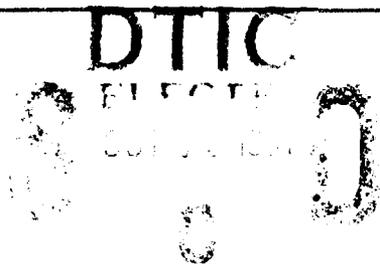


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**US Army Corps
of Engineers**
Construction Engineering
Research Laboratory



USACERL Interim Report P-91/55
September 1991

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Application of Automated Data-Scanning Techniques to U.S. Army Directorates of Engineering and Housing Operations

by
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U.S. Army Directorates of Engineering and Housing (DEHs) are responsible for operating and maintaining a large infrastructure of real property, including millions of acres of land and about 194,000 facilities. Effective management of these resources requires the collection of accurate data on a large quantity of labor, equipment, and material resources. Automated data-scanning technologies, already successfully applied in the private sector, are far more accurate than manual data collection and entry, and can help ensure a maximum return on the Army's sizeable real property investment.

This interim report gives an overview of currently available automatic data-scanning technologies, and summarizes the DEH activities and computer programs that may operate more efficiently and effectively through the application of automatic data entry. It is anticipated that the conclusion of this project will present an overall plan for a unified approach to DEH data collection and entry.

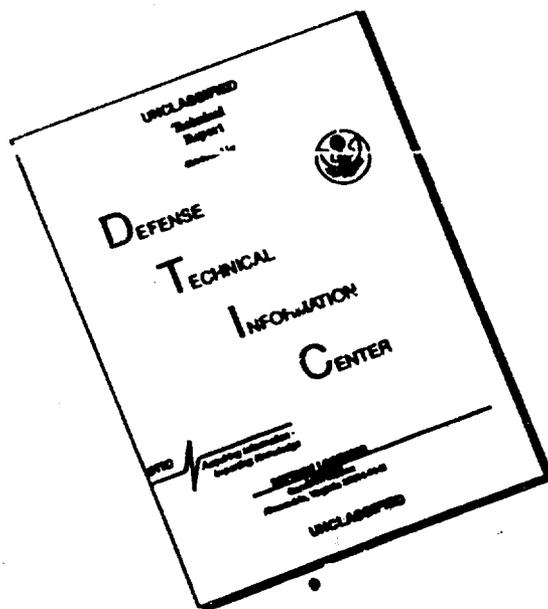
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FOREWORD

The study was performed for the U.S. Army Engineering and Housing Support Center, Fort Belvoir, VA, under Project 4A162784AT41, "Military Facilities Engineering Technology"; Task SB; Work Unit AK1, "DEH Data Entry Concepts." The technical monitor was Mr. Walter Seip, CEHSC-FB-1.

This work was done by the Facility Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USACERL). The USACERL principal investigator was Mr. Donald Hicks, and the USACERL associate investigator was Mr. Glenn Rasmussen. Mr. Robert Neathammer is Team Leader of the Real Property Maintenance Activities Team. Dr. Michael J. O'Connor is Chief, USACERL-FS. The USACERL technical editor was Mr. William J. Wolfe, Information Management Office.

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CONTENTS

		Page
	SF298	1
	FOREWORD	2
1	INTRODUCTION	5
	Background	
	Objectives	
	Approach	
	Scope	
	Mode of Technology Transfer	
2	CURRENT TECHNOLOGY	7
	Overview	
	Bar Code	
	Touch Screens and Light Pens	
	Biometric ID	
	Electronic Data Interchange (EDI)	
	Machine Vision	
	Magnetic Stripe	
	Optical Character Recognition (OCR)	
	RF Data Communications (RF/DC)	
	RF Identification (RF/ID)	
	Smart Cards	
	Voice Input/Output	
3	APPLICATIONS	16
	Anticipated DEH Application of Technology	
	Under Development	
4	SUMMARY	20
	REFERENCES	20
	APPENDIX: Firms Producing End-Use Automated Data-Collection Software	22
	DISTRIBUTION	



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APPLICATION OF AUTOMATED DATA-SCANNING TECHNIQUES TO U.S. ARMY DIRECTORATES OF ENGINEERING AND HOUSING OPERATIONS

1 INTRODUCTION

Background

The Army owns, operates, and maintains a very large inventory of facilities, including over 1 billion sq ft of floor area in approximately 194,000 facilities, millions of acres of land, and an infrastructure that supports the Army's mission. U.S. Army Directorates of Engineering and Housing (DEHs) are responsible for operating and maintaining these resources cost effectively and efficiently while providing the Army with an environment in which to efficiently and effectively function. DEH activities include meeting all the troop and family housing and housing maintenance requirements.

Effective management requires the collection of accurate data on a large quantity of labor, equipment, and material resources. In fiscal year 1986 (FY86), maintenance and repair of these assets constituted a capital outlay of over \$1.2B.¹ Part of this cost is due to outdated manual data collection and entry methods. Automated data collection, widely used in the private sector, is more efficient and accurate than manual data collection and entry. Incorporating state-of-the-art automated data collection methods can help achieve a maximum return on this very sizeable investment. Presently, the Army has begun to field a system to support automated data collection at the installation level. The Integrated Facilities System, Micro/Mini (IFS-M) collects and reports the installation facility data for local and higher level management use.

Computers that assist in the decision making process ultimately rely on the accuracy and speed of raw data collection. In manual data entry, errors occur about one in every 300 characters entered from legible forms. This rate increases when working with numbers or with less legible forms such as the Labor and Equipment card (historically a high-error case). It is conservatively estimated that the cost to find and correct a single keyboard data entry ranges from \$10 to \$25.² Conversely, automatic data identification techniques offer error rates of less than one in one million characters.³ The two most frequently cited benefits of automated data entry are: (1) accurate information, and (2) instant feedback on current organization conditions. Early identification of automatic data collection methodologies and inclusion of these in the system design ensures that the power and speed capacity of the computer is not restricted by a slow, error-riddled, and costly manual data-entry process.

^{*} 1 sq ft = 0.093 m²; 1 acre = 0.405 hectare.

¹ *Facilities Engineering and Housing (FEH) Annual Summary of Operations Report* (Office of the Assistant Chief of Engineers [OACE], 1986).

² Jeff Laurel, "The Role of the Systems Integrator in Auto ID," *ID Systems*, Vol 9 No. 2 (Helmets Publishing Inc, Peterborough, NH, February 1989).

³ Kevin Sharp, *Automatic Identification: Making It Pay* (Van Nostrand Reinhold, New York, NY, 1990).

Objectives

The objectives of this part of the study were to:

1. Review the "state-of-the-art" in available automated data collection and entry methodologies
2. Identify in general terms the DEH's data collection and entry requirements
3. Match the capabilities of automated data collection entry systems to DEH activities and computer programs that may benefit most from automated data entry.

Overall objectives of this study are to identify those research and development areas that offer the best return on investment, and to articulate and outline a general plan for developing and implementing a unified approach to DEH data collection and entry.

Approach

A literature search was conducted to develop an overview of automated data collection methodologies and use within both the commercial and government sector. The American Public Works Association (APWA), the Construction Industry Institute (CII), and the Building Research Board (BRB) were contacted to identify agencies, organizations, or companies actively conducting research, development, or implementations in these areas. As a result, several agencies were contacted directly for additional information.

In addition, USACERL operations research analysts, engineers, and architects reviewed trade and specialty periodicals and manufacturers' catalogues and directories,⁴ attended trade shows and exhibitions, and consulted with other researchers in the field. Contacts were made with other military services,⁵ private developers and consultants, and public agencies with a shared interest in automated data collection.

Scope

This report is limited to the review, identification, and analysis of only those systems/methodologies judged to have the highest potential for return on investment (ROI) when applied to the DEH environment. Scanning systems must be applicable to the broadest possible range of installations, and have a strong potential for field adaptation.

