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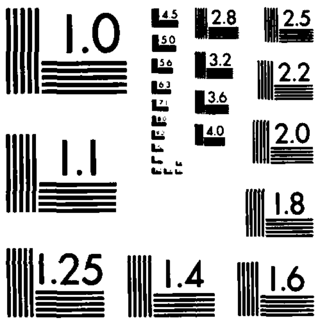

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FACSIMILE TRANSMISSION OF MICROFORMS
(Final Report)
December 30, 1983

Statement of Work TCN: 83-359
Delivery Order No.: 0748

prepared for

Department of the Army
TRADOC
Fort Monroe, Virginia

by

William Saffady
124 Carnousti Road
Franklin, TN 37064

NOTE: The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Libraries and technical information centers are storing increasingly large amounts of information in microform. In the process, they have generated a tremendous problem in delivering documents to the end user. When needed research documents are available in microform, no rapid transmission of the information contained in them is possible. Mailing microforms is too slow a method to meet information needs of today's researcher. Some form of tele-facsimile transmission of microform is needed. This study is designed to to describe the current state of the technology, and to recommend directions

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PURPOSE AND ORGANIZATION

OF THIS REPORT

This final report fulfills the requirements of Statement of Work TCN 83-359 dealing with the facsimile transmission of microforms. Specifically, the report addresses the following tasks:

a. Task 1. "Make a comprehensive literature search covering DoD, other Federal government, and non-government resources . . .Professional literature in the field must be thoroughly covered, and the search documented in sufficient detail, using standard bibliographic techniques, that the government may evaluate the bibliographic work performed." The result of Task 1 is presented in Section I of this report.

b. Task 2. "Identify and evaluate any ongoing programs which are developing equipment or techniques for facsimile transmission of microforms, or using such equipment operationally." The result of Task 2 is presented in Section II of this report.

c. Task 3. "Describe and evaluate the questions to be resolved in reconstituting the transmitted images in microform versus paper copy." The result of Task 3 is presented in Section III, Subsection 1 of this report.

d. Task 4. "Describe and evaluate the questions to be resolved in selecting scanning techniques." The result of Task 4 is presented in Section III, Subsection 2 of this report.

e. Task 5. "Recommend promising avenues of approach for a future development program by the Army. The recommendations must relate the cost, speed of transmission, scanning technique, resolution, and difficulty of development of the technology required. Specifically, the feasibility of developing a sub-minute, three-minute, or six-minute per page transmission capability must be addressed, with the arguments for and against each mode." The result of Task 5 is presented in Section IV of this report.

SUMMARY OF REPORT CONTENT

This final report is divided into four sections:

SECTION I is a bibliographic survey which discusses 116 published sources dealing with microfacsimile. These sources include general technological overviews, specific state of the art reviews, and case studies reporting microfacsimile activities in the United States and foreign countries.

SECTION II discusses the evolution of microfacsimile systems and describes the available product lines of 12 vendors. These vendors are divided into 3 broad groups: 1) manufacturers of automated microform storage and retrieval equipment who offer microimage transmission as an optional component; 2) system integrators who implement customized microfacsimile systems designed for specific applications; and 3) companies who manufacture scanners or other components for use in microfacsimile applications. Analysis of available product lines indicates that none of them meet the requirements of a straightforward, economical, "off the shelf" device for the transmission of microforms among TRALINET library installations. The majority of available systems provide microfacsimile capabilities as a component in a complex automated document storage and retrieval system which is neither required nor desired in the TRALINET application. The available systems are not designed for long distance transmission and cannot accomodate a variety of microform types. If a microfacsimile system is to be used in the TRALINET application, it must be custom developed.

SECTION III, Subsection One recommends the use of paper output as the most appropriate and effective approach for the reconstituting of transmitted images at the receiving location. It rejects microform output and video display output as too costly and unsuited to application requirements.

SECTION III, Subsection Two recommends the use of a solid state microimage scanner operating at a resolution of 200 by 200 lines per inch. It further recommends the digital encoding of scanned picture elements, thereby permitting the use of data compression techniques to speed transmission.

SECTION IV, Subsection One recommends general and operating characteristics for a standalone microfacsimile scanner which will transmit microimages to remote facsimile receivers over voice grade telephone lines using the standard CCITT Group III facsimile communications protocol. This microfacsimile scanner will feature straightforward operation, with manual microform loading and image positioning. No such product currently exists. Estimated development costs for a one operational demonstration model range from $100,000 to $500,000, depending on desired features.

SECTION IV, Subsection Two recommends that the scanner operate at a resolution of 200 by 200 lines per inch. It indicates that the development of a demonstration scanner will be simplified if microform input is restricted to 24x microfiche -- the most important format in most library applications. An analysis of possible transmission speeds recommends the subminute, CCITT Group III protocol as the only viable option. Three-minute, CCITT Group II transmission is judged inappropriate from the standpoint of resolution, speed, and future product viability. Six-minute transmission is dismissed as inadequate in resolution and technologically obsolete.

SECTION I

BIBLIOGRAPHIC REVIEW

1.1 TECHNOLOGY OVERVIEWS

1.1.1 General Works

Compared to other types of information processing technology, the published professional and trade literature dealing with microfacsimile is small. A significant percentage of the literature provides a technological overview, discussing the concept and potential of microfacsimile rather than specific products or applications. Several books and a number of articles briefly mention the existence of microfacsimile in the context of a broad discussion of emerging developments in information dissemination. While the majority of such publications contain little useful information, Costigan (1971a) presented the first comprehensive discussion of facsimile technology and products, including a brief but informative section on microfacsimile which provides both technical information and a description of operational systems which reflects the state of the art through the late 1960s. While the products he describes are no longer available, much of the technical discussion remains relevant and the product descriptions provide an interesting historical perspective on the development of microfacsimile technology. Costigan (1978) updates the earlier work and again includes a brief section on microfacsimile. Although recent developments in facsimile technology -- notably, the development of C.C.I.T.T. Group III and emerging Group IV standards -- necessitate the updating of certain sections, it remains the most comprehensive and authoritative study of facsimile and related document transmission methodologies. Unfortunately, the brief section on microfacsimile does not reflect the significant developments in that technology since the mid 1970s.

Both of the standard micrographics textbooks -- Costigan (1980) and Saffady (1978b) -- contain brief sections on microfacsimile which do little more than describe the technology and indicate its status and potential. Saffady (1978) includes a brief description of microfacsimile in an analysis of facsimile transmission systems for library applications. The PRC Telefiche system, introduced in 1977, is briefly described, but because all of these works were published before the major equipment introductions of the early 1980s -- they cannot give an accurate picture of the current state of the art. Saffady (1981) contains a short section on microfacsimile which mentions and illustrates several of these newer products in the context of a discussion of automated office technology.

Among other general works discussing the broad potential of microfacsimile without detailed consideration of actual applications or of technological or other impediments to implementation, Miller (1981) discusses emerging interfaces between facsimile and other technologies, including micrographics. Neary (1979) and Aaron (1983), both of Eastman

Kodak, discusses the potential of microimage transmission as an alternative to more costly, computer-based mass storage systems. McArthur (1978) and Shepard (1979), both of 3M Company, predict the future use of microfacsimile in automated document storage and retrieval system. In an older paper, Hilton (1970) suggests the possible use of then emerging CATV systems for the transmission of microform materials from libraries to homes. While impractical at the time, this idea was subsequently adopted in the Japanese videotext experiments discussed in a later subsection. Meyers (1970) likewise suggests the use of microfacsimile for the transmission of library materials. A compilation by Henderson (1969) of papers delivered at a National Bureau of Standards conference on storage and transmission systems for libraries includes several discussions of the transmission of microform images.

1.1.2 State of the Art Surveys through 1975

Turning from general works which treat microfacsimile within the context of broader discussions of micrographics or telecommunications technology, a number of articles and technical reports survey the state of the art with respect to microfacsimile concepts, technology, and available products. Early surveys, while no longer reflecting the state of the art accurately, provide valuable historical information which indicates the successes and failures of particular approaches to systems design. Based on research conducted at Bell Telephone

Laboratories, Costigan (1971b) is the most informative and useful of these early status reports. In somewhat more detailed fashion than the previously cited Costigan (1971a), it surveys the state of the art through the 1970, describing and illustrating available products. Anticipating the future development of microfacsimile systems, the National Microfilm Association (1973) joined the Electronics Industries Association in publishing a standard for the facsimile transmission of microimages. Costigan (1975) explains the standard's background and purpose.

Papers by several equipment manufacturers discuss microfacsimile technology and describe developments in their particular product lines. Jackson and Jackson (1967); Jackson, Jackson, and Lariviere (1968); and Szabo (1970) describe the Automated Microfilm Aperture Card Updating System (AMACUS), an early microfacsimile system developed by Singer Link for engineering applications. It was, in some respects, a forerunner of the Versatec IMPRES system discussed in Section Two of this report. Szabo (1972), also of Singer-Link, reviews that company's microfacsimile research and development activities, discussing the use of an aperture card scanner to transmit images of engineering drawings to a Singer MS-5000/6000 COM plotter for recording on microfilm.

In a discussion of automated document storage and retrieval systems for engineering information, Martin (1970) briefly describes the Sanders Diebold 500 and Mosler 410 systems, both of which could be equipped with closed circuit television systems for the remote transmission of drawings stored on aperture cards. The Mosler 410 later became the basis of the Infodetics product line described in Section Two. In one of a series of articles dealing with facsimile technology, Stafford (1971, 1975) discussed microfacsimile concepts, as well as products developed by the Alden Electronic and Impulse Recording Equipment Company, one of the early leaders in facsimile technology and the first company to develop microfacsimile systems as more or less "off the shelf" products. An Alden microfilm scanner, designed to operate in conjunction with a Kodak MIRAcode retrieval system, is depicted in Ballou (1975). Groves (1974) and Shephard (1975) describe the design of flying spot CRT scanners for microfilm applications. Kelly and Torok (1973) of Bell Telephone Laboratories discuss magnifying attachments which allow Picturephone to transmit microfilm images and other small objects. Szabo (1970) and Gillis (1974) discusses the development of a mass memory storage device which an integral microfiche digitizer. A forerunner of the Harris MASTAR system noted below, it combined human-readable microform images with machine-readable digital data recorded on silver halide film. A patent assigned to Plessy (1970) describes an information retrieval system which scans microfilm strips to display specified images.

Reader (1970) of Information Utility Systems provides a very basic discussion of microfacsimile technology. Kamen and

McDevitt (1969) and Kamen and Jacob (1970) of Comfax Communications Corporation describe the development of a microfacsimile device which used variable velocity scanning and white space skipping to transmit document images over ordinary telephone lines at a rate of one minute per page. Tregay (1973), also with Comfax Communications, provides a similar discussion. Dobrin (1975) of Faxon Communications presents a state of the review. Spear (1970) of Scan Graphics Corporation discusses the potential of microform scanning in micropublishing applications. Mallender (1969) of Singer-General Precision provides an early discussion of the digital coding techniques which now dominate microfacsimile technology. The discussion is continued in Mallender (1971a, 1971b) where the advantages of data compression and various coding techniques are described. Szabo and Hayden (1970) review the use of CRT and laser scanners for the conversion of microfilm images to digital computer storage.

