SEMI-AUTOMATED FINGERPRINT ENCODING SYSTEM (SAFES)

FINAL REPORT FOR:

GRANT NI70-095

UNITED STATES JUSTICE DEPARTMENT

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION

BY FRANK G. MADRAZO

NEW YORK STATE

DIVISION OF CRIMINAL JUSTICE SERVICES

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NOTICE

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PREFACE

The purpose of this project was to create a pilot semi-automated latent fingerprint processing system. An integral part of the program was the design and development of a Semi-Automatic Fingerprint Encoding System (SAFES). This system would allow the introduction of a minutiae-oriented search and classification system. The program was a cooperative venture among municipal police agencies, DCJS and the equipment manufacturer for the purpose of relating to "real-world" problems and subsequent evaluation of results in this context.

This project could not have been completed without the advice, cooperation and technical expertise of staff members of the groups mentioned above. The author, therefore, extends his appreciation to Captain James I. McGowan and Sergeant Robert Tacito of the Rochester, New York Police Department, Evidence Technicians Unit for their assistance in submitting "live" latent fingerprints and providing crime related details for use in our statistical studies.

Appreciation is also extended to Doctor Daryl Thornburg and Mr. James Evans of General Dynamics for their perseverance and considerable technical expertise in implementing the SAFES System.

The author also wishes to thank Mr. Richard Higgins of the Division of Criminal Justice Services, Research staff, who performed the analysis for the latent fingerprint profile chapter, assisted in the debugging of the mini-computer programs and provided valuable insights into the human factors aspects of the project.

Appreciation is also extended to Mrs. Virginia Pollock of the Division of Criminal Justice Services, Programming staff, for her work in debugging the mini-computer programs and extending their usefulness through the addition of numerous subroutines.

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I

INTRODUCTION

I

INTRODUCTION

Fingerprints have been used as the major means of identifying individuals for over sixty years, especially within the criminal justice system. Fingerprints serve two important functions within the system. First, arrest/identification fingerprint cards are used to positively identify an individual when the person is available for fingerprinting. These cards contain all ten fingerprints, in addition to personal descriptive data such as name, weight and height. They are commonly used to ensure that information submitted to or transmitted by an identification bureau is pertinent to the correct individual. Second, latent fingerprints left at a crime scene or on an object associated with a crime can be used to determine the identity of the perpetrator of the crime. Used in this way, fingerprints offer a very potent means of solving crimes.

The basic information used for classifying and searching arrest/identification fingerprints is that derived from a pattern type (loop, arch, whorl, etc.), a ridge count between a core and delta, and of a ridge tracing in the case of whorls. This information, when combined for all ten fingers, determines the Henry Classification Formula for filing purposes. Over the years, extensions and changes have been made in this system to improve its performance. For instance, the New York State Division of Criminal Justice Services (DCJS) computerized arrest/identification system currently utilizes the year of birth to accomplish further subdivision of the file.

The classical system works reasonably well for the arrest/identification fingerprint search. However, if we attempt to search a large file classified by pattern type, and ridge count on the basis of a single fingerprint (latent), the number of records that would have to be visually compared with the fingerprint being searched would, on the average, be enormous. As an example, the average number of records that would be retrieved for single fingerprints from right index fingers would be about 100,000 from a file of one million records; the maximum number retrieved would be on the order of 150,000. The reason for this large number of retrievals is that the information contained in the pattern type and ridge count is not sufficient to narrow the search to only a few records.

At the present time, most base files used for latent fingerprint searches are manually operated and are subsets of the main criminal file. With the present methods of classifying base file fingerprints (generally pattern type breakdown) and manually searching latent fingerprints, a latent search can take days even in a relatively small file representing 20,000 to 40,000 individuals. The task of searching a file containing fingerprints from more than a million individuals would be possible, but would require considerable time and effort -- probably weeks of concentrated work. This is clearly not a task that can be economically accomplished in a large identification bureau unless some significant changes are made in the entire process.

Attempts to improve latent fingerprint processing have included adding more information to the classification system so that fewer records would be retrieved during a search with a single finger. Ridge counts, core types, delta types and locations of particular ridge configurations (e.g., eyelets) have been used to subdivide single fingerprint files. Systems using this additional information have generally been manually operated and have been abandoned when the base files have grown to the point where search times and base file encoding have become prohibitive. Recently, a number of semi-automated systems have been developed utilizing microfilm technology. These systems still have the drawback of utilizing classical gross descriptors for file classification purposes.

In an attempt to provide law enforcement agencies with a modernized latent fingerprint processing system, DCJS has pursued a program leading to the development of a system which will permit a search of large criminal identification files using the information contained in a single latent fingerprint.

Preliminary studies of the latent fingerprint processing problem by governmental agencies and interested vendors have led to the conclusion that a system based on automated or semi-automated encoding and automated searching would have to be devised before the goal of searching latents against large criminal base files could be attained.*

*Studies are too numerous to credit individually. However, as examples, commercial concerns such as Systems Development Corporation, IBM, General Electric, General Dynamics have provided research assistance to DCJS during this program.

As a result of initial studies, DCJS chose to develop a search system based on the location and ridge flow direction of the fingerprint ridge characteristics (minutiae), such as ridge endings and bifurcations utilized by latent examiners for comparison purposes. Minutiae data can be converted to digital information for computer storage and search. This information can also potentially be used to derive descriptors which could serve to subdivide the file, thereby considerably reducing search time.

During the course of our research on the use of minutiae data, we used off-the-shelf display and digitizing equipment to create a base file of more than 20,000 coded fingerprints. We also developed a preliminary search algorithm. Results of these projects indicated that we would require semi-automated encoding equipment designed specifically for fingerprint work. It was also clear that additional research in the areas of classification and search would be required before a total system could be specified. The system developed under Grant NI-70-095 is a pilot system designed to evaluate the use of a Semi-Automated Fingerprint Encoding System (SAFES) in a total systems context. Concurrently, research studies will continue in the areas of classification methods and search algorithms.

The DCJS pilot system also utilizes the gross classification parameters of pattern type, finger number and core delta distance as a screening procedure. It is anticipated that other descriptors derived from the minutia data can be used in specifying a more detailed classification method.

The following sections of this report discuss the status of the DCJS pilot system with emphasis on an evaluation of the SAFES System as the basic input device.

II

PILOT SYSTEM CONFIGURATION

II

DCJS PILOT SYSTEM CONFIGURATION

The DCJS pilot semi-automated latent fingerprint processing system consists of several elements. These are shown in the functional flow chart Figure 1 (p. II-2) and are discussed in detail below.

Submission

DCJS, since it is a central information sharing agency serving all the criminal justice agencies of New York State, can potentially receive latent fingerprints from any of the State's more than 600 law enforcement agencies. However, we are currently limiting the scope of the pilot system to provide service for a large regional area of the state. This area consists of a large central city with associated suburban areas.

Our base file consists of arrest cards submitted by law enforcement agencies located within the above mentioned region. Based on fingerprintable arrest statistics, this base file should contain more than 40,000 digitally encoded fingerprints within one year.