Mode of Technology Transfer

It is anticipated that the results of this study will be forwarded to the U.S. Army Engineering and Housing Support Center (USAEHSC) for further research and development, and eventual fielding throughout Army DEHs.

⁴ *Data Sources -- Hardware, Data Sources Software, 1st Edition, Vol. 2, Vol 10, No. 1* (Ziff-Davis Publishing Company, 1991).

⁵ Mark Reboulet and Lisa Wagner, *Microcircuit Technology Logistics Applications* (U.S. Air Force, Wright-Patterson AFB, OH, 1990).

2 CURRENT TECHNOLOGY

Overview

Automated data collection and identification is a rapidly advancing field. This chapter is intended to present a "snap shot" of the offerings in today's marketplace, and does not include probable or promised research and development (R&D) in the private sector.

Bar Code

Bar code is the predominant automatic identification (Auto ID) technology used to collect data about any person, place, or thing. Its applications appear unlimited. It is widely used for item tracking, inventory control, time and attendance recording, monitoring work-in-progress, quality control, check-in/out, sorting, order entry, document tracking, controlling access to secured areas, shipping and receiving, warehousing, route management, and point-of-sale operations.

Bar code is not a system in itself, but an extremely effective identification tool that provides accurate and timely support of the data requirements for sophisticated management systems. Using bar code in place of manual data entry generally increases accuracy and productivity, yields cost savings, and improves business operations.

Bar codes are a pattern of bars and spaces of varying widths that represent digits, letters or other punctuation symbols to identify an item or to regulate its movement. The arrangement of the bars and spaces is called a "symbology." The Universal Product Code (UPC) and its worldwide counterparts, the European and Japanese article-numbering system (EAN and JAN), are symbologies extensively used in retail. Industrial, medical and government applications often favor Code 39, a bidirectional, alphanumeric symbology with self-checking properties that offers a variable length and a high degree of data security. Code 39 is endorsed by several industry trade groups, including the Automotive Industry Action Group, Health Industry Business Communications Council (HIBCC) and the U.S. Department of Defense (DOD). Also popular in industry is Interleaved 2 of 5, a self-checking, numeric symbology adopted by the Uniform Code Council for use on outer shipping containers, for identification of photofinishing envelopes, in heavy industrial applications, and for warehouse inventory handling. Code 128 and Code 93 are alphanumeric codes that offer high density and high data security. Code 128 is endorsed by HIBCC and the Uniform Code Council. New "stacked" symbologies (16K and Code 49) offer high-density data encoding in a fixed-width format with "two-dimensional" stacked rows.

In use, a beam of light scans a bar code; dark bars absorb light and white spaces reflect light back into the scanner. The scanner translates the light fluctuations into electrical impulses that contain coded information. A decoder uses mathematical algorithms to translate the electrical impulses into a binary code, and to transmit the encoded data message to a PC, controller, or host computer system. The decoder may be integrated or external.

Scanners use visible or infrared LED, helium-neon laser, or solid-state laser diode (visible or infrared) light to read the symbol. Some scanners require contact with the code or label, while other scanners may record information from distances up to several feet. Scanners may be stationary or hand-held and the beam itself may be fixed or moving. Scanner output may be either analog, digital, or ASCII. Each method provides distinct benefits, but to gain the most from a bar code system the scanner should be matched to the application.

Bar codes can be printed directly on items to be scanned, or on labels manufactured by an outside supplier or printed on site. Popular on-site (in-house) printing technologies include dot-matrix and other impact printers, thermal and thermal transfer, ink-jet printers, ion deposition, and electrophotography (lasers). Popular off-site printing technologies for preprinted labels include flexographic, laser etching, offset lithography, photocomposition, ion deposition, and electrophotography. Each technique offers benefits for specific applications. Because a high first-time read rate is important for successful scanning, adequate contrast between the bar code and the surface on which it is printed is vital, and, for a system to be successful, operators must be trained in bar code use.

All bar codes have several similar components. They all have a clear space, called a quiet zone, before and after the code. Specific start and stop patterns indicate the beginning and ending of the code. Check characters, mandatory in some codes, allow a mathematical check which ensures the accuracy of the encoded information. Bar codes also frequently contain data identifiers code prefixes that identify the meaning or intended use of the data that follows. This is an important part of bar codes to be used between companies and industries.

Verifying a bar code's conformance to specifications before it enters the system flow is essential. That verification is achieved with readily available verification or analyzer-type equipment.

Touch Screens and Light Pens

All automatic identification devices are intended to provide an easy way for humans to convey information to computers. "User-friendly" interfaces incorporate ergonomics, or human factors engineering, into hardware design. Touch screens and light pens ease the human interface with computers.

The fundamental advantage of touch screens and light pens is a "do here, see here" ability. Computers usually display an activity on a display screen, but you interact by touching a keyboard, moving a mouse, scanning a bar code, or doing some other action that is removed from the display. With touch screens and light pens, you do something directly to the screen. This greatly simplifies complicated graphical operations and lowers apprehension among users who are not "computer friendly." Public message display boards in shopping malls use touch screens to step shoppers through a series of questions ending with directions to their favorite stores.

Touch screen and light pen systems consist of a position sensor and interpreting software. The software paints an image on a computer display screen, including a specific or implicit question for the user. The user answers the question by touching an area on the screen either with a finger, in the case of touch screens, or with a special pen for light-pen systems. The software then paints another image with another question.

The fundamental difference between touch screens and light pens is the precision of the sensor. Touch screens are limited in precision by the finger, which is an imprecise pointer. This is fine for answering yes and no questions, or for pointing at a box corresponding to a restaurant menu item or a desired store at a shopping mall. Light pens, on the other hand, determine position by detecting the fast-moving electron beam that paints the screen image. This high-resolution technique allows draftsmen to manipulate drawings, and allows users to choose from large, detailed menus.

Touch-screen systems provide several different techniques for determining the location of a pointer that do not rely on special pointing devices. Most systems accept any pointing object (pencil, finger, or stick), while some require a finger to work properly. All offer low to medium resolution, about 100 or so touch points per standard 13-in. display screen.

For all touch-screen technologies the buyer needs to consider reliability, touch thresholds, and resolution. Most systems on the market today require routine maintenance. Some are designed for office use and may not stand up to the abuse that public placement may entail. Touch thresholds determine how firm a touch is required to activate a screen and how often the touch may be repeated. If a threshold is too light, a passing butterfly could enter an order, and too firm a touch may prevent a person from making an entry.

Light pens are a high-resolution cousin of touch screens. They determine screen position by detecting the passing of the scanning electron beam used to paint the computer display. Resolution of light pens is theoretically limited only by the resolution of the computer screen, usually more than 2 million points. Practically, the resolution is limited by the ability of a human to place the pen at a selected spot, a resolution of closer to 50,000 or 100,000 points on a 13-in. screen.

Biometric ID

Used for security and access control applications, biometric identification techniques digitally store some physiological trait as a means of personnel identification. In a fingerprint ID system, for example, a person gains access to a secured area after placing his or her finger on a reader that matches the fingerprint to one digitally stored in a smart card or resident data base. Identification is made in less than 2 seconds. Other personal characteristics being digitized and stored in computers include blood-vessel arrangements in the hand or wrist, blood vessels in the eye's retina, voice patterns, typing patterns and signature patterns. The most widely used of these techniques is the fingerprint scanner. Most widely implemented in high-security areas at banks and government installations, the systems are being tested in applications ranging from prisoner identification, to security for truck drivers transporting loads of dangerous gas, to health spa member identification.