Among other state of the art surveys, Tressel, Brown, and Krahn (1970) discuss the advantages and impediments associated with the transmission of COSATI format fiche for viewing at remote locations. Penniman and Tressel (1975) discuss the potential of microfacsimile for growth in micrographics applications. A series of studies prepared by the Hatfield Poltechnic School of Engineering continue to provide useful technical descriptions of facsimile technology. In a report prepared for the British Library, Barrett (1973, 1974a) presents a survey of the state of the art, emphasizing the potential of microfacsimile for the transmission of scientific and technical information. He also analyzes resolution requirements for legible transmission. Barrett (1974b, 1974c) surveys Japanese developments in micrographics and facsimile technology. In a feasibility study conducted for the Naval Ordnance Station in Louisville, McMahon (1975), assesses the technology and availability of equipment for the storage, retrieval, and transmission of engineering drawings, including drawings recorded on aperture cards. McMahon concluded that two major components needed to effectively implement such a system -- a document or aperture card scanner and an output device capable of recording images on microfilm -- were not commercially available at the time the study was prepared.

1.1.3 Recent State of the Art Reviews

The growing interest in microfacsimile's potential and the enhancement of microfacsimile technology since the late 1970s are reflected in several studies which describe and analyze microfacsimile concepts and available products in a more detailed and useful fashion than the earlier literature. In an important and informative survey, Walter (1982a) of Planning Research Corporation presents a comprehensive and comprehensible discussion of microfacsimile resolution requirements for specific types of business documents and outlines the most important data compression techniques used in microfacsimile systems. Walter (1979) provides an earlier, less detailed treatment of the same topic. Walter (1982b, 1982c) presents similar information within the context of a discussion of the potential significance of optical disk technology for the storage of office documents. He also includes a discussion of scanning technologies and of high resolution displays suitable for digitized microimages.

Barrett (1982a, 1982b) is likewise concerned with microfacsimile within the broader context of a discussion of optical disk technology. He describes the recent product developments of several important vendors and compares microform transmission technology to optical disk systems, noting the present technical and economic uncertainties associated with the latter. In an earlier study, Barrett and Farbrother (1977) discuss requirements of systems designed for microimage storage, retrieval, and transmission and describe a possible system for the transmission of document images from a microfiche library. The study proposes system evaluation through a series of controlled tests designed by a psychologist and designed to assess user performance and fatigue levels. Farbrother and Barrett (1979) provides a similar discussion. In other British studies, Horder (1980a, 1980b) surveys and describes microfacsimile systems available in Europe.

In one of the clearest and most informative state of the art, Costigan and Burger (1982) provide a good introduction to the various types of components utilized in microfacsimile systems and describe and illustrate some available products. In a feasibility study prepared for the Rome Air Development Center at Griffiss Air Force Base, McDowell (1979) indicates the technical feasibility of microfacsimile but questions its high cost. The report presents an interesting and thorough analysis of the state of microfacsimile technology in the late 1970s. Its assumptions concerning technical feasibility have been reinforced by product developments since that time. Montuschi and Sagramoso (1980) describe the use of image digitizers to revise microfilmed engineering drawings in computer-aided design applications.

Once commonplace, vendor reports describing their microfacsimile product developments are seldom encountered in recent professional and trade literature, even though more vendors are actively marketing such systems now than at any previous point in industry history. As an interesting exception, Redderson (1980) and Redderson and Ralston (1980) describe the Mass Archival Storage and Retrieval (MASTAR) system developed by Harris Corporation's Government Systems Group. In an earlier report prepared by Harris Corporation for the Rome Air Development Center, Otten and Nelson (1979) describe a Human Readable/Machine Readable (HR/MR) Microfilm Mass Memory System which can record either document images or binary data on microfiche. Up to 6,750 fiche can be stored in a single automated retrieval unit operating under computer control. Fain and Gruener (1979) of Teknekron Controls Incorporated describe the Automated Records Management System (ARMS) which can transmit microfiche or other microform images to display terminals or other output devices. Cohen (1983) describes microimage transmission systems marketed in England by Antone Systems. Several articles describe scanners or other components suitable for use in microfacsimile systems. McNaney (1982) discusses the use of a an acoustico-optic laser and precision lenses to scan microimages. Boticelli et al. (1975, 1976) of Epsco Labs summarize a parametric study which presents specifications for the development of a microfiche transmission using video display terminals. Although IBM is not involved in microfacsimile, reports by Potak (1975) and Brown and Smith (1978) describe the development of a solid-state linear scanner to transmit digitized microimages to a remote video display. Dew (1979) describes a hybrid electro-mechanical scanning array and associated computer processor developed for the Air Force.

1.2 CASE STUDIES

1.2.1 U.S. Applications

Although seldom successfully implemented, microimage transmission was a planned component in a number of information storage and retrieval systems developed from the early 1960s through the early 1970s. In a conference paper surveying microfacsimile development activities, Laurent (1968) briefly mentions the FLATTOP microfacsimile scanner, reportedly developed for library applications by the Department of the

Army, but provides no details. He further notes an interest in microfacsimile developments at Redstone Arsenal. Much fuller information is available about Project Intrex, a series of innovative experiments in the dissemination of scientific and technical information conducted by the Massacusetts Institute of Technology from the mid 1960s through the early 1970s. Designed to provide scientists and engineers with convenient access to technical documents, the project developed a computer-assisted retrieval system which was to eventually include a microimage transmission subsystem. Knudson and Marcus (1972) outline the project's basic technical concepts and proposed microfacsimile component. Gronemann, Teicher, and Knudson (1967) discuss an experimental microimage transmission subsystem for the display of text at remote workstations. The project's purpose and scope are discussed in Scott (1965) and Overhage (1967). Overhage and Reintjes (1974) provide the most comprehensive review of its accomplishments.

While microfacsimile systems have been installed by American corporations, published application reports have emphasized federal government installations. Measured by the number of published reports, the Microfiche Image Transmission System (MITS) developed by the U.S. Navy's Bureau of Naval Personnel is the certainly most publicized of these microfacsimile applications. Designed to facilitate access to microfiche records pertaining to over one million naval personnel, system planning began in the mid 1970s. The original application parameters, systems design, and justification are discussed in Hopkins (1977). Endicott, Solarek, and Drake (1976), Solarek and Endicott (1977), and Endicott and Solarek (1977) provide technical details, report the results of preliminary testing, discuss personnel requirements, and outline costs. Subsequent reports by French (1981) and Hopkins (1982) describe the further development of a test system, changes in the original design concepts to take advantages of new technology, and the implementation of a microfiche output component in which document images are transmitted to a remote graphics COM recorder. Sheposh and Hulton (1983) evaluate the MITS demonstration installation from the standpoint of operators' perceptions, user acceptance, image quality, and management considerations. They view the demonstration as successful by most measures but find any further discussion of widespread implementation premature.

Among other federal government agencies, Felton (1979) and Deakin (1981) describe a computer-assisted retrieval system with a microfacsimile component implemented by TERA Corporation at the Nuclear Regulatory Commission. The system features a computer-based online index, a specially designed microfiche retriever, and a video transmission system which permits the rapid dissemination of document images to users at remote display terminals. Peck (1983) describes a system, likewise designed and installed by TERA Corporation, at the Federal Energy Regulatory Commission. It combines 16mm microfilm storage with a computerized indexing system for rapid document location. Retrieved images are digitized by a video scanner and, depending on the user's preference, transmitted to a high resolution facsimile printer for hard copy output or to a graphics COM recorder where they are recorded on microfiche. To minimize paper production, requests involving more than ten pages are routinely routed to the COM recorder for microfiche output.

Wilkins (1982) describes the development of the Advanced Micrographic Access and Retrieval System (AMARS) by the U.S. Army Micrographics Technology Branch. A prototype system was developed by Teknekron Research (now Integrated Automation) for an installation at the Reserve Components Personnel and Administrative Center. The system includes two retrieval devices containing up to 10,000 microfiche each, a computerized document indexing subsystem, and video scanners for microfacsimile transmission to high resolution display terminals or a paper printer. Future plans call for the use of a graphics COM recorder for microfiche output from transmitted document images.

In a non-government application in the public sector, Lorenzi et al. (1979) describe the use of a high resolution closed circuit television system to transmit health related information from microfiche to patients and others at the University of Cincinnati Medical Center. Carden (1979) describes a large-scale aperture card system with a remote transmission component at Westinghouse.

1.2.2 Japanese Applications

Facsimile transmission has enjoyed longstanding and widespread acceptance in Japan where reliance on ideographs and pictorial information makes character oriented transmission methodologies impractical. It is consequently not surprising that the Japanese have demonstrated considerable interest in microfacsimile. In an early experiment designed to overcome the storage limitations associated with the computerization of pictorial information, Okamoto, Atsuya, and Ogihara (1974) of Fujitsu Laboratories report the transmission of microfilmed documents to high resolution video monitors. Kamei and Maeda (1974) discuss the use of a specially designed television camera to convert microfilm images to digital form for computer processing. Noting the increased demand for facsmile transmission of microfilmed documents, Kamada and Kobayashi (1977) of Nippon Telegraph and Telephone describe a scanner which transmits 16mm and 35mm microfilm images to ordinary facsimile receivers.

The most widely reported Japanese microfacsimile activities involve an experimental system developed at the University of Tokyo for the remote transmission of visual pattern information stored on microfiche. Using digital coding techniques with data compression to increase speed, microimages are transmitted to conventional analog facsimile receivers where they are reconstructed as paper enlargements. The system's capabilities have been demonstrated on a data base of pictorial documents containing archaeological patterns and arabesque and floral pattern roof tiles. In the first of a series of published descriptions, Tomiyama, Saito, and Inose (1979) cite the advantages of microfacsimile concepts for management of document retrieval in scientific and business applications. Technical details and a discussion of the demonstration system are provided in Inose, Saito, and Nakagawa (1980a, 1980b, 1981) and Nakagawa, Saito, and Inose (1980), all of which cite the potential of microfacsimile for automated library operations.

Among other Japanese studies, Horikawa et al. (1979) describe a system for the transmission of color images from a picture file stored on microfiche. The system has a capacity of 7,200 pictures, and the images are displayed on a low resolution color video monitor. As described by Finley (1979a, 1979b), the transmission of color microfiche images to ordinary television receivers is employed in the widely publicized Hi-OVIS interactive videotext experiments in Higashi-Ikoma. In one of the most interesting Japanese microfacsimile experiments, Ogawa et al. (1982) describe a system developed by the Office Automation Systems Research and Development Laboratories of Matsushita Graphic Communication Systems. It permits the automated retrieval of up to 30,000 document images stored on microfiche and their remote transmission to a high resolution video display terminal or to a facsimile printer using the standard C.C.I.T.T. Group III facsimile communications protocol. Hard copy output up to the B4 international size is possible. As an indication of likely future Japanese directions in miniaturized document storage and transmission, Izawa and Nakayama (1980) describe an optical disk recording and image transmission system developed by Toshiba.

1.2.3 Applications in Other Countries

Several older studies report German interest in microfacsimile technology. Schon (1970) describes an experimental system developed by Siemens for engineering applications. Koch (1974) and Rupp (1977) describe the TELEVIT video communications system developed by Telefunken and intended for the transmission of data and documents in closed communications networks. Based on the BSG-15 Videophone which can reproduce images in accordance with either broadcast television standards or high resolution requirements, TELEVIT was designed to permit the transmission of document images from centralized microfilm files to office workstations.