Latent fingerprints are generally submitted to DCJS in the form of 1:1 photographs of the lifted latent obtained at the crime scene. The volume of latents submitted to a central agency generally depends on the following factors:

- The priority given to obtaining latents by the individual law enforcement agencies.

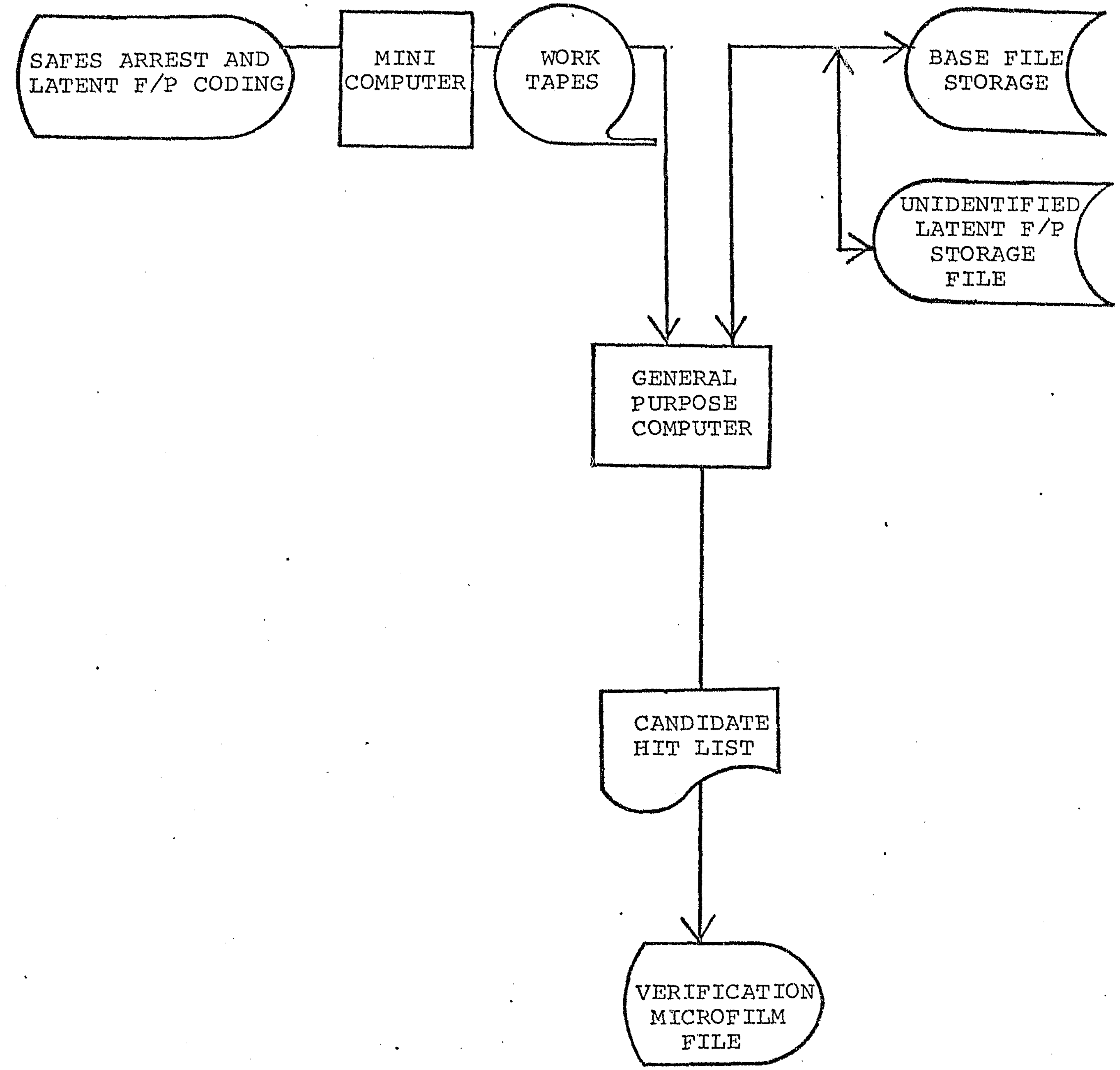

FIGURE 1

DCJS PILOT SEMI-AUTOMATED

LATENT FINGERPRINT PROCESSING SYSTEM

- The extent of service capable of being offered by the central agency.
- The past performance of the central agency in providing identifications.

During the project period (late 1971 to the present), we have received more than 200 good quality crime scene latents from the cooperating agencies. We are maintaining close liaison with the cooperating law enforcement agencies in an attempt to maintain this volume of latents. These agencies are also submitting latents identified with suspects for use in our research.

Encoding

The Semi-Automated Fingerprint Encoding System (SAFES System) generates a computer compatible file of minutiae location and ridge flow direction data from fingerprints for subsequent automated comparison with data from latent fingerprints. Fingerprint card identification data and individual fingerprint data such as finger number, pattern type, and core, delta, and minutiae positional information is converted into digital form and stored on magnetic tape by the SAFES System. In the current system configuration, the search and matching functions are performed by an independent, general purpose computer.

Retrieval

After the general purpose computer searches a latent against the stored base file, a listing of fingers that potentially match the input data is produced.

Currently, the retrieval base file is stored in 16mm microfilm cassettes for use with a Kodak Miracode retrieval system. The computer printout lists a cassette number and film frame number (entered in the ID block as part of the SAFES encoding process), for retrieval purposes. The DCJS number is also listed for quality control purposes.

The examiner accesses the fingerprint by inserting the proper cassette into the microfilm reader and then entering the frame numbers through a keyboard. The equipment passes the film through the reader and stops at the proper card. The computer listing is sorted in two ways:

- Frame number order so that the operator can continue through the cassette in sequence.
- Hit probability order so that the operator can concentrate his verification task on the highest probability candidates.

We store approximately 1,500 arrest fingerprint cards per cassette at a 17x reduction ratio. With the reader used, the reduced fingerprint image is magnified 23x, thereby displaying an approximately 1/3 enlarged image of the individual fingerprint. The specific finger or fingers on the card matching the latent are also included in the B-6700 output to assist the fingerprint examiner in the verification process.

Verification

If a particular base file print shows promise of being an identification, the examiner can produce a photographic hard copy of the image on the screen or as an alternative, retrieve the fingerprint card from the master hard copy base file for closer comparison.

If a hit is made, the examiner then prepares enlarged photographic exhibits for court purposes. These exhibits show each point on the latent corresponding to the base file print.

III

SAFES HARDWARE DESCRIPTION

III

SAFES HARDWARE DESCRIPTION*

PHYSICAL DESCRIPTION

General

The SAFES System Figure 2 (p. III-2) is comprised of a dual console-table and an equipment rack to facilitate mounting of the subsystem assemblies. Table 1 (p. III-3) lists the major assemblies and subassemblies utilized in the SAFES System. The dual console-table consists of front and rear consoles bolted together to form an assembly measuring 28 inches high, 46 inches wide and 48 inches deep. Levelling adjustments are provided on each of the console-table legs. An equipment rack is provided as a separate assembly with surface mounting provisions for the camera stand and rack provisions for the camera electronics equipment. The equipment rack measures 28 inches high, 22 inches wide and 23 inches deep with levelling adjustments on each leg. Distribution panels are provided on the rear of the console-table and equipment rack for interconnection of power, signal and control cables.