Electronic Data Interchange (EDI)

EDI is the company-to-company electronic exchange of common business data found in invoices, purchase orders and shipping notices. Not an Auto ID technology per se, EDI is the keyless transmission of data between computers in different companies. Data is initially entered into the computer either by keyboard or an Auto ID system, such as a bar code, mag stripe, optical character recognition (OCR), etc. Because the communication is between companies, a third-party EDI network is frequently used as a translator of various computer formats and as a post office to store information in "mailboxes" until it is brought directly into the receiving computer for processing.

Bar codes often work as the "key" to tying EDI transmissions to the physical goods that they describe. For example, a bill of lading may be sent electronically; when the merchandise arrives at its destination, the warehouse dock worker scans a bar code on the shipping container to identify the goods with the electronic documentation. EDI reduces lead times, improves bidirectional information accuracy, and reduces management costs.

One of the first EDI users was the transportation industry. EDI has since been widely adopted by the automotive, drug, grocery, and hardware industries and is being adopted by many more.

Machine Vision

Filmless machine vision is part of the larger electronic imaging field that uses electronics to generate, operate on, and/or display images. Computer vision is a type of electronic imaging that uses

computers to process and analyze image data, typically to assist an operator in making an on-the-scene decision. Machine vision is a type of computer vision that uses computer vision techniques and decisionmaking strategies without human intervention.

Machine vision systems are appropriate for a variety of applications such as: automatic identification, measurement and inspection, robot guidance and control, materials handling and sorting, and a variety of natural- and medical-science uses (e.g., X-ray interpretation and cartography). These electronic vision systems use a video camera interfaced with a computer to create a representation of (digitized) a scene in the computer's memory. Software programs then process this scene representation to obtain the desired information. Many of today's machine vision systems perform this processing with specialized electronic circuitry (hardware) instead of software because hardware-based processing is much faster. Fast performance usually requires expenditures on additional computer hardware.

Many different algorithms have been developed for processing digitized images. Some algorithms (e.g., processing procedures or methods) perform optical character recognition (OCR) or read a bar code. Others identify and locate moving objects in a stationary scene or categorize objects by their shape (shape discrimination). Without fail, if some desired information is contained within a scene, an algorithm can be devised to extract it.

Machine vision systems are much more expensive than bar code readers. This is a natural consequence of the quantity of hardware and complexity of the software contained in a typical vision system. Even at this greater cost, vision-based automatic ID systems will be applied in industry when more conventional forms of Auto ID (e.g., bar codes or radio frequency tags) cannot be used. Vision-based Auto ID systems are practical in applications that require other aspects of machine vision such as quality inspection, gauging, or robotics assembly. In these combined applications, a single vision system can be used to perform both functions.

Machine vision technology continues to improve at a rapid pace. Presently, machine vision systems are used in the automotive, electronic, aerospace, food, drug, beverage, lumber, rubber, and metals industries. As it continues to mature, machine vision technology is expected to generate even greater acceptance and penetration in the industry workplace.

Magnetic Stripe

Magnetic stripe technology uses the magnetic field of an encoding head to record magnetic flux reversals. This information is placed onto a layer of magnetic material similar to that on an audio or video tape. The layer, called a magnetic stripe, is generally attached to the front or back of a paper or plastic card. A decoder reads the flux reversals and translates them into letters and numbers for processing by a computer.

The best-known applications of magnetic stripes are on credit and debit cards for use in automatic teller machines (ATMs) and point-of-sale (POS) terminals. Magnetic stripes are also used for access control to secured buildings and other facilities. Further uses are for time and attendance systems, inventory tracking, personnel identification, amusement parks and games, and manufacturing process control, transit fare collection, and vending.

Compared to printed data, magnetic stripe allows the storage of large amounts of data in a small area. A single magnetic stripe can have several tracks of recorded data, which can be rewritten and updated. Because it requires sophisticated equipment to mass produce cards, "mag stripe" is popular for high-security applications.

Magnetic stripe standards have been developed in two major segments: physical and application standards. Physical standards define recording track locations, encoding methods, data densities, and magnetic recording qualities. Application standards deal with data content and format for different market usages. Additional standards and guidelines for magnetic stripe media and equipment, and for nonfinancial applications, are in the draft stage. Presently, adherence to standards is mandatory only if the card will be used in the financial system.

A fast-growing application is the use of the magnetic stripe cards as a vehicle to authorize and disburse government benefits such as funds, food stamps, and services. Another application gaining momentum is stored value. This is a type of decrementing card. It is purchased in advance of its use and encoded with a specific value. This card is then used to purchase goods or services and the value of the card is magnetically decremented with each use. One ideal application well under way is for telephone toll calls. Other uses include student meal programs, bridge, tunnel and road fees, mass-transit tickets, video clubs, and vending machines.

Optical Character Recognition (OCR)

OCR is a technology that has been used in commercial applications since the 1950s. It was initially designed to read what is known as "stylized" fonts. These "stylized" fonts such as OCR-A, included full alphanumeric character sets with special characters to be scanned or read mechanically, thus providing a method for high speed keyboard-free data entry. However, unlike bar code, the data can be read without decoding.

In the past 3 or 4 years, OCR technology has been improved significantly due mostly to the availability of relatively low-cost, high-powered personal computers. This has allowed for the development of much more powerful software. For example, some of today's OCR equipment is capable of reading common office fonts (e.g., courier) as well as "stylized" fonts. In fact, many manufacturers use the term Intelligent Character Recognition (ICR) which they believe more fully describes today's OCR hardware and software.

In certain applications, OCR/ICR is far better suited for use than bar code. Examples include applications where human readability is required, where high character density is needed, or where converting to and maintenance of bar code labels is expensive or impractical. OCR/ICR is also ideal for reading typewritten or computer-printed material without an *additional* step. OCR/ICR is used most frequently in retail at point of sale, libraries, publishing, payment processing, check reconciliation, billing, and other general data-entry applications.

The two main principles that distinguish optical character recognition techniques are template matching and feature extraction. Template matching "sees" the printed character and matches that image to a data base of possible choices. Feature extraction looks at the structural elements and their combination to recognize the character. In either case, the characters are scanned with a light source; the system recognizes the characters based upon either one, or a combination of the two principles, and converts the data to electronic impulses for transmission to a computer.

OCR, like bar code, is affected by poor printing. However, with minimal care in media preparation and application design, performance can be significantly improved. Recognition of characters is usually slower than bar code recognition. Also, accuracy is not as high as bar code without the use of check digits or other editing schemes. With them, however, transaction readers can be programmed to calculate the check digit of a scanline, thereby reducing errors to fewer than one in 3 million characters.

There are three broad categories of OCR/ICR readers: page readers, transaction readers, and hand-held readers. Page readers scan pages of text either directly from paper or from digitized images of documents stored in the computer system. Transaction readers scan a relatively short stream of data, such as account numbers on payment coupons. The biggest difference between transaction readers and page or text readers is that transaction readers typically provide higher accuracy. Transaction readers are also typically mounted on some sort of mechanical transport. Hand-held readers are used primarily to enter data when mechanical methods are too expensive or impractical. For example, some retailers use hand-held readers to enter item numbers for price look up and inventory control at the point of sale to speed up the check-out process. Hand-held readers are also used in general data entry applications because they allow a user to scan information selectively from forms or other documents.

RF Data Communications (RF/DC)

Radio frequency data communications (RF/DC) is not an automatic identification alternative, but a complementary technology that can be used with Auto ID technologies to communicate from distant locations to host computers in real time. The terminals communicate data over a wireless RF/DC link with an RF base station to a host computer. RF data communications offer the capability of an on-line, real-time communications link without the need for traditional wired transmission lines.

RF/DC terminals use a combination of two proven technologies (radio and digital electronics) to provide interactive communication between free-roaming terminal operators and the host computer. Such terminals can be hand-held or secured to forklifts or other materials handling equipment. In the material-handling industry, RF/DC allows shipping, receiving, storage, retrieval, order picking, pick-slot replenishment, and other instructions to be transmitted directly to/from terminal operators and the host computer. As each task is completed by the operators, appropriate information is transmitted to the host computer for immediate record verification and update. On the retail side, RF terminals are used for price verification, order entry, and direct store delivery.