Russian interest in microfacsimile systems is reflected in an article by Karbachinskij and Antonenko (1975) which surveys recent developments in image transmission technology. Ishutinov et al. (1975) describe a computer-aided design system which can transmit document images stored on microfilm cassettes to remote terminals. The operational status of the system is difficult to determine. Kan et al. (1977a, 1977b) and Brodolin (1972) suggest the use of scanning electron microscopes as an alternative to other optical systems for the transmission of images from microfilm.

In Great Britain, Windrum (1981) describes a closed circuit television system for the transmission of document images stored in hard copy or on microfilm. Earlier studies by Brooks et al. (1972) and Davey, Harris, and Loken (1974) describe the Oxford Precison Encoding and Pattern Recognition (PEPR) system which used a specially developed CRT to scan microfilmed meteorological charts. Bergsten and Zetterberg (1978) indicate plans to incorporate microfacsimile capabilities within an experimenal video communication network planned in Sweden.

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SECTION II

AVAILABLE MICROFACSIMILE SYSTEMS

2.1 INTRODUCTION

2.1.1 Early Microfacsimile Products

As indicated in the preceding section, operational microfacsimile systems date from the early 1960s. Through the early 1970s, several companies introduced automated microform storage and retrieval systems with an image transmission component. Examples designed for the storage, retrieval, and transmission of aperture cards in engineering applications included the Magnavox DARE system, the Sanders Diebold 500, and the Mosler 410. Alden introduced a microfacsimile system designed to interface with Kodak MIRAcode equipment, and Image Systems implemented a closed-circuit television subsystem for its automated microfiche retrieval unit. Planning Research Corporation and Dymat Photomatrix developed a microfiche transmission system at Randolph Air Force Base. In a simpler approach involving the manual microform selection and loading, Comfax Communications, Faxon Communications, and Telemechanics Incorporated (Microphax) demonstrated straightforward scanners designed to transmit microfilm images to remote printers. Outside of the United States, similar product developments were undertaken by Japanese, German, and British companies.

While these early systems demonstrated the technical feasibility of remote transmission of microimages, none of them were commercially successful. Of the vendors listed above, only Planning Research Corporation continues to be actively involved with microfacsimile. For the most part, user acceptance of early microfacsimile systems and concepts was limited by several significant impediments:

a. The majority of early microfacsimile systems were developed on a one-of-a-kind basis for specific applications at high cost, and many of them were only operational on an experimental basis designed to demonstrate technical feasibility. Among the vendors listed above, only Alden advertised its microfacsimile system as commercially available. While prototype models were routinely demonstrated at micrographics conferences and related trade shows, prospective users were too often confused about the availability and viability of microfacsimile products.

b. Product viability aside, the potential microfacsimile market is significantly narrowed by the ease with which microforms can be duplicated for distribution to remote locations in anticipation of need. As an alternative to maintaining a centralized collection of microimages to be transmitted to remote workstations on demand, microfilm and microfiche collections can be inexpensively duplicated for decentralized storage at multiple locations.

c. Through the mid 1970s, facsimile technology in general suffered from low user acceptance which was largely attributable to the limited performance and unreliability of available equipment.

d. In the early to mid 1970s, the information processing industry emphasized data storage and retrieval, giving relatively little attention to the document collections which microfacsimile systems are designed to manage. The computer industry in particular viewed documents as "transitional" information carriers which would eventually be replaced by the development of large-scale, online data storage systems.

Taken together, these factors effectively stifled user awareness of and interest in microfacsimile. While a number of interesting experiments were conducted during this period, few information systems analysts viewed microfacsimile as a viable option for the broad spectrum of document retrieval applications.

2.1.2 Recent Product Developments

Beginning in the late 1970s, some significant changes in information processing technology and information management practice stimulated renewed interest in the potential of microimage transmission. These changes included:

a. An emphasis on the productivity of office workers, highlighted by an intense interest in office automation and growing awareness of the amount of time wasted in document retrieval and dissemination;

b. Renewed awareness of the importance of documents, coupled with an interest in centralized storage, retrieval, and dissemination systems comparable to those available for computer-maintained data bases;

c. Significant improvements in facsimile technology — especially the introduction of digital systems using data compression techniques to improve transmission speed and the development of standards to permit communication between machines of different manufacturers — with resulting significant increases in user acceptance;

d. New developments in communications technology — including the proliferation of terrestrial microwave, satellite, and coaxial cable facilities — which could provide the wideband communication links required for high speed, high resolution microimage transmission;

e. Increased awareness of the role of video technology and video transmission, including video disk and videoconferencing systems, in business;

f. The growing size of microform collections, with resulting high duplicating costs associated with distribution to remote points in anticipation of demand; and

g. Most important, the development of commercially available microfacsimile systems from a growing number of vendors.

During the late 1970s and early 1980s, the number of vendors involved in the development and implementation microfacsimile systems and related products increased significantly. For purposes of this report, these vendors can be divided into three broad groups:

a. Manufacturers of automated microform storage and retrieval equipment who offer microfacsimile as an optional component in a computer-assisted retrieval system. Examples include Access Corporation and Ragen Information Systems.

b. System integrators or system contractors who implement customized microfacsimile systems designed for specific applications. While these system integrators may have designed special video scanners, retrieval units, display terminals, or other components for use in microfacsimile applications, they typically specialize in the development of hardware and software interfaces designed to link equipment manufactured by other companies. The system integrators often purchase components from one another, and their system development efforts may consequently prove similar. The system integrators typically implement microfacsimile as a component in a large scale document storage and retrieval system which combines computer, micrographics, and telecommunications technologies. As a group, they have been responsible for the most complex and widely publicized microfacsimile system implementations. Examples of system integrators include Integrated Automation, Omex Corporation, Planning Research Corporation, and TERA Corporation.

c. Companies which manufacture video scanners, high resolution video display terminals, or other components suitable for use in microfacsimile applications. These companies offer discrete components rather than self-contained microfacsimile systems. While they may provide electrical interfaces to computers or other control devices, the software interfaces which are crucial to system implementation remain the customer's responsibility. These companies sell their products to system integrators and to end users interested in customized system development. In some cases, they also function as system integrators undertaking special product development work. Examples of these companies include Datacopy, Eikonix, and Terminal Data Corporation.

The following subsections identify and describe the product lines and/or system integration capabilities of vendors currently involved with microfacsimile. Using standard industry sources, every attempt has bee made to identify all active vendors and obtain appropriate information about their current microfacsimile activities. Attempts to obtain information about the Harris MASTAR system were unsuccessful, but it is adequately described in various publications previously cited in Section One. Both Eastman Kodak and the 3M Company, the two leading vendors of micrographics products, have discussed the possibility of marketing microfacsimile systems, and the 3M Company has demonstrated such a system in prototype. But since, neither of these companies currently offers microimage transmission products, they are omitted from this discussion.

Vendors are presented below in alphabetical order. The discussion outlines the nature and extent of each vendor's microfacsimile activities. If special products or complete system configurations are involved, they are described. The vendor survey is followed by a collective analysis of the suitability of available systems for the TRADOC application.

2.2 VENDOR SURVEY

2.2.1 Access Corporation

Access Corporation (4815 Para Drive, Cincinnati, Ohio 45237) is a manufacturer of large capacity automated document storage and retrieval systems for index cards and flat microforms, including microfiche, aperture cards, and microfilm jackets up to 5 by 8 inches in size. Access offers two storage modules -- the System 60 and System M -- together with various supporting devices. The two modules differ in capacity but share certain basic components. Both store microforms enclosed in special transparent carriers which are notched with an alphanumeric identifier. These carriers are placed in random order in specially designed trays which are, in turn, placed in an electromechanical selector unit which automatically identifies and partially removes those carriers which correspond to retrieval requests entered at the system's keyboard. The Access System 60 can contain approximately 20,000 microform carriers. Access System M is a high capacity storage device which can be configured for 20,000 to 200,000 microforms. In either case, the entire file is searched in parallel and retrieval requires only a few seconds. If desired, the selector mechanism can operate under computer control, and Access offers several turnkey computer-assisted retrieval (CAR) configurations for this purpose. The Access Integrated Document Control System (ICDS) is designed for ordinary business documents. The Access Drawing Control System is designed for engineering applications. These turnkey configurations feature a minicomputer, related peripheral devices, and indexing and retrieval software.

Whether operated as components in a turnkey system or as standalone devices, the Access storage modules merely eject the retrieved microform from the file. The operator must manually carry it to a reader, reader/printer, or other display device. For automated image dissemination, the Access 2010 is a version of the Integrated Document Control System which includes a microfacsimile subsystem. The Access 2010 is a turnkey computer-assisted retrieval system designed for high capacity storage, rapid retrieval, and "closed loop" control of document images recorded on microfiche. In the manner described above, the Access 2010 selector unit retrieves a requested microfiche. But rather than merely ejecting it from the file, the Access 2010 automatically conveys the microfiche to an integral solid-state video scanner. The scanner, which is manufactured by Terminal Data Corporation (see the discussion later in this section) digitizes the microform image for remote transmission to facsimile printers, high resolution video terminals, or a graphics COM recorder. A magnetic disk serves as a buffer for the digitized image. The Access 2010 requires diazo microfiche duplicates, produced in the NMA Type-1 standard 24x format on a Terminal Data Corporation DocuMate II microfilmer or equivalent device capable of recording a bar-coded identifier.

The Access Aperture Card Video Transmission System (ACVTS) is a special version of the Access 2010 designed for engineering applications. The operator, working a remote terminal, submits a retrieval request, identifying a desired drawing by number or other parameters. The requested aperture card is selected from the Access storage unit, delivered to a video scanner, and digitized for transmission to a high resolution video terminal equipped with such special features as panning and zooming.

2.2.2 Antone Systems

Antone Systems Limited (11 Cabot Lane, Creekmoore, Poole, England BH17 7BX) is a system integrator which acquired the microfacsimile product line of Stabletron Limited, a now defunct company involved in microimage transmission during the 1970s and early 1980s. Like most system integrators, Antone Systems offers microfacsimile as a component in a turnkey computer-assisted retrieval system with minicomputer hardware plus document indexing and retrieval software. Specific hardware and software characteristics of the CAR subsystem will vary from application to application, and the document indexing and retrieval software is reportedly available for separate sale. As is customary with system integrators, Antone tailors its equipment configurations to individual application requirements.

Antone's microform retrieval and transmission subsystem utilizes components manufactured by Terminal Data Corporation. A central storage module (the TDC Scrollfile, described in a later subsection) can contain up to 400,000 document images on a continuous reel of 105mm diazo microfilm containing uncut microfiche. These diazo duplicates are made from masters produced on a TDC DocuMate II or other step-and-repeat camera. Alternatively, Antone Systems offers a desktop document scanner which can be used for fiche production. Regardless of the production methodology utilized, the requirement for uncut fiche on 105mm diazo film stock limits the system's applicability to existing microform collections. Antone does offer an option which can accept manually inserted cut fiche, but roll microforms cannot be accomodated. As an additional option, aperture card images can be converted to 105mm microfilm for use in the system.