Encoding Keyboard

An encoding keyboard Figure 3 (p. III-5) is provided on a chassis measuring 6 inches high, 11 inches wide and 13 inches deep, with an enclosed vertical numeric display panel and a sloping keyboard surface. The keyboard contains 21 keys, 5 lighted pushbutton switches and system controls. An internal backplane-wired logic subassembly contains the integrated circuit sockets into which the logic elements are inserted.

*Taken in part from Semi-Automated Fingerprint Encoding System (SAFES), Document R-74-046, Part Number 2000000, General Dynamics, 1974.

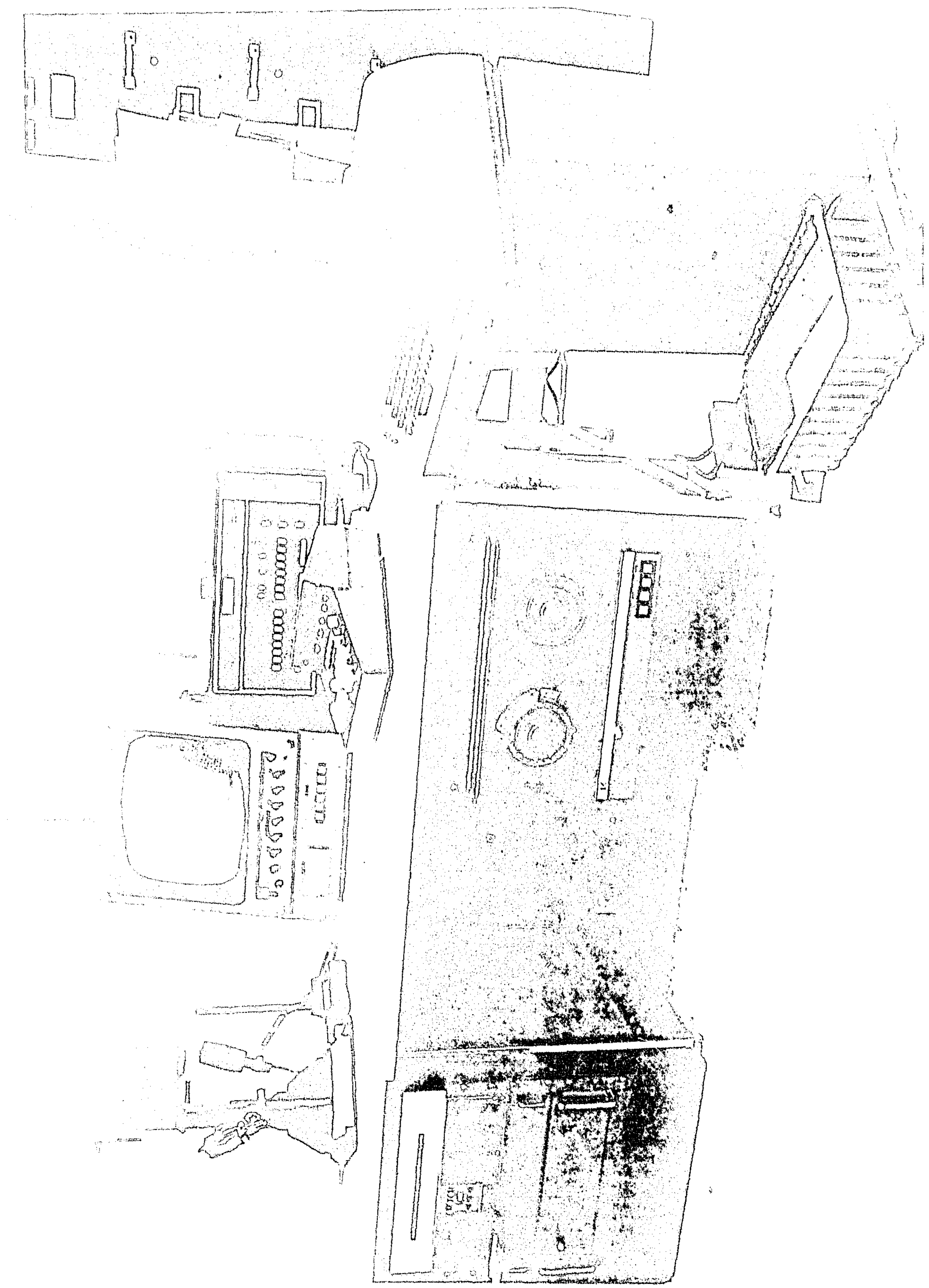

TABLE 1

SAFES System Major Assemblies

ASSEMBLY	MANUFACTURER/DESIGNER
Encoding Keyboard	General Dynamics
Magnetic Tape Unit	Kennedy Company
Digitizer Platen	Hewlett Packard
Computer Base	General Dynamics
System Computer	Varian Data Machine
CCTV Monitor Base	General Dynamics
Error Indicator and Tape Control Panel	General Dynamics
CCTV Monitor	Conrac
Distribution Panel	General Dynamics
CCTV Camera	COHU
CCTV Camera Control Assembly	COHU
Interface Control Unit	General Dynamics
Digitizer Electronics	Hewlett Packard
Distribution Panel	General Dynamics
Teletype	ASR33 Modified by Varian Data Machines

Signal input/output and power connections are made via a single rear-panel connector. Table 2 (p. III-6) lists the keyboard control indicators with the function of each.

<u>Magnetic Tape Unit</u>

The Kennedy Model 1600-9 Track-800 BPI Magnetic Tape Unit is vertically mounted in rack space provided in the right front section of the front console. Reel installation and removal and operation of transport controls can be accomplished from the operator's position.

<u>Digitizer Platen</u>

The Hewlett Packard Model 9107A Digitizer Platen including a modified cursor control, is recessed in the surface of the front console at the operator's position.

<u>Computer Base</u>

A computer base provides the signal and power interface for the encoding keyboard in addition to the front panel MAIN POWER circuit breaker which controls power application to all subassemblies of the SAFES System.

<u>System Computer</u>

The Varian Data Machines 520i Computer is mounted on the computer base on the right side of the rear console. All front panel controls and indicators are accessible from the operator's position.