Generally, there are two types of RF transmission or multiplexing: polling and contention. In a polling system, each RF terminal is polled or queried in a specific sequence. In a contention system, each terminal transmits of its own accord, listening to the RF channel before transmitting to ensure the channel is clear. If the channel is busy, the terminal delays a random number of milliseconds and then tries again. The polling method is the best one for a transaction-heavy system with a smaller number of terminals such as retail-price verification because the polling overhead generally makes it too slow in systems with more terminals. Contention is most successful in systems with many terminals that transmit intermittently because it does not have a polling overhead, making response times shorter. Some RF/DC suppliers combined the polling and contention protocols to capture benefits of both methods.

An essential step in establishing an RF/DC system is a site survey to determine base station placement and radio-wave interference, so RF transmission is guaranteed throughout the building. Some RF systems can operate all terminals on one frequency, while others require multiple frequencies from the FCC (i.e., one per base station).

Until recently, all RF/DC systems required site licensing by the Federal Communication Commission; now some companies are using the "spread spectrum," a new radio band close to the cellular telephone wave length that does not require such license approval. Spread spectrum does just what the name suggests; it spreads the signal over a wider frequency band. The FCC allows such operation in three radio bands: 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz, with the most popular being 902-928 MHz because of the availability of low-cost components. The FCC also limits the range of transmission power to under 1 watt, making it ideal for unlicensed commercial use in short-distance communications. RF/DC radios using spread spectrum usually feature data rates of up to 244,000 bits per

second. This allows simultaneous real-time communication between multinode networks and base stations. As a result, interactive operation, such as hospital personnel entering patient data and confirming medication with the central computer, is now feasible.

Data-throughput rates are a valuable comparison tool in selecting an RF data system because message throughput is the key to a successful RF system. The bottom line is the number of messages an RF system can handle per hour. Baud rates, the speed at which data can be transmitted over the radio link, vary from 2400 to 9600 baud, but higher rates don't always mean higher throughput. Other variables that affect the rate are antenna efficiency, band width, noise, filtering in the modem, and clock-recovery schemes. The time it takes to bring a transmitter up to power, number of units in use, length of transmission, type of multiplexing used, and host response time all influence data throughput rates.

A major concern of RF/DC users is maintenance of plant operations when the host is down. When "dumb" terminals are used, work must stop when the host goes down unless a buffer in the base station or controller can store the data until the host comes back on line. Smart terminals, while more expensive, store the data in RAM until the host is available.

RF/DC provides accurate, timely information by allowing the host computer to interactively check data. It increases labor and equipment productivity and inventory accuracy, eliminates paperwork, reduces space requirements, and increases customer service response time. RF/DC can be used by management to monitor transactions as they occur and dramatically improve an operation's efficiency.

RF Identification (RF/ID)

Radio frequency identification (RF/ID) is analogous to radio transmitters and receivers. Electronic labels (or "tags") are programmed with unique information and attached to objects that need to be identified or tracked, such as pallets, vehicles, automated guided vehicles, etc.

Antenna sensors read information as tagged objects pass. Some RF/ID systems let readers add new information or change existing information on the tag, called "writing" to the tag. All RF/ID systems have noncontact readability. Read ranges from distances of less than an inch to 30 or 40 ft or more are useful in rugged industrial environments where other contact or near-contact ID readers would be damaged or misaligned during operations.

RF tags allow greater placement flexibility than optical bar code labels. RF/ID systems have no line-of-sight requirements, are extremely accurate, and have calculated error rates as low as 1 in 100 trillion. Dirt, paint, and other opaque substances do not affect the tag's readability. Nonmetallic objects can come between the reader and electronic labels without response interference. RF/ID also allows "on-the-fly" identification tagged objects do not need to stop. Metal, however, does affect the ability of all RF systems to read or write information.

RF/ID tags can be used on people, places, objects, animals, and even money. Automated guided vehicles use tags in the floor to guide their direction. Other uses include automated storage and retrieval, tooling ID, personnel monitoring, package and baggage sorting, vehicle monitoring or access, or pallet ID.

Tags come in active (battery-operated) or passive types (where the power comes from the interrogating/reading transmitter). RF/ID tags can have high, medium, or low frequency. Active high-frequency tags transfer data faster and have a longer range than low-frequency types. Low-frequency systems, however, use smaller tags, experience less environmental interference, and are omnidirectional.

RF/ID systems can have either "Read/Write" or "Read/Only" capacity. Read/Only systems only allow information to be read from the tag. Read/Write systems both read and change or add information to the tags as they pass. For example, Read/Only systems identify and track palletized parts or can be attached to pallets while readers are placed throughout the plant at points where parts are to be identified. Once identified, a computer can instruct a machine to perform a specific action on the part.

In a Read/Write information system, the part's tag would give the machine instructions. After work is completed, the machine could report its actual performance to the tag, where it becomes the part's history. An added benefit of decentralized memory in a Read/Write system is that it can relieve the memory and processing duties of the central controllers or host computers.

The most commonly used large RF/ID memory is 64K, but some systems operate with as little as 8K memory. Larger memories are planned for the future.

RF/ID systems add a new dimension to automatic identification by providing solid solutions to the environmental challenge that alternative systems have been unable to meet.

Smart Cards

The Smart Card is an automatic identification technology that uses a credit-card-sized plastic card with one or more micro chips embedded in it. Strictly speaking, smart cards are programmable; each contains a microprocessor chip and can carry a large data base. The term "smart card" is also applied to plastic cards that only contain memory. These IC ROM (integrated circuit, read-only memory) cards or IC memory cards are not programmable, but can contain a large amount of data. They are similar in concept to magnetic stripe cards, but the data is hidden and the card can hold far more data.

Optical cards are also credit-card-sized plastic cards, but the data is stored on many tracks that can be read optically, similar to the way data is stored on optical disks. However, the data is stored on a number of parallel, instead of circular, tracks. These cards can store a great amount of data in a very small space, but the data is not easily updated or changed.

Both smart and optical cards can be either alterable or unalterable. The unalterable versions of both are called ROM (read-only memory) cards. The alterable version of optical stripe cards are designated DRAW (directly read after writing) cards, while the term "smart card" is assumed to designate an alterable version. The optical DRAW card and alterable smart card allow information to be added, but existing information cannot be erased.

Smart cards can carry magnetic stripes or embossed characters that contain some of the data stored in the smart card's memory. This allows the card to be used like an ordinary plastic card with pre-existing terminals. Optical cards often use most of the card's surface to store data and cannot normally be embossed or have a magnetic stripe added. All smart cards contain some memory, and most contain a microprocessor. IC cards that don't have processors are similar in function to optical cards.

Voice Input/Output

Voice recognition technology converts sounds, words, or spoken phrases into electrical signals, and transforms these signals into coding patterns with assigned meanings. This system translates the spoken word into machine-readable form that usually initiates some action. Voice recognition operates as a standalone system or may be integrated with other technologies. It captures data at the source, resulting in real-time data. Voice recognition is ideal where speed, accuracy, and real-time data are a requirement.

or when an operator's hands and/or eyes are occupied, such as in laboratory activity, inventory control, PC-board inspection, forklift operations, sorting or materials processing, and especially for quality control in automotive manufacturing. When combined with radio frequency, voice-data collection permits mobility while verbally capturing data. Voice recognition technology is gaining popularity because it requires minimal training, allows capture and entry of data while operators are performing their normal work, and is cost efficient.