Up to five storage modules can be contained in a single equipment rack for a total capacity of 2,000,000 pages. Images identified by the computer-assisted retrieval system are automatically located, extracted from the appropriate storage module, and positioned for scanning by an image digitizer which consists of a solid-state CCD array operating at a resolution of 200 by 200 lines per inch. Digitized images are recorded on a magnetic disk which serves as a temporary buffer for video display terminals and printers. For soft copy output, Antone Systems utilizes the TDC Videomate terminal, a high resolution CRT device which features an 8.5 by 11 inch (letter-size) screen. The display resolution is 200 by 200 lines per inch or 2,200 horizontal lines of 1,720 picture elements each. When equipped with an optional alphanumeric character generator, the Videomate terminal can operate as a single workstation for both index searches and document viewing.

Where paper output is desired, Antone Systems offers an electrostatic printer which can produce letter or legal size copies at a resolution of 200 by 200 lines per inch. When connected to the microimage transmission unit by a coaxial cable, the print speed is approximately 10 seconds per page.

2.2.3 Datacopy

Datacopy Corporation (1070 East Meadow Circle, Palo Alto, California 94303) is a manufacturer of image digitizers for a wide variety of applications, including document transmission, electronic publishing, and industrial inspection. Unlike Access Corporation and Antone Systems, Datacopy does not offer a self-contained microfacsimile system but instead manufactures components which can be used in custom-developed microimage transmission systems. The most important of these components is a solid-state scanner which resembles an overhead planetary microfilmer with a digitizing camera mounted on a vertical column positioned perpendicular to a flat copyboard. Configurations are available for the scanning of either paper documents or microfilm, and microfacsimile is listed as a possible application in Datacopy product brochures.

Datacopy scanners are delivered with a 50mm Nikon lens as standard equipment. Other lenses are optionally available. Resolution varies with the model. Model 322, which is most suitable for microfacsimile applications, operates at 200 by 200 lines per inch or 1,720 horizontal lines by 2,592 picture elements. Model 320 operates at 1,280 horizontal lines by 1,280 picture elements, and Model 312 operates at 640 horizontal lines by 640 picture elements. The ability to encode up to 256 shades of gray per picture element makes the scanner suitable for use with graphic as well as textual documents.

Datacopy sells its scanners as discrete components to be used with a customer's own control electronics. Alternatively, Datacopy can provide several control options or deliver complete systems designed to interface with the most popular computers. The scanner produces an unprocessed signal representing the light reflectance values of successively encountered picture elements in the subject copy. A computer is required to process the signal prior to transmission to remote video displays or printers. The software required to link these components must be developed by the customer or a system contractor. Datacopy does, however, offer interfaces to Versatec printer/plotters.

In addition to the scanners described above, Datacopy manufactures a high resolution video monitor suitable for use as a "soft copy" output device in custom-developed microfacsimile configurations. It is available with either a 15-inch or 19-inch (diagonally measured) screen in either a portrait (vertical) or landscape (horizontal) orientation. In the vertical orientation most useful for microfacsimile applications, the display resolution is 2,200 horizontal lines by 1,728 picture elements (nominally, 200 by 200 picture elements per inch). A direct interface is provided for connection to a the Datacopy model 322 scanner. Interfaces are also available for the most commonly encountered computer systems.

2.2.4 Eikonix

Like Datacopy, Eikonix Corporation (23 Crosby Drive, Bedford, Massachusetts 01730) is not a vendor of turnkey microfacsimile systems but a manufacturing and engineering company specializing in image processing technology. Its products include image digitizers, plotters, and related items.

None of these products are designed specifically for microimage transmission, but several of them can be used as components in custom-developed microfacsimile systems. In addition to its standard product line, Eikonix has designed customized digitizers and image processing systems for a wide variety of applications. Examples similar to microimage transmission include the digitizing of x-ray photographs in medical, construction, and petroleum engineering applications; the scanning of autoradiographs in medical research; and the digitizing of maps for computer processing.

The standard Eikonix product of greatest relevance to this discussion is the Model 78/99 EikonixScan, a general purpose image digitizer suitable for use with transmissive or reflective subjects. It is a solid-state device which utilizes a photodiode array operating at a standard resolution of 2,048 horizontal lines by 1,728 picture elements (nominally, 200 by 200 picture elements per inch). Optional resolutions include 3,000 lines by 1,728 picture elements; 2,048 lines by 2,048 picture elements; and 3,000 lines by 2,048 picture elements. To encode gray scale information in pictorial applications, up to 12 bits can be used to represent each picture elements. Scanning speed ranges from 5 to 60 seconds per page, depending on the amount of gray scale information.

In its standard configuration, the EikonixScan camera is mounted on a vertical column in the manner of an overhead planetary microfilmer. Film stages, roll film transports, and other accessories are available for microfacsimile applications. For the effective scanning of microforms and other transmissive subjects, Eikonix offers an optional workstation equipped with a special illumination system. In its standard configuration, the EikonixScan is equipped with a 55mm Nikon lens. Other lenses are optionally available.

The EikonixScan is not a standalone device but is instead designed to operate with a host computer. Eikonix offers interfaces to Digital Equipment minicomputers. Alternatively, the scanner can be equipped with an integral microcomputer consisting of a Motorola MC68000 microprocessor with 32K or random-access memory and 64K of read-only memory. The microcomputer includes four slots for the addition of signal processing function boards such as a display controller or a data compression board.

2.2.5 Infodetics

Infodetics Corporation (1341 South Claudina, Anaheim, CA 92805) was one of the first companies to offer video-based document transmission as a component in an automated microform storage and retrieval system intended primarily for engineering applications. Infodetics' primary product is the Model 410 retrieval system, a large-scale, random-access storage device for aperture cards. Based on a retrieval unit originally designed by Mosler, the Infodetics 410 consists of two parallel walls which together hold 2,000 specially designed cartridges.

Each cartridge may contain as many as 100 aperture cards for a total module capacity of 200,000. Under computer control and on receipt of a retrieval command, the appropriate cartridge is selected from the storage module and delivered to an input/output port. From there, the cartridge is shunted to a selector mechanism which extracts the indicated aperture cards for display, duplication, or other processing. Cards to be stored in the Infodetics 410 file module must be specially coded with identifying notches. For high volume installations, the capacity of the basic module can be expanded to more than 10,000,000 aperture cards. A low volume storage unit, with capacity for 50,000 cards expandable to 100,000 cards, is also available.

The Infodetics 410 can operate as a standalone microform storage and retrieval unit or as a component in Infodetics' CADMAC (Computer Assisted Document Management and Control) 410 System. A typical CADMAC 410 configuration consists of computer hardware, document indexing and retrieval software, and one or more microform storage units. In its standard mode, the Infodetics 410 -- like the Access Corporation retrieval units described above -- operates as an aperture card selector. Cards retrieved by the unit must be manually taken to readers, reader/printers, or other devices. Infodetics offers interfaces which will automatically deliver retrieved aperture cards to a duplicator or an enlarger/printer. Alternatively, cards can be delivered to a video scanner for transmission to remote workstations. While earlier Infodetics equipment configurations utilized conventional analog video cameras for this purpose, newer installations feature a solid-state image digitizer operating at a resolution of 200 by 200 lines per inch. The digitizer will scan drawing images up to E-size and produces output compatible with commonly encountered digital plotters. Infodetics itself offers several electrostatic printers which operate at resolutions of 200 by 200 lines per inch. If desired, the video scanner can be configured for the manual insertion of aperture cards.

Digitized drawing images can be transmitted to remote display terminals or printers. For "soft copy" output, Infodetics offers a 19-inch (diagonally measured) graphics display terminal which offers resolution of 100 lines per inch. It is available in two models which are identical in appearance but differ in internal memory capacity: 1) model 819 offers sufficient internal memory to accomodate digitized images of E-size drawings; 2) model 219 has a smaller internal memory capable of storing drawings up to C-size. Model 219 displays D and E-size drawings scaled to C-size. Both models offer zoom capabilities which permit the magnification of specified areas of a drawing. When configured with an optional character generator, both models can likewise operate as Dasher 200 alphanumeric terminals.

Infodetics computer and workstation components can be interconnected via coaxial cable, fiber optics links, or other communication facilities.

2.2.6 Integrated Automation

Formerly known as Teknekron Controls Incorporated, Integrated Automation (2121 Allston Way, Berkeley, CA 94704) is a system integrator specializing in the development of large scale, automated document storage and retrieval systems. One of the best known and most experienced of system integrators, Integrated Automation has been involved with microimage transmission since the late 1970s and has developed and installed systems for the U.S. Army Reserve Components Personnel and Administrative Center, Detroit Edison, Power Authority of the State of New York, Texaco, Washington State Department of Labor and Industries, and the Kingdom of Saudi Arabia. Recent projects have emphasized the use of optical disks rather than micrographics technology, the most widely publicized of these being a materials preservation project at the Library of Congress. Integrated Automation is also implementing an optical disk storage system for the French Ministry of Communications and Postal Affairs.

Being customized for particular applications, microfacsimile configurations developed by Integrated Automation are highly varied. Microfacsimile is typically one component in a computer-assisted retrieval system which provides document indexing and retrieval capabilities. Integrated Automation can develop microimage systems for microfiche, roll microforms, or aperture cards, depending on application requirements. Early installations utilized the Image Systems retrieval unit for microfiche. In the early 1980s, Integrated Automation developed a special storage and retrieval unit with a 10,000 microfiche capacity and an integral, solid-state image digitizer. Resolution of 200 by 200 lines per inch is adequate for most applications. Where required, Integrated Automation can provide resolution of 300 by 300 lines per inch.

There is likewise considerable variety in output devices. Depending on application requirements, Integrated Automation has utilized high resolution video display terminals, high speed printers, conventional facsimile receivers, and/or graphics COM recorders. Microforms designed for storage, retrieval, and transmission can be created by ordinary cameras. Alternatively, Integrated Automation can provide document scanners which transmit digitized document images to graphics COM devices for recording on roll film or microfiche.

2.2.7 Omex Corporation

Omex Corporation (2323 Owen Street, Santa Clara, CA 95051) is a system integrator specializing in the development and implementation of high capacity automated document storage and retrieval systems, some of which include a microfacsimile component. Like Integrated Automation, Omex is interested in the use of innovative optical recording materials and has developed an optical mass memory unit which stores digitized document images on glass slides mounted in an automated retriever. Reported system capacity is 800 billion bytes.

As with most system integrators, Omex's microfacsimile systems are typically implemented within the context of a computer-assisted retrieval system which includes computer hardware, computer software, and micrographics equipment. Specific computer hardware and data management software configurations are tailored to particular applications. A typical configuration consists of a minicomputer, multiple alphanumeric terminals, printers, and hard disk storage devices. Currently, Omex is using a 16mm microfilm storage and retrieval device manufactured by Ragen Information Systems (to be discussed in a later subsection). This unit includes a solid-state image digitizer which can transmit microimages to video display terminals or printers. For "soft copy" output, Omex offers a graphics display terminal with a resolution of 100 by 100 lines per inch. When equipped with a character generator, the terminal can also operate as a conventional alphanumeric display device. For hard copy output, Omex offers electrostatic facsimile printers capable of operating at 100 by 100 or 200 by 200 lines per inch. It can produce copies measuring up to 8.5 by 14 inches. The rated printing speed is 5 pages per minute.

