of speech, digital data, analog data, or facsimile, generally with a usable frequency range of about 300 to 3400 cycles per second (Hz).
Volatile Display	The nonpermanent image appearing on the screen of a visual display terminal.
Voxel	(Volume Element) Three-dimensional volume of a scan represented in two dimensions by the pixel.

GLOSSARY (Concluded)

Watchdog Timer	A timer set by the computer program which interrupts the program after a given period of time (e.g., one second). This prevents the system from going into an endless loop due to a program error, or from becoming idle because of an equipment fault.
Weighted Average	The mathematical operation used in spatial convolution to compute the result of each output pixel based on input pixel and its eight neighbors. Each pixel and its neighbors are multiplied by their respective convolution coefficients as defined in the convolution mask. The results are summed, yielding the weighted average.
Wet Reading	A preliminary interpretation given soon after completion of the study in order to expedite patient care. These readings are called "wet" after the obsolete practice of viewing films prior to drying them in the darkroom. These are usually followed by a final (definitive) reading and final report.
White Noise	Noise (electrical or acoustical) whose energy spectrum is uniformly distributed across all frequencies within a band of interest.
Wideband Channel	A communication channel having a bandwidth greater than that of a voice-grade line, and usually some multiple of the bandwidth of a voice-grade line.
Window Level	The middle value of the gray scale of the window width.
Window Width	The range of the gray scale of the image appearing on a screen.
Word	In computing, a sequence of bits or characters treated as a unit and capable of being stored in one computer location. Usually considered to be 16 bits long.
Workstation	A device suitable for human use that is interfaced with a computer system.
Wrap Data	The transmission of data through a communications system and the return of the data to its source to test the accuracy of the system.