The operator using voice-recognition equipment may carry a telephone-like handset or wear a microphone/speaker headset connected to a unit that recognizes words in a programmed vocabulary and converts them into analog electrical signals. The analog signals are usually changed into digital values and decoded by template-matching or feature analysis. That unit's output goes into a personal computer or to a standalone voice recognition device that can connect to or activate a wide range of computer-based equipment like scales, instruments, programmable logic controllers (PLCs), conveyors, workstations, terminals, and printers.

In some applications, particularly multistep inspections, synthesized voice prompts help to verify complete inspection. Voice recognition combined with voice output prompts the operator through a series of tasks and verifies for correct input. This process can also speed training of new inspectors.

Most voice systems are speaker-trained, i.e., a vocabulary has to be read into the system by each user when installed. Such voice training accommodates speakers with accents and dialects, as well as work-specific vocabulary or jargon. Speaker-independent systems understand words stored from a prerecorded average pool of speakers and therefore require no training, but have limited special vocabularies.

Voice systems are divided into two other categories: those that recognize continuous speech, and those that recognize isolated words. Continuous-speech systems allow users to talk at a normal speaking rate. Isolated-word systems require a slight pause after each word or phrase is spoken. Isolated-word systems are usually less expensive than continuous-speech, but can be tiring for users. Continuous-speech, speaker-dependent systems are available, while continuous-speech, speaker-independent systems are still in the laboratory. These systems someday may have the potential to recognize almost anyone saying anything. In the meantime, there are significant benefits to implementing voice recognition-based systems in those areas where speed, accuracy and real-time data are critical business needs.

3 APPLICATIONS

Anticipated DEH Application of Technology

This section provides a listing of major end-use applications for Auto ID technologies, from Access Control to Work-in-Process. A list of companies that offer hardware/software packages suited to those applications is included in the Appendix to this report, and show the magnitude and variety of the available systems in each of the categories.

The automatic identification and data collection industry separates systems development into the following applications:

1. Access Control. The DEH's mission to maintain and regulate installation/housing facilities requires the regulation of entry and exit to buildings and grounds. The current use of metal keys for entry access requires a significant investment in inventory and inventory maintenance. The use of programmable keying mechanisms, magnetic stripe cards, or smart cards has the potential for enhancing operations in this area.

2. Asset Management. The Installation DEH spends significant resources each year identifying and tracking fixed assets, i.e., installation facilities. Most of Auto ID technologies have a potential for practical incorporation into DEH operations. Using these technologies to input and maintain systems such as IFS-M, can make human operators more efficient than they presently are. Automatic identification and data collection would significantly increase the ability to efficiently gather, store, and transfer field data. Of major significance here is the contribution Automatic ID and data collection is making to the process of gathering data in the field.

3. Cataloging. Maintaining the catalogue for the Facility Engineer Supply System (FESS) would be greatly simplified by taking advantage of the bar coding already used in normal army supply channels. At this time, most of the FESS catalogue operation is hand-entered. A system for identification, listing, and displaying supply information in a specified order would greatly facilitate the supply management process in the DEH.

4. Tracking. Tracking anything is greatly aided by the use of one or more of the Auto ID applications. Having the real time status and location of these items allows all responsible authorities within the DEH to prepare reports with a minimum of effort, and ensures that decisions are based on the same data. The DEH has the responsibility to efficiently track the following items as part of its mission:

a. Document. A document such as a service order/work order can be tracked by barcoding the document number and scanning that number as it passes various locations or stages. Its status is then available in a central location.

b. Item. Recording an item's status and location, relevant operator or handler information, and date and time data will enhance the DEH's ability to function in a real time environment. Using barcoding, RF/ID, or smart cards would allow these capabilities.

c. Lot. Tracking lots/batches to and from points of origin by barcoding or RF/ID has particular application in the area of hazardous substance and waste management. The use of smart cards would allow for complete history records to be maintained on lots being tracked. This will help keep records required by Environmental Protection Agency (EPA) regulations. Another application would be to track the identification and allocation of materials for a specific project and to identify them for a specific location, time, or sequence in the construction or installation process.

d. Package/Delivery. Tracking and recording packages by source, destination and status could be enhanced through barcoding or RF/ID. This would enhance the DEH mission of packing and transporting Army equipment, and would make lost shipments easier to trace. Currently, most shipping companies track packages by this method.

5. Electronic Forms Automation. Electronically capturing and storing forms and documents could be accomplished through the use of OCR. Forms and documents would be printed only when they are necessary, thereby reducing the necessity of keeping a large inventory of these items.

6. Fingerprint Identification. Positive personnel identification using digitized fingerprint images is presently an expensive option used in high-security areas that is inappropriate for DEH applications.

7. Inspection. Incorporating Auto ID technologies, particularly voice recognition and barcoding, into existing inspection systems, such as USACERL's PAVER⁶ or ROOFER⁷ Engineering Management Systems (EMS), would increase the entry accuracy and data collection time. Future inspection systems could be designed to use Auto ID.

8. Job Costing. Using a barcoded catalogue of materials, subassembly and component pricing, and quantity estimates could be constructed based on actual material cost from FESS.

9. Just-in-Time Manufacturing/Construction. Supplies of component materials and parts can be closely controlled to keep inventory levels low while avoiding stock-outs by using Auto ID technologies. This approach to managing DEH construction and other projects would help maintain construction schedules and support more efficient DEH operations.

10. Labor, Time, and Attendance Reporting. Barcoding or OCR can help track the involvement of individual hourly employees on a given job to compute the number of billable hours and employee productivity, and to report these figures to accounting systems such as IFS-M.

11. Order Entry. Barcoding and Voice recognition can be used to enter customer service/work orders in a DEH computer system such as IFS-M. Estimators could also apply this technology to the process of entering materials orders for DEH projects.

12. Personnel Identification. ID media, or various physical characteristics (e.g., photo matching) can be used to call up identifying data in a computer. Media may include ID cards with bar codes or magnetic stripes, or something more sophisticated. Applications may range from the post library checkout to weapons issue. This application is not currently being considered for DEH operations, but has potential for solving security problems.

13. Production Control. Production can be regulated via scheduling, work-in-process, tracing inventory status/control, and/or raw materials/components management by the DEH through the use of Auto ID technologies.

14. Quality Control. Use of automated data collection can guarantee that product production meets pre-defined standards.

⁶ Mark D. Ginsberg, Mohamed Shahin, and Joan Walther, *AutoPAVER, A Software Package for Automated Pavement Evaluation*, TR M-90/15/ADA224176 (USACERL, July 1990).

⁷ David M. Bailey et al., *ROOFER: An Engineered Management System (EMS) for Bituminous Built-Up Roofs*, TR M-90/04/ADA218529 (USACERL, December 1989).

15. Security. Taking readings at checkpoints can verify that sensitive areas are inspected and secured. This is not currently an application to be considered for inclusion in DEH operations.

16. Robotics. Machine control of inspection processes, especially in remote or inaccessible locations. Video filming of the existing conditions and comparing the results to a condition index, such as USACERL's PIPER⁸ program, is one such industrial process.

17. Vehicle Identification. Auto ID technologies can be used for Vehicle Identification Number (VIN) data collection, access control, and management. The DEH usually has a fleet of vehicles that must be tracked for usage and maintenance. Using RF/ID tags or RF smart cards for certain tracking functions related to access and data collection would produce cost savings and more realistic usage factors by automatically recording usage when the vehicle passed a certain point entering or leaving the DEH area. Rental car companies have already automated their operations with this technology.

18. Warehousing, Inventory Control, and Shipping/Receiving. Inventory control records the receipt, automated manifest preparation, validation, storage, and disbursement of products from a facility such as a warehouse. A wide range of Auto ID technologies can record and track items from reception, to inventory status, to issue and increase inventory control and management. FESS operations are prime candidates for these applications. The FESS database is currently maintained on a Motorola Four Phase Computer. Auto ID applications would not replace the current system, but would enhance the functionality of the overall FESS operation.