2.2.8 Planning Research Corporation

PRC Government Information Systems (1500 Planning Research Drive, McLean, VA 22102) is a system integrator specializing in the development of customized microfacsimile systems for particular applications. It is perhaps best known as the developer of the Telefiche system. While the term Telefiche is often used to refer to equipment developed by PRC for microfiche transmission, the term is actually a marketing designation which refers broadly to the company's digital imaging technology. PRC is a systems contractor rather than a hardware manufacturer, and, like other system integrators, it has implemented systems utilizing components from a variety of manufacturers. Its microfacsimile capabilities are not limited to microfiche but extend to roll microforms as well. Telefiche systems are customized for particular applications and range from straightforward microfacsimile installations to complex computer-assisted retrieval systems in which microfacsimile serves as a document delivery component. In the latter category, PRC has developed a complex data management software package called the Intelligent Query System (IQS).

PRC was the contractor for the Navy's Microfiche Image Transmission System (MITS) described in Section One of this report. It has also installed several systems in the private sector. As noted above, PRC was involved in the development of the Microfilm Information and Dissemination System (MIDS) at Randolph Air Force Base during the 1970s.

Among the microfacsimile components specifically developed by PRC, an Image Acquisition Unit is an image digitizer for 24x or 48x microfiche. It permits the manual insertion of one to ten fiche and can operate as a straightforward microfacsimile device designed to scan microform images for transmission to a specified remote workstation. The standard resolution is 200 by 200 lines per inch, although PRC now offers resolution capabilities of 300 by 300 lines per inch. Unlike some other scanners which will only operate effectively with specific film stocks, the PRC unit can accomodate silver, diazo, or vesicular microfiche in various thicknesses. Where automated film handling is required, the Telefiche scanner can be configured with microfiche retrievers, roll film retrieval devices, or aperture card retrieval units. Whether film handling is manual or automated, the Image Acquisition Unit is connected to a system control processor which performs any required data compression and provides high speed data links and disk storage which serves as an image buffer.

For use at remote workstations, PRC offers a choice of several display terminals, including a graphics video monitor with resolution of 200 by 200 lines per inch. PRC also offers a dual-screen workstation which combines a graphics video monitor with a conventional alphanumeric display. The workstation is microcomputer controlled and is capable of standalone word processing and other operations. The graphics display measures 15 inches diagonally and features zoom capabilities. For hard copy output, PRC offers a high speed electrostatic printer or a low speed facsimile receiver.

2.2.9 Ragen Information Systems

Ragen Information Systems (500 Belleville Turnpike, North Arlington, NJ 07032) is best known for the development of automated storage and retrieval systems for 16mm microfilm cartridges. The device can store up to 300 cartridges, each containing approximately 4,000 document images reduced 24x. On instructions received from an operator or a computer, the unit will automatically select a desired cartridge, mount it in a viewing mechanism, and advance the film to display a specified image on an integral reader screen. Certain restrictions apply to film production: 1) each frame must be encoded with image count marks (blips); 2) diazo duplicates are required; and 3) the film length must be 140 feet and the film thickness must be 2.7 mils. Although Ragen offers a specially designed microfilming station based on Minolta planetary cameras, a variety of available cameras are acceptable for document conversion. Ragen also offers conversion support for microfiche files through its subsidiary company Morgan Data Conversion.

Introduced in the early 1970s, the Ragen storage and retrieval unit is offered as a component in the Ragen 95, a turnkey computer-assisted retrieval system designed for the storage of local cartridge files at decentralized workstations. Where centralized cartridge storage is desired, the Ragen 1010 combines the automated storage and retrieval unit with an image digitizer which can transmit retrieved images to remote workstations. The Ragen 1010 is a complex computer-assisted retrieval system which includes a unique microimage transmission component. It is offered in a turnkey configuration which includes computer hardware and software. Ragen has used both Prime and Data General minicomputers for this purpose. Document indexing and retrieval software is also available for computers of other manufacturers. Specific data management capabilities are typically configured to particular application requirements. As noted above, a single cartridge storage and retrieval device can contain up to 1.2 million document images. A single Ragen 1010 system can support up to 128 such devices for a maximum storage capacity of 150 million pages.

The storage and retrieval device features an integral solid-state image digitizer. Operating under computer control, microimages identified by the document indexing and retrieval system are automatically located and positioned for scanning. Movement of film from its cartridge storage location to the scanning position requires a maximum of 16 seconds. The scanner's resolution is 2,850 horizontal lines by 1,728 picture elements each.

For document retrieval operations, the Ragen 1010 can support multiple remote workstations connected to the centralized computer and image transmission system by coaxial cable or other wideband telecommunication facilities. Each workstation includes a conventional alphanumeric video display terminal which is used for index searches and other data management operations. For the display of transmitted document images, the HSD-1185 Hard/Soft Display is a unique product developed specifically for use with the Ragen 1010. Using electrostatic printing technology and a powdered toner, it reconstructs received images as paper documents. When the document image is first printed, the toner is not fused to the paper, and the document is displayed for examination under a clear protective cover. To receive a hard copy of the document, the workstation operator activates a control button which fuses the toner and ejects the copy. If the document image does not meet the operator's information requirements, the toner is erased and the process repeated for any additional document images. The printer's resolution is 2,850 lines by 1,728 picture elements (nominally, 200 lines per inch), and it can produce copies up to 8.5 by 14 inches. It can also operate in an alphanumeric mode as a conventional computer printer.

2.2.10 TERA Corporation

TERA Corporation (2150 Shattuck Avenue, Berkeley, California 94704) is a system integrator specializing in customized document storage and retrieval systems, most of which employ micrographics technology. TERA is a subsidiary of Integrated Automation (formerly, Teknekron Controls Incorporated), a system integrator discussed earlier in this section. But while the two companies offer similar capabilities, TERA's primary market is energy-related organizations and utility companies, for which it offers a wide range of services other than document retrieval.

The TERA Automated Recods Management System (ARMS) is a broad product concept which integrates various modular components, including computer-assisted retrieval and microimage transmission. TERA has certain standard components which it has utilized with considerable success, but, as a system contractor rather than a hardware manufacturer, it can provide a wide range of capabilities and utilizes the components of various manufacturers. TERA is one of the most successful of system integrators, having installed microimage transmission systems at the Nuclear Regulatory Commission, the Federal Energy Regulatory Commission, McDonnell Douglas Corporation, Pratt and Whitney Aircraft, General Electric Drive Systems Engineering Automation Group, and the Kingdom of Saudi Arabia.

All TERA configurations are customized for particular applications. In most cases, microimage transmission is a component in a large scale computer-assisted retrieval system which can be developed by the customer or by TERA itself. Where a turnkey installation is desired, TERA offers its Records and Data Management System (RDMS) software which provides online, multiterminal access to an integrated data base It has been implemented on both mainframe and minicomputers. In terms of microform storage, retrieval, and transmission, TERA can implement systems for microfiche, aperture cards, or roll microfilm. Microforms identified through computer-based index searches are automatically retrieved and positioned for scanning by a solid-state image digitizer. Specific retrieval components are acquired from other companies as required. TERA creates the hardware and software interfaces required to link these devices to computers and workstations.

For use as a document retrieval workstation in general business applications, TERA offers the Model IDT-4000 multi-mode video display terminal. For microimage transmission, it can operate in a graphics display mode at a resolution of 200 by 200 lines per inch. It is also equipped with a character generator which enables it to function as a conventional alphanumeric terminal for index searches or other data processing operations, displaying 70 lines of 80 characters each. The IDT-4000 can also operate in a mixed alphanumeric/graphic mode which permits the display of a document image plus one line of alphanumeric data. For engineering applications, the IDT-4020 provides a large screen for the display of drawings and features zoom capabilities. Like the IDT-4000, it is capable of alphanumeric or mixed mode operation as well as graphic display. Where hard copy output is desired, TERA can provide facsimile receivers or high speed electrostatic printers.

2.2.11 Terminal Data Corporation

Terminal Data Corporation (21221 Oxnard Street, Woodland Hills, CA 91367) is best known as a manufacturer of step-and-repeat cameras, especially the DocuMate II high speed microfilmer which is used in large scale micrographics conversions by business and government agencies. Of significance for this discussion, TDC manufactures several interesting video-based information products, including scanners for paper documents and microforms, high resolution video display terminals, and automated microfiche storage and retrieval units. TDC does not offer self-contained microfacsimile systems. Instead, its products are sold separately to system integrators and end-users who are developing customized microfacsimile equipment configurations. Several of the companies discussed in preceding subsections have utilized TDC products in their systems.

The ImageScan IS-2000 is a solid-state video scanner sold as a digitizing camera suitable for interfacing with other electronic components. Like other state of the art digitizers, it utilizes CCD technology and operates at a resolution of 2,200 lines by 1,728 picture elements per line (nominally, 200 by 200 lines per inch). Lens are available for use with microforms at reductions up to 48x. The TDC Video Image Processor VIP-2000 serves as an interface between the video scanner or other video products and a host computer. It features an integral Intel 8086 microprocessor, a minimum of 156K of random-access memory, various interface boards, and a 120 megabyte hard disk which serves as a buffer for digitized images.

For applications requiring the soft copy display of transmitted microimages, the Videomate-2020M terminal features a 15-inch (diagonally measured) screen in a portrait (vertical) orientation. The high quality, flicker-free display offers resolution of 2,200 lines by 1,728 picture elements (nominally, 200 by 200 lines per inch), and the terminal is equipped with 3.8 megabytes of internal memory. Where one device will be used for both index searches and the display of transmitted microimages, the Videomate-2030 terminal can operate as either an high resolution image display device or as a conventional alphanumeric terminal capable of displaying 85 lines of up to 96 characters each. For computer interaction, it is equipped with a full alphanumeric keyboard.

For automated microfiche retrieval, the TDC Scrollfile stores up to 400-feet of uncut 105mm film in a special cassette. When configured with the the ImageScan IS-2000 or other image digitizer, individual frames can be automatically located for scanning and transmission to remote workstations. These components are sold separately, however, and their integration is the responsibility of the system contractor or end user.

2.2.12 Versatec

Versatec (2710 Walsh Avenue, Santa Clara, CA 95051), is a subsidiary of Xerox Corporation which specializes in the development of electrostatic plotters and similar printing devices for engineering applications. As its name suggests, the Versatec Aperture Card Raster Input Scanner (ACRIS), introduced in 1983, is an image digitizer specifically designed for use with engineering drawing and other graphic documents recorded on aperture cards. Cards are manually inserted in the unit which operates at a resolution of 200 by 200 lines per inch and can scan up to 3 cards per minute. It accepts either silver or diazo film stock.

The scanner is designed for connection to any of several Versatec plotters capable of 11, 22, 24, or 36 inch output. For high speed transmission, these plotters can be connected via coaxial cable at distances up to 1,000 feet or by fiber optics at distances up to 4 miles. Telephone lines are used where longer distances are involved. Although data compression is used, transmission will still prove much slower than it does with the wideband communication facilities used for shorter distances. ACRIS is designed exclusively for use with aperture cards and cannot accept other microforms.