<u>CCTV Monitor Base</u>

The CCTV monitor base is recessed at an angle on the left side of the rear console, directly facing the operator. The Error Indicator and Tape Control Panel (Figure 4,

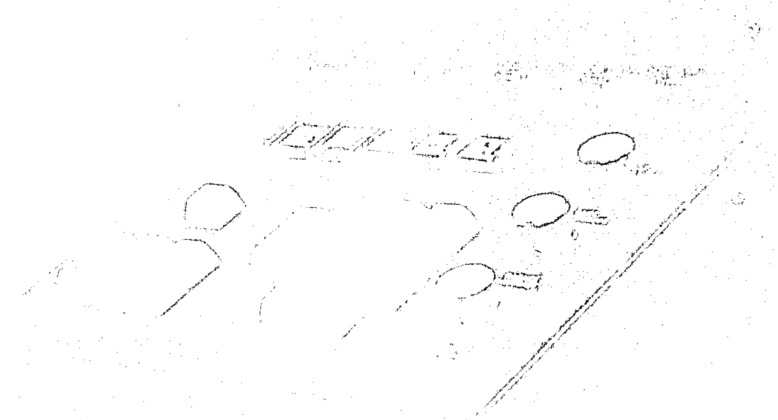

TABLE 2

ENCODING KEYBOARD CONTROLS AND INDICATORS

CONTROL/INDICATOR	FUNCTION
NUMERIC DISPLAYS	
IDENTIFICATION NUMBER	Indicates the Identification number entered (7 digits allowed)
REEL NUMBER	Indicates the Reel Number (microfilm cassette) entered (2 digits allowed)
FRAME NUMBER	Indicates the Frame Number (microfilm) entered (4 digits allowed)
FINGER NUMBER display	Indicates the Finger Number entered (1 digit allowed)
PATTERN TYPE	Indicates the Pattern Type entered (1 digit allowed)
SWITCHES	
START/STOP pushbutton	Combined function control switch. When START is illuminated encoding is permitted. When STOP is illuminated encoding is not permitted
END OF FILE pushbutton indicator switch	Combined function control switch. Momentarily depressing the switch causes an "End of File Gap" to be placed on the magnetic tape
POS/NEG pushbutton indicator switch	Combined function control. Controls the video image as displayed on the CCTV Monitor
TRACE pushbutton indicator switch	Combined functions control. Controls and indicates encoding program mode. When illuminated, indicated RIDGE TRACING mode enabled
RIDGE COUNT pushbutton indicator switch	Combined function control. Controls and indicated the encoding program mode. When illuminated, indicates RIDGE COUNT mode is enabled

TABLE 2

ENCODING KEYBOARD CONTROLS AND INDICATORS (Continued)

CONTROL/INDICATOR	FUNCTION
0 thru 9 numerics	When depressed each key enters numeric identification data
SPACE	When depressed, generates a signal to separate numeric data groups
IRG	When depressed, causes data transfer to magnetic tape and generates an "Inter-Record Gap"
ΔL	When depressed, generates a signal to identify coordinate data as the LEFT DELTA coordinates
CO	When depressed, generates a signal to identify coordinate data as the CORE coordinates
ΔR	When depressed, generates a signal to identify coordinate data as the RIGHT DELTA coordinates
M1	When depressed, generates a signal to identify coordinate data as type M1 minutiae
M2	When depressed, generates a signal to identify coordinate data as type M2 minutiae
D	When depressed, generates a signal to identify coordinate data as the ridge flow DIRECTION of minutiae
DR	When depressed, generates a signal which causes all data recorded since last IRG to be deleted from the computer and/or tape record
DP	When depressed, generates a signal to delete minutiae coordinate data from computer storage

TABLE 2

ENCODING KEYBOARD CONTROLS AND INDICATORS (Continued)

CONTROL/INDICATOR	FUNCTION
ER key	When depressed, generates a signal to extinguish any ERROR INDICATOR and permit encoding
MEMORY CONTRAST	Selects positive or negative video for the encoded minutiae indicator spots
MARKER CONTRAST	Selects positive or negative video for the cursor and encoding and orientation circles
LAMP BRIGHTNESS	Selects one of four intensity levels for illuminating the fingerprint card

p. III-10) is vertically positioned immediately behind the digitizer platen. This panel contains a field of 10 indicators to inform the operator of procedural errors. An additional field of switches/indicators is provided for convenient control of the magnetic tape unit. Table 3 (p. III-11) lists the control/indicators and the function of each.

CCTV Monitor

The Conrac Model CQF-17/C CCTV Monitor is mounted on the base at the operator's station. A hinged front panel door provides access to video controls, and the 12-inch by 16-inch viewing screen is protected by a polarized glass-laminate plate. The monitor base provides a backward sloping face on the TV monitor to reduce reflected glare.

System Power Supply

The system power supply is shelf-mounted in the right section of the rear console directly behind the magnetic tape unit.

CCTV Camera

A camera stand bolted to the top of the equipment rack provides the vertical mounting for a COHU Model 6113-000 CCTV camera. Electrical interconnection of the camera is accomplished through a single connector at the top. A camera height adjustment is provided on the camera stand for raising or lowering the camera.

CCTV Camera Control Assembly

The CCTV camera control assembly is comprised of a modified camera control unit and dot-bar generator module

FIGURE 4

SAFES MONITOR WITH ERROR INDICATORS AND TAPE CONTROL PANEL

TABLE 3

ERROR INDICATOR AND TAPE CONTROL PANEL

CONTROLS AND INDICATORS

CONTROL/INDICATOR	FUNCTION
ID ERROR	Illuminates to indicate a procedural error during entry of ID NUMBER, REEL NUMBER and FRAME NUMBER
FINGER/PATTERN ERROR	Illuminates to indicate a procedural error during entry of FINGER NUMBER and PATTERN TYPE
LAMP INDICATORS	
WRONG FINGER	Illuminates to indicate the entry of an out-of-sequence of incorrect Finger Number
NO CORE	Illuminates to indicate the absence of an entry of the CORE location
NO CORE ORIENT	Illuminates to indicate the absence of an entry of the CORE direction
WRONG KEY	Illuminates to indicate an improper entry following the entry of CORE and CORE direction
MINUTIAE ERROR	Illuminates when two minutiae entries have been made without a minutiae direction entry for the first minutiae or when two minutiae direction entries have been made without a minutiae location following the first minutiae direction
NO IRG	Illuminates when an IRG entry was not made at the proper time
MORE THAN 1 CORE	Illuminates when two CORE locations are selected on one fingerprint
PARITY ERROR	Illuminates when a parity error is detected on the magnetic tape

TABLE 3

ERROR INDICATOR AND TAPE CONTROL PANEL

CONTROLS AND INDICATORS (Continued)

CONTROL/INDICATOR	FUNCTION
SWITCHES	
WRITE/READ	Combined function control. Manually controls the WRITE mode of magnetic tape unit. The mode as indicated by the illuminated switch section
FWD/REV	Combined function switch. Manually controls the direction of tape in magnetic tape unit
SLEW	Manual control for placing magnetic tape unit in a SLEW or fast forward mode
LAMP INDICATORS	
READY	Illuminated when magnetic tape unit is in a WRITE mode - FORWARD
GAP	Illuminates when a gap passes under the read head of magnetic tape unit
END OF TAPE	Illuminates when magnetic tape unit senses the end of the magnetic tape

integrated into a single chassis measuring 5 inches high, 19 inches wide and 16 inches deep. Electrical interconnection is provided through rear panel connectors.

Interface Control Unit

The interface control unit is a front-panel mounted chassis 3½ inches high, 19 inches wide and 16 inches deep. Five rear panel connectors provide signal input/output and power connection. The internal logic chassis is a single-level backplane-wired assembly containing integrated circuit sockets into which the required logic elements are inserted.