19. Work Order Tracking/Work-in-Process. Automated tracking of an item's status, quantity and location during manufacturing procedures. As part of the Automatic Labor and Equipment Card (ALEC) system each work order could be produced with a bar-coded label for tracking and identification purposes. This code will enable the labor, equipment usage, and materials to be charged against the work order and will speed job costing.

Under Development

Currently, there are a number of applications being developed that use various scanning technologies. These applications were designed to take advantage of several technologies since no single technology is suitable for all applications. This line of development creates a flexibility not usually available in the field. One installation may wish to use OCR to scan printed forms, while another may prefer barcode wands or voice-recognition hardware.

The following listing describes systems and applications in various stages of research, development, field testing, or in daily DEH use. This list includes several of USACERL's R&D efforts related to equipment, supply, and shop operations in the DEH organization.

The **Equipment Maintenance Management System (EMMS)**, currently in operation at the Fort Lee DEH vehicle maintenance shop, uses barcoded work request forms and parts to track labor and parts. Usually when a repair part is purchased, the warranty period begins immediately. Since some parts may sit on the shelf for an extended period of time, the warranty is often expired by the time the part is installed. The system is accurate enough to allow the shop to track warranty data based on the date of installation. The savings realized by the maintenance shop in the warranty area alone have justified the system's installation.

⁸ Ashok Kumar, W. Riggs, and M. Blyth, *Demonstration of the Pipe Corrosion Management System (PIPER)*, M-86/08/ADA166807 (USACERL, April 1986).

The **Automatic Labor And Equipment Card (ALEC)**, an interface to IFS-M currently in development, will download validation data from the IFS-M database to a shop microcomputer, process and validate collected labor and equipment use data from craftspeople at the DEH shop level, and upload a file of validated labor and equipment data directly to IFS-M. ALEC's design allows for the use of varied data collection input devices. The only requirement is that the data input to ALEC be in the correct ASCII record format. L&E (Labor and Equipment) data collection devices can be as simple as a pen and an L&E card that is scanned by means of an OCR scanner, or as sophisticated as a hand-held barcode wand that collects labor and equipment data by scanning a barcoded work order form printed by ALEC. ALEC is designed to eliminate the current entry errors related to L&E cards.

The **Self-Help Program** currently in use at a number of installations is designed to automate the management of DEH Self-Help Store operations. By barcoding both inventory and personnel identification, the Self-Help stores have realized substantial increases in inventory control and customer satisfaction. Again, the Self-Help Program was designed to take advantage of a variety of scanning technologies such as handheld contact and noncontact barcode scanners, and handheld barcode scanners or voice recognition systems in conjunction with RF data communication. This is another instance where scanning technologies have created savings through increased efficiency.

The **DEH Paperless Shop** is a shop-level maintenance management system, including inventory control, for DEH use in the operation of the various maintenance and repair shops. The system is "paperless" in as much as it uses barcode readers as the primary input device. Each mechanic uses a personal wand to read, record, and time-date stamp all transactions. Data are collected to track receipt and execution of all job orders, work performed, parts and POL (petroleum, oils, and lubricants) used, and the dispatching of vehicles. The data is downloaded into the computer at day's end. This comprehensive system can handle tasks such as inventory control, labor tracking, and work-order management. It will generate reports for use by local and upper-level managers as well as higher authorities. This system will interface with ALEC and will electronically enter and upload the labor and equipment data to IFS-M with no more additional interaction than a visual check of the system data. The system also maintains reports on shop inventory data.

The **Quality Assurance Scheduling and Inspection Maintenance System (QASIMS)** is a fully integrated QA scheduling system used to verify completed work from the IFS-M database. QASIMS randomly samples completed work according to a predetermined strategy, schedules the required inspections according to the priority of the job and the skill category of the inspector, and produces a detailed daily schedule for each inspector. The routine and recurring inspection data will be collected using barcode or other automated data collection systems.

4 SUMMARY

This initial stage of the study has reviewed available state-of-the-art data-collection and entry technologies. DEH requirements for this technology were generally outlined, and areas where DEHs may benefit from such applications were identified. Several automated data-collection and entry applications currently in developmental or experimental stages at DEHs were also described.

Planned final stages of this study include:

1. Proceeding with the investigation of opportunities to incorporate automatic identification and data collection into the DEH organization and operation.

2. Organizing a group within USACERL to gather information and develop expertise in the area of automatic identification and data collection technology. This group would link the various researchers at USACERL and other laboratories in the Department Of Defense, and would be responsible to inform the DEH community of its findings.

3. Developing and organizing an Auto-ID and data-collection users' group with DEH, USACEHSC, and USACERL participation.

4. Continuing a liaison with APWA, BRB, ASCE, and CII to foster technology transfer between federal, nonfederal, and private sectors.

5. Developing an overall plan that delineates a unified approach to DEH data collection and entry.

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APPENDIX: Firms Producing End-Use Automated Data-Collection Software

This Appendix provides a listing of major end-use applications for Auto ID technologies -- from Access Control to Work-in-Process. The list consists of companies that offer hardware/software packages suited to those applications. A preliminary review was made of their applicability to the concepts presented within the text of this report. This list does not constitute an endorsement of these products, a statement of suitability for use in the DEH environment, or a recommendation, but is presented to give some concept of the magnitude of the private sector offering in the field.

Access Control

The regulation of entry and exit of buildings/grounds via Auto ID technologies:

Accusys, 6 Venture St. 100, Irvine CA 92718, 714/727-0478

Computype Inc, 2285 W County Rd C, St Paul MN 55113, 612/633-0633, 800/328-0852

Eastman Kodak Company, Edicon System Div. 95 Allens Creed Rd, Rochester NY 14618, 716/271-2950

Intermec, 6001 36th Ave W, PO Box4280, Everett WA 98203-9280, 206/348-2600

Identatronics, 425 Lively Blvd, Elk Grove IL 60007, 708/437-2654

Identicard Systems Inc, 630 E. Oregon Rd, Lancaster PA 17601, 717/569-5797

Identification Systems, 2 Kane Industrial Dr, Hudson MA 01749, 508/568-9000

Plastic Card Systems, 85 Hayes Memorial Dr, Marlboro MA 01752, 508/485-2050

Polaroid Corporation, Electronic Security Systems, 575 Technology Sq, Cambridge MA 02139, 617/577-3540

Welch Allyn Inc, Data Collection Div, Jordan Rd, Skaneateles NY 13153, 315/685-8945

Asset Management

Identification and tracking of fixed assets:

ABS Associates Inc, 1930 N. Thoreau Dr Ste 190, Schaumburg IL 60173, 708/397-8700

Compuspeak Laboratories, 15095 W 116th St, Olathe KS 66062-1098, 913/491-3444

Dept Of Defense Logmars Program, AMCPSCC-ALOG ATTN: SDSTOTA, Tobyhanna PA 18466-5097, 717/894-7146

Facility Management Systems, 6160 N Cicero Ste 108, Chicago IL 60646, 800/553-1234

ROI Systems Inc, 8892 Quail Run Dr, Sandy UT 84093, 801/942-1752

TISCOR, 15150 Ave of Science, San Diego CA 92128, 619/451-3710

Systacom Inc, 12 Westerville Sq Ste 255, Westerville OH 43081, 800/544-5303

Cataloging

Identification and listing in a specified order of many items or documents for semi-permanent storage:

Barcode Industries Inc, 12240 Indian Creek Ct, Beltsville MD 20705, 301/498-5400

Duplo U.S.A. Corporation, Sales Div, 17481 Mt Cliffwood Circle, Fountain Valley CA 92708, 714/540-8222

Fargo Electronics Inc, 7690 Golden Triangle Dr, Eden Praire MN 55344, 612/941-9470