The ACRIS scanner is also used in Versatec's IMPRES 500, a computer-aided design system which digitizes microfilmed drawing images for storage on a magnetic disk from which they can be modified and routed to a plotter.

2.3 EVALUATION OF AVAILABLE PRODUCTS

Given the fact that more microfacsimile systems and components are available now than at any previous point in the history of this product group, the simplest approach to the TRADOC application would involve the purchase of an existing preconfigured product or the replication of a system custom-developed for another application. Unfortunately, none of the existing microfacsimile systems or available microfacsimile products meets TRADOC's requirement for a straightforward, relatively economical system designed to transmit images from a variety of types of microforms. Specifically, available microfacsimile products and system development activities are inappropriate in the following respects:

a. Unlike regular facsimile equipment which is readily available on a preconfigured basis, it is not possible to purchase an "off the shelf" microfacsimile system. To a greater or lesser extent, all vendors customize their systems for particular applications.

b. Most vendors and applications emphasize the implementation of microfacsimile as one component in a computer-assisted document storage and retrieval system. This is most obviously the case with the Access 2010 and Infodetics 410, where the an automated microform retrieval device is the primary system component and microimage transmission is offered as an optional feature. This broader system scope is also characteristic of microfacsimile applications implemented system integrators. In addition to video scanners, output devices, and related electronics, the typical microfacsimile equipment configuration includes computer hardware plus document indexing and retrieval software. Such a computer-assisted retrieval component is not required or desired in the TRADOC application.

c. Available microfacsimile subsystems cannot be readily isolated from their broader system context for standalone operation. While video scanners, video display terminals, or other components are sold separately by such companies as Datacopy, Eikonix, and Terminal Data Corporation, the purchaser is responsible for the development of the hardware and software interfaces essential to microimage transmission.

d. Most current system development efforts likewise emphasize the transmission of microfilm images from centralized storage locations to remote workstations located within the same building or office complex. Coaxial cable is used to interconnect these components and permit high speed transmission. Video display terminals, high speed printers and other workstation components are specifically selected for compatibility with particular scanning devices. The TRADOC application, by way of contrast, requires the long distance transmission of microform images among the various TRALINET libraries. Telephone lines or other narrowband communication links must be utilized.

e. While some high speed transmission links and printing devices might ultimately prove desirable in high volume installations, many of the TRALINET libraries are in locations equipped with ordinary facsimile receivers which could serve as economical output devices for occasional printing. Like the standard Group III facsimile equipment manufactured by various companies, most microfacsimile systems utilize digital image coding and operate at a resolution of 200 by 200 lines per inch. They do not observe Group III telecommunication protocols, however, and such data communication interfaces would have to be developed if local facsimile receivers are to be used as output devices. Additional interfaces must likewise be developed if communication with Group I and Group II analog facsimile equipment is desired.

f. The majority of available systems are designed for the transmission of one type of microform only. This is the case, for example, with the Ragen storage and retrieval unit for roll microfilm, the Access retrieval unit for microfiche, the Telefiche Image Acquisition Unit, and the Infodetics 410 retrieval system for aperture cards. While several of the system integrators have developed systems for 16mm roll microfilm, microfiche, and aperture cards, such a mixture of microform types is not encountered in a single application. The TRALINET libraries, however, maintain all three of these microform types plus microfilm jackets and 35mm roll microfilm. No existing microfacsimile system can accomodate this diversity in a single equipment configuration.

g. Most of the available microfacsimile scanners employ automatic microform loading and frame selection for transmission. They consequently require microforms made to rigid specifications. Microfiche must be produced in one of the NMA standard reductions and formats, and fiche of different formats cannot be mixed within a given system. Roll film images must blip-encoded. Of the fully operational systems discussed in preceding subsections, only the Telefiche Image Acquisition Unit permits manual microfiche loading, but reduction and format restrictions still apply. None of the available microfacsimile systems can accomodate microfilm jackets with their characteristically variable image positioning and spacing. The video scanners manufactured by Datacopy, Eikonix, and Terminal Data Corporation can be configured for manual operation with a variety of microforms, but such devices are sold as discrete components and considerable custom development is required to implement operational systems based on them.

h. In addition to restrictions on microform type, reduction, and format, some of the video scanners discussed in the preceding subsections will only operate with diazo microforms. Library microform collections typically contain a mixture of silver, diazo, and vesicular film stocks.

These limitations argue for the customized development of amicrofacsimile system to meet the requirements of the TRADOC application. Issues associated with such customized development are discussed in the next sections.

SECTION III

OUTPUT AND SCANNING CONSIDERATIONS

3.1 OUTPUT ALTERNATIVES

3.1.1 Paper Copies

The microfacsimile systems described in the preceding section transmit document images to remote locations where they can be reconstituted in any of three forms: as paper copies, in microform, or as a video display. This subsection describes each of these output alternatives and analyzes their advantages and disadvantages.

Facsimile technology takes its name from the paper copies produced by conventional facsimile receivers. Like their conventional counterparts, microfacsimile systems have historically emphasized paper output, and only recently have other alternatives been widely considered and utilized. For library applications in general, and the TRADOC application in particular, paper copies are the preferred output alternative. Specifically, paper copies offer the following advantages:

a. Facsimile printers are a well established, well understood product group that offers the broadest equipment selection options of any of the three facsimile output alternatives. For low volume applications, ordinary facsimile receivers can be used as paper output devices. For higher output volumes, high speed electrostatic printer/plotters are available. Some models will print onto plain paper; others utilize coated papers.

b. When facsimile receivers are used as printers, paper copies are the least expensive of the three facsimile output options. The cost of facsimile printers has fallen to the point where a digital receiver with C.C.I.T.T. Group III compatibility can be purchased for less than $5,000.

c. Some TRALINET libraries are in locations already equipped with one or more facsimile receivers and/or plotters capable of paper output. Assuming that a satisfactory data communications interface can be developed, this installed equipment base could be used for facsimile output, eliminating the need for special equipment purchases in applications where a low volume of activity is anticipated.

d. Paper output is compatible with the reception of a small number of pages. In the case of microform output, as discussed below, short documents waste film space.

e. Unlike the video output alternative where an operator must be present to inspect transmitted document images, paper output is compatible with the unattended reception of multiple pages for examination at a later time. This capability is especially relevant for journal articles and similar multipage library documents.

f. In many cases, the end user prefers paper documents for familiarity, portability, and ease of reference without special display equipment. Even where microform or video display output alternatives are utilized, reader/printers or facsimile printers are typically provided for the production of paper copies of selected document images.

The major disadvantage of paper facsimile is one associated with paper records generally: uncontrolled, paper documents can require significant storage space and create other records management problems. This is unlikely to happen in the TRADOC application, since transmitted documents will be sent for the convenience and personal use of individual researchers and other library clientele. If a library wants a copy of a given document to add to its permanent collection, it can request a microform duplicate to be sent by mail or other conventional methodologies. As an additional disadvantage, the printing of irrelevant document images wastes supplies. As will be noted below, the use of video display output permits the examination of document images prior to printing. Finally, paper printers typically contain mechanical parts which can result in slow operation. This is rarely a problem when transmission depends on telephone lines, since the telecommunications link is the most significant constraint on output speed.

3.1.2 Microform Output

In some applications, document images transmitted via microfacsimile are recorded on microfilm or microfiche at the receiving location. A COM recorder with raster graphics capability serves as the output device in such applications. As noted in Section One, the technical feasibility of this approach to microfacsimile output was demonstrated in the MITS system implemented by Planning Research Corporation for the Bureau of Naval Personnel. Microform output is also a feature of the system installed by TERA Corporation at the Federal Energy Regulatory Commission (FERC). It is reportedly planned for the AMARS system being implemented by Integrated Automation at the Army Reserve Components Personnel and Administrative Center.

Compared to conventional paper copies, microform output offers the traditional records management advantage of saving space. Document handling is typically simplified at the reception point, and supply costs may even be reduced where a high volume of transmission is involved, although detailed study of particular applications would be required to confirm the potential for such savings. In most cases, any supply cost savings would be more than offset by the significantly higher cost of microform output equipment when compared to paper printers. An additional potential advantage, cited in the FERC application, is the ability to rearrange document images and to convert images from one microform type to another -- that is, the ability to transmit scattered images from 16mm microfilm for recording on microfiche as a unit record.

While the advantages noted above may prove meaningful in certain applications, some important disadvantages argue against the use of microform output in the TRADOC application. Specifically,

a. The graphics COM recorders required for microform output are available from a very limited number of manufacturers and are very expensive. Manufacturers include the 3M Company, Information International, and Dicomed, typical equipment configurations are priced at $200,000 or higher. This high cost alone should preclude any further consideration of microform output in microfacsimile applications where recorders would be required at multiple sites. While there has been some recent discussion of lower cost raster COM recorders, prices cited are still in the $60,000 to $100,000 range.

b. Cost aside, site preparation, operation, maintenance, and other requirements for COM recorders are significantly more complex than for most paper output devices.

c. While COM devices are typically capable of much faster image recording than paper output devices, this speed advantage is irrelevant in applications where images will be transmitted over telephone lines or other low-speed telecommunication links.

d. Available graphic COM recorders produce conventional silver gelatin 16mm microfilm or microfiche which require external development, thus adding worksteps, complexity, and delays not present in systems producing paper copies.

e. Once developed, microform copies must be viewed in a reader. In many cases, the end user will make paper copies on a reader/printer, thus defeating the purpose of providing microform output.

3.1.3 Video Display Output

The use of video display output, while relatively recent, is characteristic of many newer microfacsimile systems, especially those in which microimage transmission is a component within a broader computer-assisted document storage and retrieval system. Unlike the conventional alphanumeric CRT terminals which are commonplace in computer installations, the video display devices used in microfacsimile applications are high-resolution, graphics CRT terminals. Such devices are described as "bit-mapped" because individual areas of the CRT screen can be selectively illuminated in a manner corresponding to picture elements in a scanned document image. High resolution video display technology has improved significantly over the last several years, and attractive devices are available from an increasingly large number of vendors. Examples cited in Section Two include Datacopy, Infodetics, Planning Research Corporation, TERA Corporation, and Terminal Data Corporation.

Much of the current popularity of video display output in microfacsimile applications is attributable to the widespread acceptance of paperless information system concepts. When used as the exclusive microfacsimile output device, video displays produce no paper to glut files or cause other records management problems. In many office applications, simple information requests can often be satisfied by consulting displayed images. If paper copies are required, video displays permit the browsing and selection of pages prior to printing, thereby eliminating some unnecessary paper consumption. For CAR applications, several of the vendors discussed in Section Two offer multi-mode terminals suitable for both index searching and document display.

While these advantages can prove significant in applications where microfacsimile serves as the document delivery component for microimages identified by a computer-assisted retrieval system, the video display output alternative has several significant limitations. Specifically:

a. Video displays are poorly suited to library applications where prolonged examination of multipage documents are involved. In such applications, the end user is better served by paper copies. As with microforms, the end user will often make paper copies for reference, mailing, or other purposes.

b. Where telephone lines are used as the transmission medium, one minute or longer may be required for the complete display of a single document image, leaving the user with little or nothing to do while the image is being reconstituted. Video display output is best suited to applications in which coaxial cable or other wideband communication links permit high speed image transmission.

c. As an economic constraint, prices of graphics terminals suitable for document display -- while falling steadily -- remain high. As an example, the Datacopy Model 521 video display, mentioned in Section Two, costs $15,500 exclusive of data communication interfaces. While many TRALINET libraries are already equipped with video display terminals for OCLC or online bibliographic searching applications, such terminals are alphanumeric devices designed for computer generated data rather than document display. Special high resolution video displays would have to be purchased for each site.