Digitizer Electronics

The Hewlett Packard Model 9107A digitizer electronics are housed in a front panel mounted assembly located in the lower portion of the equipment rack. The assembly measures 5 inches high, 19 inches wide and 16 inches deep and has a front panel power switch and associated indicator. Three rear panel connectors provide power and signal interface.

FUNCTIONAL DESCRIPTION

General

As illustrated in Figure 5 (p. III-14) the SAFES System is comprised of the following functional subsystems:

- computer subsystem
- interface subsystem
- CCTV subsystem
- digitizer subsystem

These subsystems are integrated within the overall system to efficiently display, encode and record fingerprint data for the subsequent computerized retrieval and matching processes. The

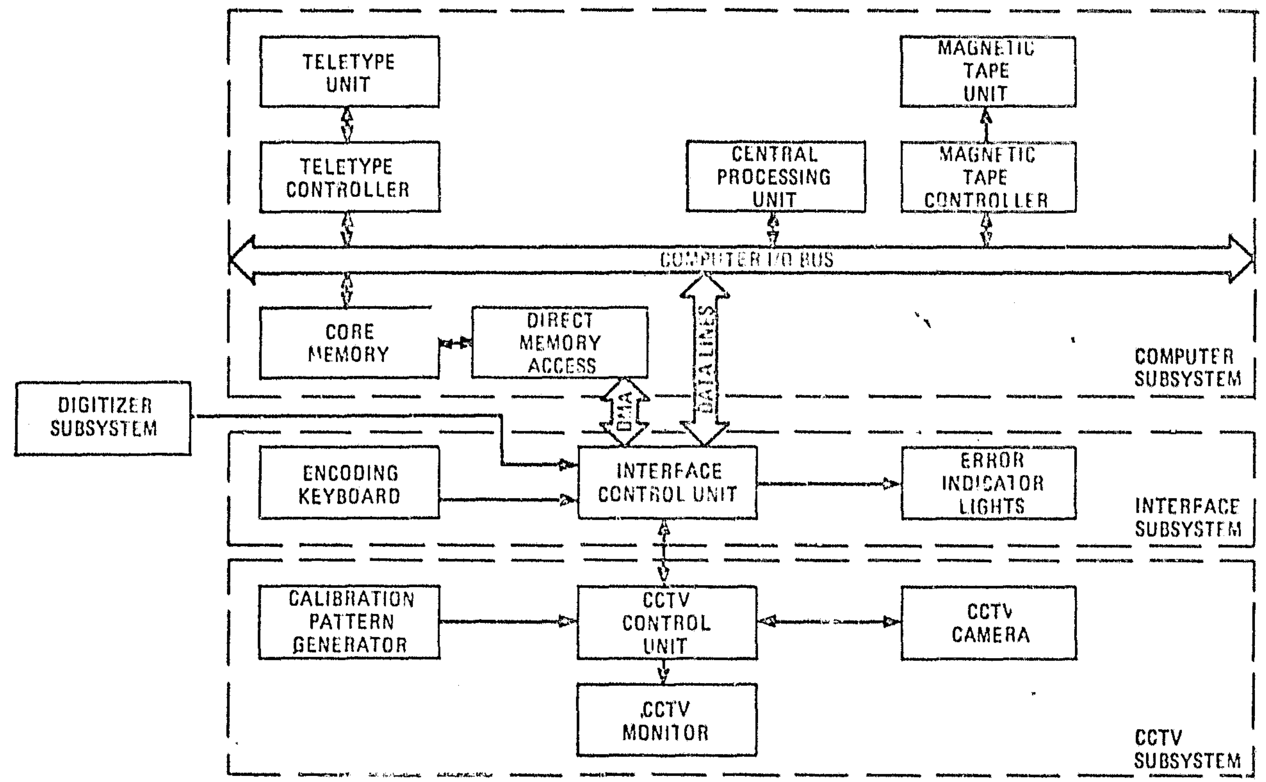

FIGURE 5

SAFES SYSTEM FUNCTIONAL BLOCK DIAGRAM

following paragraphs describe the functional subsystems in detail.

CCTV Subsystem

The CCTV subsystem consists of a high-resolution (1225 line) CCTV camera, a camera control assembly, including camera control unit and dot-bar generator, and a high-resolution CCTV monitor. The CCTV subsystem displays a magnified fingerprint to increase the operator's ability to identify fingerprint characteristics. The CCTV system provides nominal 10:1 magnification of the fingerprint image.

The dot-bar generator, in conjunction with an integral RTMA linearity chart in the camera stand base, provides a means by which CCTV subsystem linearity can be verified without the need for additional test equipment.

A special purpose sync generator located in the camera control unit derives the required 36.75 kHz line rate by dividing a 37.632 MHz clock frequency by 1024. This provides a resolution of approximately 1 part in 760 for the visible portion of each horizontal scan line. A 73.5 kHz signal derived from the 37.632 MHz clock is divided by 1225 to obtain the 60 Hz field rate and provide a resolution of approximately 1 part in 1130 for the visible portion of the vertical sweep.

A marker generator and a memory generator are included as a part of the sync generator. The marker, in the form of a cross-hair, is generated by combining the outputs of X and Y position comparator circuits. The vertical line of the cross-hair is generated by comparing the X positional data from the digitizer subsystem with the parallel output of the line rate divider (1024). When a comparison is made, a pulse is generated and injected into the video. One pulse will be generated and injected for each horizontal scan line.

The horizontal line of the cross-hair is generated by comparing the Y positional data from the digitizer subsystem with the parallel output of the field rate divider (1225). When a comparison is made, a pulse is generated which causes the entire horizontal scan line to be blanked. Only one horizontal line is blanked in each video frame.

In addition to generating the cross-hair, the marker generator is also used to display the encoding and orientation circles. The stored X and Y coordinates of the circle circumference are compared with the outputs of the line rate divider and field rate divider, respectively. A pulse is generated by the marker generator when both the X and Y position comparators are true.

The memory generator consists of X and Y position comparators. X and Y positional information from the digitizer subsystem is compared to the X and Y coordinates of minutiae previously encoded. The minutiae locations are stored in an ordered stack in the computer with the first data point being that point closest to the upper left-hand corner of the CCTV monitor. Additional points are ordered by increasing Y coordinate. When more than one point occurs with the same Y coordinate, the points are ordered by increasing X coordinate. Each set of minutia coordinates is recalled from the stack in sequence as the scan lines are generated.

Digitizer Subsystem

The digitizer subsystem, consisting of a digitizer platen with free-moving stylus, and digitizer electronics is a two dimensional coordinate-measuring device that converts the position of the stylus into digital form. The digital output is used to superimpose the cross-hair on the CCTV monitor and provide minutiae positional data to the system computer. The cross-hair is directed by the operator to each minutia position on the televised fingerprint image by movement of the stylus. The X-Y positional data from the digitizer for each minutia point is stored by the computer and subsequently used to display the encoded minutiae using the memory generator circuitry as an aid to the operator.