NCR Corp Cimel Mfg, 1700 S Patterson Blvd, Dayton OH 45479, 513/445-7257

Image Scan Inc, 2515 McCabe Way, Irvine CA 92714, 714/833-0155

Office Automation Systems, 9940 Barnes Canyon Rd, San Diego CA 92121, 619/452-9400

Check-In/Out

On-line tracking of items, people or documents checked in/out of centralized storage or a specific location:

Adaptive Technologies, 810 Los Vallecitos Ste 208, San Marcos CA 92069, 619/591-9121

Percon Inc, 2190 W 11th St, Eugene OR 97402-3503, 503/344-1189

PSC (Photographic Sciences Corp), 770 Basket Rd, Webster NY 14580, 716/265-1600

Telxon Corporation, 3330 W Market St, Akron OH 44313-3352, 216/867-3700

Timekeeping Systems Inc, 1306 E 55th St, Cleveland OH 44130, 216/361-0030

Yankee Concepts Inc, The Concord Center, 10 Ferry St, Concord NH 03301, 603/25-5500

Document Tracking

To follow a document through various locations or stages via Auto ID technologies so its status is available in a central location:

Accusys, 6 Venture Ste 100, Irvine CA 92718, 714/727-0478

ASAP Inc, 1041 41st Ave, Santa Cruz CA 95062, 408/476-3933

Cognitive Solutions Inc, 7850 Carmelita, Altascadero CA 93422, 805/461-1598

Genicom Corporation, One Genicom Dr, Waynesboro VA 22980, 703/949-1000

Panasonic Communications & Systems Inc, 9940 Barnes Canyon Rd, San Diego CA 92121, 619/452-9400

Intermec, 6001 36th Ave W, PO Box 4280, Everett WA 98203-9280, 206/348-2600

Videx Inc, 1105 NE Circle Blvd, Corvallis OR 97330-4285, 503/758-0521

Vocollect Inc, 664 Linden Ave, East Pittsburgh PA 15112, 412/829-8145

Item Tracking

To record an item's status and location plus relevant operator information along with date and time data:

Data Collection Systems, 5959 Baker Rd, Minnetonka MN 55345, 612/938-6461

HandHeld Products Inc, 8008 Corporate Center Dr, Charlotte NC 28226, 704/541-1380

IBM Corporation, Old Orchard Rd, Armonk NY 10504, 407/443-9344

Intermec, 6001 36th Ave W, PO Box 4280, Everett WA 98203-9280, 206/348-2600

CTG/ Scientific Systems Services, 475 S. John Rodes Blvd, P.O. Box 610, Melbourne FL 32902-0610,
407/725-1300

Genicom Corporation, One Genicom Dr, Waynesboro VA 22980, 703/949-1000

Lazerdata Corporation, Electro Corp, 2400 Diversified Way, Orlando FL 32804, 407/843-8975

Electronic Forms Automation

Electronic capture and storage of forms and documents:

Automatic Identification Systems, 397 Venture Dr, Westerville OH 43081, 614/431-3300

Grid Systems Corp, 47211 Lakeview Blvd, Fremont CA 94537, 415/656-4700

Softstrip Inc, 835 S Main St, Waterbury CT 06706, 203/573-0150

Data Recall Inc, 1711 Dell Ave, Campbell CA 95008, 408/354-7555

Fingerprint Identification

Digitized images of fingerprints for positive personnel identification:

Avant Inc, One Avant Way, West Concord MA 01742, 508/369-0860

Drexler Technology Corp, 2557 Charleston Rd, Mountain View CA 94043, 415/969-7277

Identix Inc, 510 N. Pastoria Ave, Sunnyvale CA 94086, 408/739-2000

Scantron Corp, 1391 Valencia Ave, Tustin CA 92680-6463, 714/259-8887

Manco Systems Inc, 850 N Winchester Blvd, San Jose CA 95128, 408/243-4877

Inspection

Comparison of desired items with actual item to detect flaws and errors. Usually of a machine vision system. Typically these systems are menu driven:

Ball Industrial Systems Div, 3400 Gilchrist Rd, Mogadore OH 44260, 216/784-4456

Dravo Automation Sciences Inc, One Olive Plaza, Pittsburgh PA 15222, 412/566-5100

Grid Systems Corp, 47211 Lakeview Blvd, Fremont CA 94537, 415/656-4700

Radix Corp, 4855 Wiley Post Way, Salt Lake City UT 84116, 800/367-9256

Verbex Voice Systems Inc, 1090 King Georges Post Rd Bldg 107, Edison NJ 08837, 210/225-5225

Vocollect Inc, 664 Linden Ave, East Pittsburgh PA 15112, 412/829-8145

Inventory Control

To record the receipt and distribution of items to and from a centralized location:

Barcode Industries Inc, 12240 Indian Creek Ct, Beltsville MD 20705, 301/498-5400

Accu-Sort Systems, 511 School House Rd, Telford PA 18969-9990, 215/723-0981

Datalogic Inc, 301 Gregson Dr, Cary NC 27511, 919/481-1400

Intermec, 6001 36th Ave W, PO Box 4280, Everett WA 98203-9280, 206/348-2600

HandHeld Products Inc, 8008 Corporate Center Dr, Charlotte NC 28226, 704/541-1380

Unarco Material Handling, 332 S Michigan Ave, Chicago IL 60604, 312/341-1411

Rice Lake Weighing Systems, 230 W Coleman, Rice Lake WI 54868, 715/234-9171

Sy-Con Systems Inc, The Alpha Bldg Ste 802, P.O. Box 229, Easton PA 18042-0229, 215/253-0900

Standard Register Co, 600 Albany St, Dayton OH 45408, 513/443-1000

Job Costing

Sub-assembly and component pricing, quantity, and status for bids, proposals and other estimating need:

Ahearn & Soper Co Inc, 27280 Haggerty Rd C19, Farmington Hills MI 48331, 313/489-1953

Birmingham Computer Grp Inc, 30850 Telegraph Rd Ste 250, Birmingham MI 48010, 313/540-0640

Deltron Corp, 4801 E Independence Blvd, Charlotte NC 28212, 704/563-9174

Watson Label Products, 3684 Forest Park Blvd, St. Louis MO 63108, 314/652-6715

Stromberg Products, 446 Blake St, New Haven CT 06515, 203/387-2572

Just-In-Time Manufacturing/Construction

Carefully controlling the supplies of component parts to keep inventory levels low while avoiding stock-outs:

American Turnkey Corp, 3505 Cadillac Ave Bldg L-3, Costa Mesa CA 92680, 714/557-9050

Aztech America, P.O. Box 43200, Detroit MI 48243, 313/963-2048

Dytec, 1336 Energy Park Dr, St. Paul MN 55108, 612/645-5816

Foretell Corp, 155 N. Pfingsten Rd Ste 210, Deerfield IL 60015, 708/272-1850

DL Hiller & Assoc Inc, 14536 Island Dr, Sterling Heights MI 48078, 313/247-0394

Systacom Inc, 12 Westerville Sq Ste 255, Westerville OH 43081, 800/544-5303

Toledo Scale Corp, 350 W Wilson Bridge Rd, Worthington OH 43085, 614/438-4511

Labor Reporting

Tracking involvement of individual employees on a given job to compute the number of billable hours:

ABS Associates Inc, 1930 N. Thoreau Dr Ste 190, Schaumburg IL 60173, 708/397-8700

Barscan Inc, 810 Peace Portal Way #113, Blaine WA 98230, 604/683-7226

Data Collection Systems, 5959 Baker Rd, Minnetonka MN 55345, 612/938-6461

Dytec, 1336 Energy Park Dr, St. Paul MN 55108, 612/645-5816

Intermec, 6001 36th Ave W, PO Box 4280, Everett WA 98203-9280, 206/348-2600

Key Tronic Corp, P.O. Box 14687, Mail Stop 142-D, Spokane WA 99214, 913/345-0690

Peak Technologies Inc, 315 W University Dr, Arlington Heights IL 60004, 708/255-0707