3.2 MICROIMAGE SCANNING

3.2.1 Scanner Type

A microfacsimile scanner is a microdensitometer which operates according to raster scanning principles. The scanner divides the microimage into a grid of very small areas called picture elements or pixels, each of which are analyzed for their light reflectance properties. The scanner's output is an electrical signal which reflects the varying light reflectance values of successively encountered pixels. This signal is typically fed to processing circuitry which may enhance or compress it prior to transmission. The design of microfacsimile systems requires attention to the scanner type, its operating resolution, and the pixel encoding method utilized.

Various types of scanners have been proposed and/or actually utilized in microfacsimile systems. Older equipment configurations typically utilized conventional television cameras equipped with relatively expensive image orthicon or with less expensive vidicon tubes. These cameras permit rapid image scanning as well as zoom capabilities which can prove useful in engineering applications. On the negative side, television cameras typically operate at low resolution. While models offering up to 1200 scan lines per document image are available, such resolution will typically prove too low for many office documents. As will be discussed later in this subsection, it is likewise inappropriate for the small typefaces characteristic of many library documents. In addition, television cameras are vulnerable to burning, blooming, poor linearity, and other image distortions. Because they utilize tubes, they can prove bulky and require high voltage power supplies.

Among other approaches proposed for microfacsimile scanning, flying spot CRT scanners utilize an electron beam which traverses an entire image from the top left to the lower right corner, illuminating successive pixels. The intensity of reflected light is measured by a photosensor. This approach is entirely electronic and permits very fast scanning, but it is too expensive for widespread use. Flying spot laser beam scanners may use mirrors or non-mechanical acoustical/optical techniques to illuminate successive pixels. This approach ofers high resolution capabilities, but high cost and slow scanning speeds make it impractical.

Charge-coupled device (CCD) scanners are now being used in most newer microfacsimile equipment configurations. Developed by Bell Laboratories, CCD scanners are solid state devices which consist of a linear array of light sensitive elements. The array corresponds to one horizontal scan line, and it typically consists of one light sensitive element for each pixel in the microimage. The array traverses the microimage during scanning. Although mechanical movement is required, CCD scanners offer significant advantages which account for their current dominance. They are relatively inexpensive. As discussed later in this subsection, they offer high resolution and are generally free of the image distortions associated with conventional television cameras. Because they are composed of integrated circuits, CCD scanners are very compact and offer the long service life customarily associated with solid state devices.

Among the vendors discussed in Section Two, Eikonix utilizes a solid-state, linear, photodiode array as an alternative to a

CCD scanner.

3.2.2 Resolution

Regardless of the scanner type, resolution is an expression of the potential for image quality in terms of the depth of scanning in a given linear dimension of the subject copy. Facsimile resolution is typically expressed in lines or pixels per inch or -- outside of the United States -- per millimeter, and it is measured both horizontally and vertically. Alternatively, horizontal resolution may be expressed in terms of the number of scan line and vertical resolution in terms of the number of pixels per line. With solid state scanners, resolution is typically expressed in terms of the number of photosensitive elements in a linear array. If the array represents a horizontal scan line, then the number of photosensitive elements indicates the vertical resolution. For letter size documents, a 512-element array provides the equivalent of 60 vertical lines per inch, a 1024-element array provides the equivalent of 200 vertical lines per inch, a 2048-element array provides the equivalent of 240 vertical lines per inch, and a 2550-element array provides the equivalent of 300 vertical lines per inch. Horizontal resolution is determined by the array movement pattern, but is typically equal to the vertical resolution.

Through the mid-1970s, facsimile scanners for paper documents typically operated at an approximate resolution of 100 by 100 lines per inch. While such resolution will generally prove satisfactory for most typewritten office documents where mere legibility is required, it is unacceptable for journal articles and other library documents which may contain footnotes, captions, or other text set in small typefaces. Three decades of experience with facsimile equipment indicates that a resolution of 200 by 200 lines per inch produces highly legible output from a very broad range of office documents and is acceptable for the legible transmission of most library materials. Such resolution is typically provided by the majority of currently available microfacsimile scanners. Where higher output quality is desired, some vendors offer resolution of 300 by 300 lines per inch and such higher resolutions are planned for the CCITT Group IV facsimile devices which are currently under development by a number of manufacturers. While the resulting facsimile images approach the quality of original documents, it should be noted that any increase in resolution will correspondingly increase transmission time and cost where ordinary telephone lines are used as the communication link.

3.2.3 Pixel Encoding

Regardless of resolution, the microfacsimile scanner generates a continuously varying analog signal which represents the light reflectance values of successive pixels. While some older microfacsimile systems transmitted the scanner's analog signal directly, newer systems convert it to digital form prior to transmission. Such analog-to-digital conversion permits the application of redundancy reduction and other data compression techniques which can significantly reduce transmission times. Digital pixel encoding is the only practical approach in microfacsimile systems where high resolution is desired and ordinary telephone lines will be used for transmission. In the absence of data compression, the transmission of document images scanned at 200 by 200 lines per inch could require as long as 25 minutes per letter size page.

Digital pixel encoding is based on a thresholding technique in which pixels which generate scanner outputs above a predetermined level are encoded by a "0" bit as white and those with outputs below that level are encoded by a "1" bit as black. While the scanner's analog signal may have reflected grayscale variations in the original microimage, this approach to digital encoding results in the elimination of tonal gradations. While it is suitable for the transmission of text and line drawings, it cannot accomodate the continuous tone illustrations encountered in some library materials. This limitation can be overcome by utilizing more than one bit to encode each pixel. Thus, a system which provides 4 bits per pixel can encode up to 16 shades of gray, while a system which provides 8 bits per pixel can encode up to 256 shades of gray. Such systems are adequate for the useful representation of the photographs or other artwork encountered in the majority of library materials. As potentially significant constraints, however, multi-bit coding schemes are more complex than their single-bit counterparts, and, because they generate much more data, they will significantly increase the transmission time per document image. The higher costs associated with such systems must be weighed against any benefits to be derived from the transmission of continuous tone illustrations.

SECTION IV

EQUIPMENT DEVELOPMENT RECOMMENDATIONS

4.1 CUSTOMIZED MICROFACSIMILE SCANNER

4.1.1 Recommended General Characteristics

As previously discussed in Section Two, none of the currently available microfacsimile systems or components meet the TRADOC's requirement for a straightforward, relativelv inexpensive microimage transmission device to be used in the TRALINET application. Simple microimage transmitters have been proposed for commercial development in the past, but no such devices are currently available. The current activities of equipment manufacturers and system integrators emphasize large, complex equipment configurations in which microfacsimile is merely one component in a sophisticated and expensive automated document storage and retrieval system. While several of the companies discussed in Section Two offer components which might be used in a straightforward microfacsimile equipment configuration, considerable development work is required to combine such components in an effective microimage transmission system.

If TRADOC is to implement a microfacsimile system for the TRALINET libraries, customized equipment development will be required. The most straightforward and versatile approach involves the development of a microimage scanner/transmitter which will function in a manner similar to ordinary facsimile transmitters for paper documents but which will accept microform rather than paper input. The scanner will be designed to facilitate resource sharing among TRALINET libraries and must consequently offer capabilities suitable for the transmission of typical library microforms as outlined below. In meeting the rather stringent requirements of library applications, it should also prove useful for office documents. The scanner will have the following general characteristics:

a. Within the various TRALINET libraries, the microform materials to be transmitted will be identified and located through the library catalog or other bibliographic aids. A complex and expensive computer-assisted retrieval subsystem -- a characteristic component of many of the existing microfacsimile systems described in Section Two -- is neither required nor desired.

b. Materials to be transmitted will be manually removed from their storage locations and carried to the microfacsimile scanner for manual insertion. An automated microform storage and retrieval unit is neither required nor desired.

c. Like conventional facsimile transmitters, the microfacsimile scanner must be designed for ease of operation by clerical personnel.

d. The scanner's output signal must be suitable for transmission over ordinary voice-grade telephone lines using the public switched telephone network.

e. The intended receiver will be a conventional facsimile printer, the nature of which will be discussed below. The use of conventional facsimile receivers will eliminate the need for additional customized equipment development. In addition, as previously noted, such equipment is now installed at many TRALINET locations.

4.1.2 Recommended Operating Specifications

The proposed custom-developed microimage scanner will have the following operating specifications:

a. Microforms accepted: 24x microfiche required; other microfiche, microfilm jackets, and 16mm roll microfilm created at nominal 20-30x reductions optional (see discussion in following sections). 2. Input method: manual microform insertion and manual image positioning prior to scanning.

b. Resolution: nominal 200 lines per inch, both horizontal and vertical, for fine detail; nominal 200 (horizontal) by 100 (vertical) lines per inch optional capability (see discussion in following sections).

c. Coding method: digital.

d. Transmission protocol: CCITT Group 3 compatibility (see discussion in following sections).

e. Data compression methodology: modified Huffman;

modified READ optional.

f. Modem speed: 9600 bps with automatic fall-back to 7200, 4800, or 2400 bps as specified in CCITT recommendations V.27 TER and V.29.

g. Receiver: any CCITT Group 3 facsimile receiver

h. Operating environment: nominally, 60 to 95 degrees farenheit; 10 to 95% relative humidity

4.1.3 Cost Estimate

The estimated cost to develop a demonstration microimage scanner with the general and operating characteristics outlined above will range from $100,000 to $500,000, depending on the variety of microforms to be accomodated. A system for 24x microfiche would be the simplest and least expensive to implement, followed by a system which combines fiche, 16mm roll film, and microfilm jackets. The most expensive approach would involve combinations of these microforms with 35mm roll microfilm and aperture cards. As discussed in the following section, the development of a demonstration system for such a wide variety of microforms is not recommended.

Companies which have demonstrated an interest in, and capabilities appropriate to, the development of a demonstration microimage scanner suitable for the TRADOC application include (in alphabetical order): Eikonix Corporation (23 Crosby Drive, Bedford, Massachusetts 01730), contact -- Fred Sheldon; PRC Government Information Systems (1500 Planning Research Drive, McLean, VA 22102), contact -- Walter Smith; Telemechanics, Incorporated (135 Rome Street, Farmingdale, NY 11735), contact -- George Nagrodsky; and TERA Corporation (7101 Wisconsin Avenue, Bethesda, MD 20814), contact -- Linda Reeder. Terminal Data Corporation (21221 Oxnard Street, Woodland Hills, CA 91367) does not undertake such development work but will provide names of engineering consultants who are competent to develop such equipment configurations using TDC components.