Computer Subsystem

The primary element of the computer subsystem is the system computer with 8K of 8 bit variable precision core memory, direct memory access, power fail/restart and real time clock. The computer performs the following functions:

- Accepts and orders all data from the digitizer subsystem and encoding keyboard.
- Formats the data.
- Writes the data onto magnetic tape at the completion of the encoding procedure for each finger.
- Translates all data from an arbitrary coordinate system to a system whose origin is the fingerprint core.

- Rotates all data such that the negative Y-axis of the new coordinate system corresponds to the core direction entered by the operator.
- Reduces the magnitude of the data to fingerprint life size using the CCTV subsystem magnification factor.
- Calculates the coordinates of the two displayed circles during initialization and transfers them to an external solid state memory for storage. Utilization of the solid state memory frees the computer to perform the required formatting, ordering and output tasks.

Interface Subsystem

The interface subsystem consists of the encoding keyboard, error indicator and tape control panel and interface control unit.

The encoding keyboard provides the means for entering fingerprint identification numerics, system mode, minutiae identification and several magnetic tape control functions. All logic necessary to monitor the encoding procedures for errors is located in the keyboard. Procedural errors cause the appropriate error indicator to be displayed on the error indicator panel identifying the error. Further input of data to the computer is inhibited until corrective action is accomplished. The illumination of an error indicator display is augmented by an audible tone to the operator. The tape control panel provides displays indicating the tape mode function currently in operation.

The interface control unit provides interface and buffering requirements between the computer, magnetic tape unit, digitizer, keyboard, and CCTV subsystem. The interface control unit is subdivided into five sections:

- computer buffer
- external memory
- magnetic tape controllers
- digitizer controller
- keyboard buffer

The computer input/output (I/O) and direct memory access (DMA) channels and associated control lines are monitored by the computer buffer. The buffer decodes the I/O channel address and control lines to route data to and from the appropriate peripheral device.

As mentioned above, circumferential coordinate data for the orientation and encoding circles is generated by the computer and stored in the external memory. The memory is organized as a 1024 word by 22 bit unit providing capability for up to 256 orientation circle coordinates and 768 encoding circle coordinates. An X-Y coordinate pair is recalled from memory once every 27 microseconds. Each coordinate pair is compared with line rate and field rate counters for the purpose of generating a circle outline on the CCTV monitor.

Commands from the keyboard, computer, and tape control switches affecting the operation of the magnetic tape unit are controlled by the magnetic tape controller. The rate of transfer of data between the magnetic tape unit and the computer is under the control of the tape controller because of the slower operating speed of the magnetic tape unit.

The digitizer controller generates the sampling signals required by the digitizer subsystem to transfer the positional data and formats and routes the data. Each X and Y positional word is used to generate the cursor on the monitor and as a data input to the computer when the system operation mode is TRACE. In the normal mode for minutiae encoding, only those X and Y positional words corresponding to a desired minutia are selected.

The keyboard buffer formats the fingerprint and minutiae data for transfer to the system computer.

IV

SAFES SOFTWARE

IV

SAFES SOFTWARE

The link between the human operator and the hardware of the SAFES System is the operating program which resides in the computer subsystem. This program controls the operating procedure based on specific subroutines. The operational programs supplied with the system were designed functionally and procedurally to conform with specifications developed as a result of previous DCJS studies utilizing off-the-shelf hardware.

Three independent operating programs are available for use with the system. Each of the programs has 3 functional sections:

1. Initialization

   The initialization routines enable the operator to specify system operating parameters before program operation.

2. ID Procedures

   These subroutines allow the operator to enter identification information to uniquely identify each input document.

3. Encoding Procedures

   These subroutines allow specific digital information to be extracted from the analog information contained on the input document. The detailed operating characteristics of each program are described in the following paragraphs.

Minutiae Encoding Program

The minutiae encoding program enables the operator to obtain accurate positional data on deltas, ridge endings, ridge bifurcations and combinations of these, relative to an axis system described by the fingerprint core location and core direction. Upon completion of minutiae encoding for each fingerprint, the positional data together with the identification information is transferred to magnetic tape for storage.

Following loading of the computer program or initiating the program at "START OF PROGRAM," (a specific memory address manually entered on the computer console display) the operator enters the encoding and orientation circle sizes, the minimum allowed separation between minutiae (epsilon), and the system magnification factor. This initialization data is stored in the computer for use in later computations.

In response to program-generated requests (output to the TTY), the operator enters the identification number of the fingerprint set being encoded and the microfilm reel and frame numbers, if available. This identification information is immediately transferred to magnetic tape upon the activation of the inter record gap (IRG) key in the correct procedural sequence.

In response to further program-generated requests, the operator then enters the finger number and the fingerprint pattern type. Table 4 (p. IV-3) lists the pattern type codes used in the pilot system. The pattern type and finger number are checked to determine if further encoding is required. If the

TABLE 4

PILOT SYSTEM PATTERN TYPE CODES

PATTERN TYPE	CODE
Amputated Finger	0
Plain Arch	1
Tented Arch	2
Right Slant Loop	3
Left Slant Loop	4
Plain Whorl	5
Double Loop Whorl	6
Accidental	7
Scarred or Mutilated Finger	8

pattern type is 0 or 8, or if the finger number is 5 or 10, no further encoding is required and the operator sends this information to tape using the IRG key on the encoding keyboard. For any other valid pattern type or finger number, encoding of at least the core location and core direction is required. The program then branches into the digital data acquisition subroutines to receive fingerprint data.

The minutiae positional data is organized with respect to the location and direction of the fingerprint core. A small circle of selectable diameter is generated to aid the operator in determining the direction of the core. The intersection of the small circle and the core ridge (defined by specific rules) defines the core direction.

The core location and core direction data are used by the computer to derive an X-Y coordinate system whose center is the fingerprint core and whose negative Y-axis passes through the point on the core ridge selected as the core direction.

A second computer-generated circle of selectable diameter is displayed to aid the operator in defining an area in which to select minutiae for encoding. The circle size does not restrict the operator's selection of minutiae. Minutiae outside the circle can be encoded provided the number does not exceed 80. Before the encoded minutiae data are transferred to magnetic tape, they are rotated and translated to the fingerprint coordinate system and then reduced in dimension to actual size by utilizing the magnification factor of the system calculated by the initialization procedures.

Minutiae data input is accomplished by moving the stylus to the desired point and pressing the appropriate key (M_1 or M_2) on the encoding keyboard. The specific minutiae type is determined by decoding an identifier included in the minutiae positional data and is processed accordingly. Delta positional data is stored directly. M1 or M2 is compared with minutiae data previously encoded to determine if any other minutiae is less than epsilon from the new point. Minutia within epsilon are replaced by the new minutia. If all previously encoded minutiae are greater than epsilon from the new minutia, the new minutia is inserted into the stack.