Turnkey Systems Inc, 615 Barksdale St, Jackson MS 39202, 601/353-3638

Lot Tracking

To trace lots/batches to point of origin or to disposal:

ASAP Inc, 1041 41st Ave, Santa Cruz CA 95062, 408/476-3933

Avalon Design & Manufacturing, 130 McCormick Ave #113, Costa Mesa CA 92626, 714/432-7227

Lord Label Systems Inc, 3435 Madison St, Skokie IL 60076, 708/673-0039

Standard Register Co, 600 Albany St, Dayton OH 45408, 513/443-1000

Order Entry

Use of Auto ID technology to enter customer orders in a computer system:

ABS Associates Inc, 1930 N. Thoreau Dr Ste 190, Schaumburg IL 60173, 708/397-8700

Barcode Industries Inc, 12240 Indian Creek Ct, Beltsville MD 20705, 301/498-5400

Data Automation Systems Inc, 999 Town & Country Village, San Jose CA 95128, 408/983-0449

Grid Systems Corp, 47211 Lakeview Blvd, Fremont CA 94537, 415/656-4700

Infolink Corp, 1925 Holste Rd, Northbrook IL 60062, 708/291-2900

Optical Data Systems Inc, 653 N. Ash St, Escondido CA 92027, 619/745-6563

Synergistic Systems Inc, 442 Third St, Neptune Beach FL 32233, 904/249-0201

Votan, 4487 Technology Dr, Fremont CA 94538, 415/490-7600, 800/877-4756

Personnel Identification

Use of ID media or physical characteristics of personnel to call up identifying data in a computer:

Behavior Tech Computer Corp, 46177 Warns Springs Blvd, Fremont CA 94539, 415/657-3956

Datacode Systems, 5122 St Clair Ave, Cleveland OH 44103, 216/881-2120

Identification Systems Inc, 2 Kane Industrial Dr, Hudson MA 01749, 508/568-9000

Softstrip Inc, 835 S Main St, Waterbury CT 06706, 203/573-0150

THORN Automated Systems Inc, 835 Sharon Dr, Westlake OH 44145, 216/871-9900

X-cyte Inc, 1708 N. Shoreline Blvd, Mountain View CA 94043, 415/962-0840

Production Control

The regulation of production via scheduling, work in process, inventory status/control, and/or raw materials/components management:

Ahearn & Soper Co Inc, 27280 Haggerty Rd C19, Farmington Hills MI 48331, 313/489-1953

Data Automation Systems Inc, 999 Town & Country Village, San Jose CA 95128, 408/983-0449

Integrated Automation Solutions, P.O. Box 20237, Baltimore MD 21284, 301/879-3722

Scantron Corp, 1391 Valencia Ave, Tustin CA 92680-6463, 714/259-8887

Telesis Corp, P.O. Box 5000, Chillicothe OH 45601, 614/642-3200

Security

Taking readings at checkpoints to verify that sensitive areas are inspected and secured:

Automatic Access Controls Inc, 7609 Energy Pkwy #101, Baltimore MD 21226, 301/437-9788

EDICON A Kodak Co, 95 Allens Creek Rd, Rochester NY 14618, 716/271-2950

Guard Control System/GCS Inc, 221 Boston Post Rd E Ste 460, 508/485-2554

C E Glew & Assoc Inc, 892 Worcester Rd, Wellesley MA 02181, 617/431-7755

Sensormatic Electronics Corp, 500 NW 12 Ave, Deerfield Beach FL 33442, 305/427-9700

Time Keeping Systems, 1306 E 55th St, Cleveland OH 44103, 216/361-9995

Shipping and Receiving

Automated manifest preparation, validation and internal distribution for items received and shipped from a facility such as a warehouse, store or production plant:

American Turnkey Corp, 3505 Cadillac Ave Bldg L-3, Costa Mesa CA 92680, 714/557-9050

ASAP Inc, 1041 41st Ave, Santa Cruz CA 95062, 408/476-3933

Bar Code Solutions Inc, 4105 Metro Pkwy Ste 101, Sterling Heights MI 48310, 313/268-9350

HandHeld Products Inc, 8008 Corporate Center Dr, Charlotte NC 28226, 704/541-1380

Peak Technologies Inc, 315 W University Dr, Arlington Heights IL 60004, 708/255-0707

Verbex Voice Systems Inc, 1090 King Georges Post Rd Bldg 107, Edison NJ 08837, 210/223-5225

Vocollect Inc, 664 Linden Ave, East Pittsburgh PA 15112, 412/829-8145

Time and Attendance

Hourly employee wage/productivity tracking:

Appel Co, 7039 Valjean Ave, Van Nuys CA 91406, 213/873-4600

IBM Corporation, Old Orchard Rd, Armonk NY 10504, 407/443-9344

Intermec, 6001 36th Ave W, PO Box 4280, Everett WA 98203-9280, 206/348-2600

NCR Corp Cimel Mfg, 1700 S. Patterson Blvd, Dayton OH 45479, 513/445-7257

Videx Inc, 1105 NE Circle Blvd, Corvallis OR 97330-4285, 503/758-0521

Xico Inc, 9737 Eton Ave, Chatsworth CA 91311, 818/709-2600

Vehicle Identification

Use of Auto ID technologies for Vehicle Identification Number (VIN) data collection, access control and management:

Amtech Corp, 4515 Cole Ave Ste 1100, Dallas TX 75205, 214/520-6900

Analog Technology Corp, 1859 Business Center Dr, Duarte CA 91010, 818/357-0098

Drexler Technology Corp, 2557 Charleston Rd, Mountain View CA 94043, 415/969-7277

Magna-Code Systems, 1552 S Anaheim Blvd Ste D, Anaheim CA 92805, 714/778-1184

ROI Systems Inc, 8892 Quail Run Dr, Sandy UT 84093, 801/942-1752

X-cyte Inc, 1708 N. Shoreline Blvd, Mountain View CA 94043, 415/962-0840

Warehousing

The receipt, storage and disbursement of products. Auto ID technologies record inventory status and increase inventory control and management. Automated pick/putaway is frequently part of the system:

ABS Associates Inc, 1930 N. Thoreau Dr Ste 190, Schaumburg IL 60173, 708/397-8700

Accu-Sort Systems, 511 School House Rd, Telford PA 18969-9990, 215/723-0981

ASAP Inc, 1041 41st Ave, Santa Cruz CA 95062, 408/476-3933

Computer Identics Corp, 5 Shawmut Rd, Canton MA 02021, 617/821-0830, 800/343-0846 x212

HandHeld Products Inc, 8008 Corporate Center Dr, Charlotte NC 28226, 704/541-1380

Unarco Material Handling, 332 S Michigan Ave, Chicago IL 60604, 312/341-1411

VL Engineering Inc, 10270-L Spartan Dr, Cincinnati OH 45215, 513/771-7988

Work Order Tracking/Work-in-process

Automated tracking of an item's status, quantity and location during manufacturing procedures:

Applied Vertical Systems Inc(AVS), 8321 Old Courthouse Rd Ste 300, Vienna VA 22182, 703/790-5712

Data Automation Systems Inc, 999 Town & Country Village, San Jose CA 95128, 408/983-0449

Gandalf Data, 1020 S. Noel Ave, Wheeling IL 60090, 708/541-6060

Informix Inc, 5 W Mill St, P.O. Box 465, Medfield MA 02052, 508/359-5378

ROI Systems Inc, 8892 Quail Run Dr, Sandy UT 84093, 801/942-1752

Vertex Industries Inc, 23 Carol St, Clifton NJ 07014, 201/777-3500

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