4.2 DISCUSSION

4.2.1 Microforms Accepted

Libraries typically purchase or otherwise acquire microforms from micropublishers or other external sources. Compared to ordinary government and business applications, library microform collections are characterized by a greater diversity of microform types. While the majority of a given collection may consist of microfiche and 16mm roll microfilm, 35mm roll microfilm, aperture cards, and microfilm jackets are also encountered. These microforms may be made from both source documents or computer output. As a further complication, a given microform type may feature different reductions and image formats. Thus, for example, microfiche files may include the 24x, 98-page, NMA Type-1 format; the older 20x, 60-page, NMA Type-2 (COSATI) format; and the 48x, 270-page, NMA Type-7 COM format. Roll microforms may likewise vary in reduction, frame size, and image spacing.

Any attempt to encompass all types of library microforms in a microfacsimile demonstration project will significantly increase the complexity and cost of scanner development without a corresponding increase in benefits. Instead, the preferred approach is to concentrate on the most common microform types, assuming that the remaining items constitute a small portion of the collection and will consequently play little role in interlibrary loan requests. Given its widespread utilization by both micropublishers and in-house microform production operations, the 24x, 98-page, NMA Type-1 microfiche format should be given first priority. The vast majority of micropublished technical reports, serials, and other materials are available in that format. Micropublications produced by the National Technical Information Service, Government Printing Office, and other government publishing operations utilize it exclusively. Future collection development efforts could be directed toward the NMA Type-1 microfiche format, so that a progressively larger portion of library microforms would consist of that format.

With a relatively small additional design effort, a manual input scanner intended for NMA Type-1 microfiche could be configured for 24x 16mm roll microfilm or for microfilm jackets made from 16mm film strips. An appropriate manual method of image positioning, comparable to that employed by microform readers or similar devices, would have to be provided. It is unlikely that the same scanner could operate effectively with

35mm microfilm rolls or aperture cards, but such microforms are presumably of less importance in library resource sharing. The extra expense associated with the development of a scanner for such microforms is of questionable justification.

4.2.2 Resolution

Unlike ordinary office documents which are typically created by typewriters and are of relatively uniform quality and appearance, library materials vary considerably in typography and can include footnotes, captions, and other information set in rather small typefaces. In addition, library microforms are typically procured from a variety of sources and may be of highly variable image quality. Consequently, a conservative approach to resolution is required. While lower resolutions may provide legibility for many microfilmed documents, a minimum resolution of 200 by 200 lines per inch is recommended for best results from the broad spectrum of microform materials. Where high quality microimages made from typewritten documents are involved, an optional additional resolution of 200 (horizontal) by 100 (vertical) lines per inch will typically provide adequate legibility while speeding transmission.

4.2.3 Communication Speed

4.2.3.1 Background

As noted above, the simplest approach to the development of a microimage transmission system involves the use of conventional facsimile receivers as output devices. Operating in much the manner of an ordinary facsimile transmitter, the proposed microfilm scanner will transmit microform images over telephone lines to a remote facsimile receiver where they will be reconstructed as paper enlargements. As noted in a preceding section, some TRALINET libraries are in locations already equipped with facsimile receivers, and the rapidly declining cost of such devices would permit their procurement for those libraries requiring an on-site machine.

The implementation of such a seemingly simple system is complicated, however, by the variety of communication protocols and transmission speeds utilized by installed facsimile receivers. From the 1960s through the mid 1970s, the most widely utilized facsimile machines were analog devices which utilized frequency modulation techniques to tranmit a letter size document in 6 minutes at a nominal resolution of 96 by 96 lines per inch. Such devices -- many of which remain in use -- were sold by Xerox, 3M, Graphic Sciences (now Burroughs Corporation), Exxon, Muirhead, Stewart Warner, Alden, and other companies. In the absence of industry standards, most vendors offered compatibility with the large installed base of Xerox equipment which served as a de facto standard. The majority of these machines could also transmit a letter size document in 4 minutes with degraded resolution, but the machines of different vendors were not compatible in the 4-minute mode. Graphic Sciences also offered analog facsimile equipment which used amplitude modulation techniques to transmit a letter size document in 3 minutes at a nominal resolution of 88 by 88 lines per inch, or in 2 minutes with degraded resolution. Other vendors of analog facsimile equipment likewise employed proprietary techniques to increase transmission speed to 2 minutes or even 1 minute, but -- being incompatible with the majority of installed devices -- such products enjoyed little market acceptance. In the mid 1970s, Rapifax, Dacom, Electronics Associates Incorporated (EAI), 3M, and Graphic Sciences introduced digital facsimile machines capable of transmitting a letter size document in as little as 20 seconds at resolutions as high as 200 by 200 lines per inch. The digital machines of different manufacturers were incompatible with one another, and all available digital models were incompatible with analog devices.

In the late 1970s, the Consultative Committee on International Telephony and Telegraphy (CCITT) announced facsimile standards designed to eliminate future problems arising from the incompatibility of equipment of different manufacturers. These standards currently dominate the design of facsimile equipment, and, while non-standard facsimile receivers remain available, their use in any proposed microfacsimile equipment configuration cannot be recommended.

Briefly, CCITT standards recognize three broad groups of facsimile equipment:

a. Group I consists of older analog devices capable

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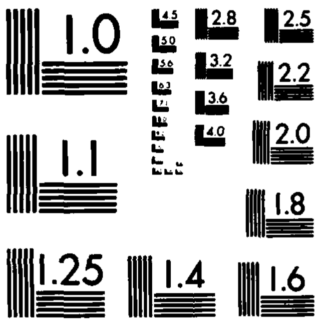

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

of transmitting a letter size document in 6 minutes.

b. Group II consists of newer analog devices capable of transmitting a letter size document in 3 minutes.

c. Group III consists of digital devices which utilize data compression to transmit a letter size document in one minute or less.

Technically, receivers from any of these three product groups might be used as the output device in a custom developed microfacsimile system. As requested in the TRADOC statement of work, the following subsections consider the advisability of subminute, 3-minute, and 6-minute transmission capability, presenting the arguments for and against each mode.

4.2.3.2 Subminute Transmission

As noted above, C.C.I.T.T. Group III facsimile systems consist of digital machines designed for subminute operation. Depending on the particular data compression technique utilized, Group III machines can transmit a letter size document in less than 30 seconds. Such machines, the majority of which are manufactured in Japan or France, are sold in the United States by such companies as Rapicom, Panafax, NEC, Canon, 3M, Xerox, Burroughs, Exxon, and Pitney Bowes. Group III machines are the current focus of industry interest and represent the overwhelming best choice as the receiver component in a microfacsimile system. Specifically, Group III machines offer the following advantages:

a. All major facsimile equipment manufacturers offer at least one Group III machine, and the number of available models is likely to increase in the coming years.

b. As previously noted in Section Three, retail prices for some Group III machines have fallen below $5,000 and further price reductions are likely as sales volume increases.

c. Group III machines offer the 200 by 200 line per inch resolution that is essential for the legible transmission of a broad range of library microforms. It should also be noted that most of the commercially available microimage scanners described in Section Two also operate at 200 by 200 lines per inch, but such devices do not observe Group III communication protocols. They can, however, serve as components in a custom developed microfacsimile equipment configuration.

d. Where the public switched network is used, high speed transmission can lead to reduced telecommunications costs in high volume applications.

e. High speed transmission is more convenient for the multipage transactions typical of library applications.

f. The digital coding techniques utilized by Group III machines are compatible with computer systems and with likely future development in optical disk technology, allowing a device developed for facsimile transmission to later be used for other purposes.

On the negative side, Group III equipment prices, while falling steadily, remain higher than those for analog Group I and Group II machines. As noted above, however, telecommunication costs will typically prove lower in high volume applications. As a further limitation, Group III machines utilize digital coding techniques which are inappropriate for photographs or continuous tone illustrations. As discussed in Section Three, multibit digital coding techniques can be used to transmit photographs, but such techniques fall outside the scope of the CCITT Group III standard.

4.2.3.3 3-Minute Transmission

As previously noted, Group II machines utilize analog encoding to transmit a letter size document in 3 minutes. Most Group II models also support 2-minute transmission with degraded resolution, but the 2-minute mode is not covered by the CCITT Group II standard. Group II equipment is reasonably priced, readily available from a large number of vendors, and widely installed. Because it uses analog encoding, it is suitable for the transmission of photographs.

But despite these advantages, several significant limitations argue against serious consideration of the Group II communication protocol for microimage transmission:

a. Group II standards provide for a resolution of 100 by 100 lines per inch. Such resolution is unsuitable for the broad range of library materials. Because analog machines do not utilize data compression techniques, any attempt to increase resolution will correspondingly increase transmission. Thus, an analog machine like the NEC Nefax System II-D offers resolution of 152 by 148 lines per inch but requires 5 minutes to transmit a letter size page. As a further constraint, such enhanced resolution is beyond the scope of the Group II standard.

b. While 3-minute transmission is acceptable for single page transactions, it requires inconveniently long transaction times for journal articles, technical reports, and other multipage documents. Thus a 10 page article would require 30 minutes of transmission time, and transmission of an entire 98-page fiche would require 5 hours.

c. While Group II machines are widely available now, the future viability of this product group is questionable. The majority of research and development work is being directed to digital Group III machines and the emerging Group IV machines which will use wideband communication facilities for very high speed digital transmission. As prices of Group III machines continue to fall, Group II products will lose market share.

4.2.3.4 6-Minute Transmission

Even considering the very low cost of 6-minute analog facsimile receivers and their installation at many sites, the development of a microfacsimile system compatible with 6-minute transmission cannot be recommended. Representing the image transmission technologies of the 1960s, 6-minute machines offer limited resolution (96 by 96 lines per inch) and require excessively long transaction times for multipage documents. The installed equipment base remains sizeable but is dwindling. No new 6-minute machines are being manufactured, and no vendors are actively marketing them. There is no further technical development within this product group.

(2) Libraries and technical information centers are storing increasingly large amounts of information in microform. In the process, they have generated a tremendous problem in delivering documents to the end user. When needed research documents are available in microform, no rapid transmission of the information contained in them is possible. Mailing microforms is too slow a method to meet information needs of today's researcher. Some form of telefacsmile transmission of microform is needed.

(3) There is no machine currently available which can cost effectively transmit microforms electronically. ~~Planning Research Corporation has such a product, but would have to build an~~ installation at a cost of approximately $500,000; ~~they~~ also report serious loss of resolution, to the point that any print smaller than standard typing would be lost. ~~3M,~~ Xerox, and Exxon do not have a microforms transmission device and report no plans to produce one. Kodak is working on one, but expects to see no commercial development for at least five years, and then only at high cost. The Navy had a large pilot project involving updatable microfiche personnel records, but has stopped the project because of hardware ~~and~~ cost problems.

(4) Although development of this capability would be of immediate value to the Army and DoD R&D community, it would quickly become useful to non-government agencies also. The use of electronic retrieval devices and large bibliographic databases has greatly widened the bibliographic horizons of all libraries. But, identifying a needed piece of information is only the first step; A researcher must also obtain the full text of that information. Libraries and library networks assist in locating copies of articles and reports; DTIC, NTIS, and similar repositories hold huge quantities of documentation. The physical delivery of a copy of this documentation is the link in the chain which needs strengthening.

~~e. Objectives of the effort~~. The study is designed to tell ~~the Army~~ what the current state of the technology is, and to recommend directions for future research and development. ~~A detailed~~

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