Curve Tracing Program

Following the entry of the initialization and identification information, the curve tracing program enables the operator to automatically record the X and Y coordinates of points from a selected start point along the ridge being traced. The points are stored according to a pre-set interval from an operator-selected starting location. Any interval in increments of ten mils can be selected. The computer automatically accepts X-Y coordinates from the digitizer at an approximate rate of 5,000 points per second. The X-Y coordinates are accepted or rejected by the computer based on the pre-set interval. Those points accepted are sequentially stored in computer memory until the operator terminates tracing. Upon termination of tracing, the X-Y coordinates are transferred to magnetic tape.

This program was developed as a research tool to allow us to test the feasibility of deriving fingerprint search descriptors from ridge configurations that could be mathematically described such as the radius of curvature of whorls, pattern size, etc.

Ridge Counting Program

The ridge counting program enables the operator to count the number of ridges intersecting a computer generated line drawn between two operator selected end points. Normally the fingerprint core and a delta are selected as the end points.

Following the entry of initialization and identification information, the program enters a loop to await entry of the core location. Upon entry of the core location, the program waits for the input of a delta location.

Upon receipt of a delta location, the program branches to a subroutine where the coordinates of the core-delta line are generated. This line is then displayed in the monitor.

The operator enters M1 or M2 for each ridge intersecting the core-delta line. The number of keystrokes is stored in memory.

If more than one delta exists, the second delta location is selected and the core-delta line generated. Ridge intersections are counted as described above.

An IRG is then entered to terminate ridge counting. The core-delta distance for each delta is calculated by the computer utilizing the two end points of the line. The core-delta distance and the ridge count for each delta are then transferred to magnetic tape.

CONTINUED

1 OF 2

This program was also supplied as a research tool to be used in gathering basic statistical data on the relationship of core-delta distance to ridge count. It has also been instrumental in an evaluation of the use of SAFES type equipment as an input device for the DCJS main ten fingerprint processing system.

Each of the programs described above contains a delete record routine which allows the operator to delete records containing errors either before or after they are recorded on magnetic tape.

Incorrectly encoded minutiae points may be deleted from the stack by an interaction of the encoding keyboard delete point interrupt key and the appropriate software subroutines.

V

HUMAN FACTORS

HUMAN FACTORS

Human factors have been defined as those elements which influence the efficiency with which people can use equipment to accomplish the functions of that equipment.*

Following are the elements generally selected for study when evaluating equipment from a human factors point of view:

- task
- personnel
- environment
- equipment

The following subsections will discuss the SAFES System with respect to these elements:

Task

The task of encoding fingerprints at the micro level is a tedious one for a number of reasons:

1. The image quality is highly variable.
2. The rules for locating reference points of interest such as the core and delta are subject to interpretation.
3. The rules for locating specific minutiae types are subject to interpretation.
4. The task requires concentration by the human encoder

*Human Factors Theory and Practice; Meister, David, Wiley 1971, Page 5.

on a small area of the overall complex pattern of the fingerprint.

Since it is not feasible to perform minutiae encoding totally manually, we must determine if SAFES type equipment assists the human in the encoding task to a degree that justifies its use in a semi-automated latent fingerprint processing system.

In evaluating the SAFES equipment with respect to its ability to assist the basic encoding task, we studied the SAFES operating procedure, and through experience determined the training required to produce an experienced operator.

Following is a summary of the SAFES Minutiae Encoding Program Procedure. This serves to illustrate the degree of man-machine interaction required to encode fingerprints with SAFES.

MINUTIAE ENCODING PROGRAM

STEP PROCEDURE

1. Upon receipt of the computer message requesting "Dimension of Encoding Circle," enter via the teletype keyboard the desired circle diameter followed by a SPACE.
2. Upon receipt of the computer message requesting "Dimension of Core Circle," enter via the teletype keyboard the desired circle diameter followed by a SPACE.
3. Upon receipt of the computer message requesting "Epsilon," enter via the teletype keyboard the desired dimension followed by a SPACE.
4. After entering the value for "Epsilon," the computer will halt. Proceed as follows:
    a. On encoding keyboard set the TRACE and RIDGE COUNT

STEP PROCEDURE

switches to ON (illuminated), actuate the START/STOP switch to STOP and depress the ER (Error Reset) key.

b. Place a fingerprint card on the camera vacuum plate. Focus the camera by first adjusting the lens focusing ring. After obtaining the focused image on the monitor, adjust the FOCUS control on the camera control unit to sharpen the image.

c. Place the Magnification Calibration Template on the camera vacuum plate. Center and rotate the template to obtain vertical alignment with the cursor as displayed on CCTV monitor.

5. Depress computer RESET switch.

6. Depress computer RUN switch.

7. Upon receipt of the computer message requesting "MAGNIFICATION FACTOR," align the cursor cross-hair on one corner of the template corner marks. On encoding keyboard depress either the M1 or M2 key. Ignore any error indication. Move the cursor cross-hair to the opposite template corner mark. On encoding keyboard U1A1, depress either the M1 or M2 key. The Magnification Factor, calculated by the computer, will be printed by the teletype.

8. On encoding keyboard actuate TRACE and RIDGE COUNT switches to OFF (extinguished), actuate START/STOP switch to START, and depress the ER key.

9. Upon receipt of the computer message requesting "NYSIIS NUMBER," enter via encoding keyboard the identification

STEP	PROCEDURE
	number. THE NUMBER MUST BE ENTERED LEAST SIGNIFICANT DIGIT FIRST.
10.	Upon receipt of the computer message requesting "REEL NUMBER," enter via encoding keyboard the reel number. THE NUMBER MUST BE ENTERED LEAST SIGNIFICANT DIGIT FIRST.
11.	Upon receipt of the computer message requesting "FRAME NUMBER," enter via encoding keyboard the frame number. THE NUMBER MUST BE ENTERED LEAST SIGNIFICANT DIGIT FIRST.
12.	On encoding keyboard, depress IRG key.
13.	Place the fingerprint card on the camera vacuum plate. Align the card such that fingerprint number 1 is displayed on CCTV monitor.
14.	On encoding keyboard depress numeric key "1" for finger number.
15.	On encoding keyboard depress SPACE key.
16.	On encoding keyboard depress a numeric key corresponding to the fingerprint pattern type.
17.	On encoding keyboard depress SPACE key.
18.	Move the cursor to the core location and depress key "CO" on the encoding keyboard.
19.	Move the cursor to the point indicating the direction of the core and depress key D on the encoding keyboard.
20.	Move the cursor to the location of the left delta and depress key ΔL on the encoding keyboard. If no left delta exists, proceed to next step.
21.	Move the cursor to the location of the right delta and depress key ΔR on the encoding keyboard. If no right delta

STEP	PROCEDURE
	exists, proceed to next step.
22.	Move the cursor to a minutiae and depress either key M1 or M2 on encoding keyboard.
23.	Move the cursor to the point indicating the direction of the minutiae and depress key D on encoding keyboard.
24.	Repeat steps 22 and 23 until all desired points are encoded.
25.	On encoding keyboard depress IRG key. This action causes the minutiae and direction data stored in the computer to be transferred to magentic tape.
26-49.	Steps 14 through 25 are repeated until the entire fingerprint card is encoded.
50.	On encoding keyboard actuate START/STOP switch to STOP and depress ER key.
51.	Depress the computer RUN switch.
52.	On encoding keyboard actuate the START/STOP switch to START.
53.	Select next fingerprint card and repeat steps 9 through 52.

As the procedural steps illustrate, there is considerable human involvement with each subsystem of the SAFES total system.

Our experience in training operators has indicated that an orientation session followed by a several hour supervised training session provides adequate knowledge for an operator to proceed through the operating sequence with little difficulty. Within a maximum of three subsequent sessions, sufficient facility in operating the equipment will have been accrued to consider an operator fully trained.

Personnel

Four latent fingerprint examiners (2 male, 2 female) from the DCJS Special Services Section participated in an experiment designed to collect data on the following personnel related parameters.

- cards coded/time period
- error rates
- inter-operator consistency
- intra-operator consistency
- rest periods required

Fifteen fingerprint cards were drawn at random from the DCJS master fingerprint file for use as the encoding file.

The experimental design called for an operator to begin encoding fingerprints as per the normal operating procedure until he/she was fatigued to the point of requiring a break. An observer monitored the encoding procedure and filled in the form shown in Figure 6 (p. V-7). Utilizing a stopwatch, the observer noted the time required to encode the identifying information (DCJS number, retrieval system reel and frame number, finger number and pattern type). The SAFES System clocked the overall procedure and printed out a time per card to the tenth of a minute. Data on the following parameters were tabulated:

- time to encode ID information
- time to encode total card
- time/finger
- number of minutiae vs. coding circle size
- number of error conditions
- qualitative comments from operators

The encoding circle parameter has the effect of delineating the area of the fingerprint to be encoded. The size

OPERATOR: OBSERVER: DATE:

Card No.	Overhead Time	No.of Image Adjustments	No.ER	No.Memory Spot Chng.	No.DP	No. DR - REASON
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

TIME FINISH: :

TIME START: :

LAPSE TIME:

COMMENTS:

FIGURE 6

HUMAN FACTORS EXPERIMENT DATA COLLECTION FORM of the encoding circles for the experiment were determined using the following criteria:

- The average number of minutiae to be found within the circle. If this average is too small, search program performance potentially suffers and the number of latents that can be searched decreases. If too large, coding time is too long and error rates potentially increase.
- Hardware limitations of the SAFES equipment. The external memory of the system utilized to store the circle can hold 768 encoding location coordinates. As the coding circle gets larger, the Sync generator external memory interface requires more coordinate locations to display the circle on the screen. With more than 768 locations the circle tends to break up, causing eye fatigue and other problems in encoding.

The circle is drawn on the screen after the core point has been entered. This eliminates the need for positioning each fingerprint precisely under the camera lens.

At this point in the discussion of the encoding circle, it must be mentioned that if an automatic scanner were available to encode base file fingerprints, the encoding circle size would become academic since the SAFES equipment would be used to encode the entirety of the latent fingerprint. That is, all discernible minutiae points would be encoded without regard to a defined circle. The results of data collection for each circle size will be discussed separately. The data has several characteristics in common regardless of the encoding circle used.

1. Intra-Operator Differences

   Because of the nature of fingerprint images, the same operator encoding the same fingerprint on two different occasions, may interpret a configuration differently. This can lead to two types of differences.

   a. Differences in the number of minutiae
   b. Differences in the locations of minutiae

2. Inter-Operator Differences

   Two operators coding the same fingerprint may interpret the same configuration differently. This can lead to a number of problems.

   a. Differences in the number of minutiae encoded.
   b. Differences in core location
   c. Differences in orientation
   d. Differences in the location of minutiae

3. Inter-Inking Differences

   The same fingerprint may exhibit differences between inkings. These differences will, of course, be exhibited in differences in the number of minutiae and their locations.

The characteristics noted above are the reasons search programs must use tolerances in basic parameters to operate effectively. For purposes of this experiment, minutiae were encoded for fingers 1-4 and 6-9 as per standard operating procedures listed in Section V, pages 2 through 5.

Circle Size - 3 Inch Diameter on 10:1 Enlarged Fingerprint

The average overhead time for the encoding of 50 fingerprint cards was 22.1 seconds. The overhead time represents the time necessary to place the card on the vacuum hold-down and enter the DCJS number, reel and frame number, finger number and pattern type of finger number 1. The average time to completely encode a fingerprint card was 8.3 minutes. This figure is based on the times to encode 44 cards. Using these averages as a guide-line, we extrapolate to an average time of 45 seconds to encode the minutiae for each of the 8 fingers per card that are encoded to the detailed level.

The average number of minutiae per finger for the 3 inch circle size was 12.1.

The inter-operator differences (2 operators coded the same 113 fingers) in the number of minutiae encoded was 4.4.

An intra-operator average difference of 2.5 minutiae was calculated by averaging the differences in the number of minutiae encoded for 2 operators. One operator coded 8 fingers twice. The other coded 40 fingers twice. The average intra-operator difference is 2.5.

Circle Size - 3.5 Inch Diameter on 10:1 Enlarged Fingerprint

The average overhead time of 29.5 seconds for this circle size is based on the times for the encoding of the same 42 fingerprint cards by 4 operators. The average total coding times per card for 37 cards by 4 operators was 9.3 minutes. The average time to encode a single finger for the 3.5 inch circle size was derived from the foregoing averages and is 45-50 seconds.

The average number of minutiae obtained from the encoding of 23 cards by 4 operators was 12.6.

The inter-operator difference in the number of minutiae encoded was 4.5.

The intra-operator minutiae difference for this circle size was 1.8. This was obtained by averaging the absolute difference in the number of minutiae encoded by 2 operators for 2 encodings of 40 fingers.

Circle Size - 4 Inch Diameter on 10:1 Enlarged Fingerprint

The average encoding times for a total of 26 cards done by the 4 operators was 11.8 minutes. The average overhead time for the encoding of 48 fingerprint cards was 26.5 seconds. The average time to encode a single finger to the minutiae level was 65-70 seconds.

An average of 18.7 minutiae per print were encoded by 1 operator. This average resulted from encoding 40 fingers.

The inter-operator difference in the number of minutiae encoded for the 4 inch circle size is 6.2.

The intra-operator minutiae difference is 2.6.

Based on the limited data presented above, several general conclusions can be drawn:

1. Coding time is dependent on circle size, not only for the reason that more minutiae will be encoded, but also because fatigue becomes a factor.

As the number of minutiae increases the memory spots are harder to see. As the circle size is increased, the circle flicker is more bothersome to the operator.

2. The data suggests that the coding time differences are not linear in nature since the average coding time differential between circle sizes 300 and 350 is not as large as that between 350 and 400.
3. The only significant complaints of fatigue problems occurred in the 400 circle size experiment. One operator complained of a pain in her left shoulder. Another complained of a hand cramp associated with maintaining an uncomfortable position on the encoding keyboard.
4. Based on limited hard data and comments of the operators, maximum coding sessions without a break should be about 45-60 minutes in duration.
5. The intra-operator consistency is better than the inter-operator consistency. Both these measures of performance are better at the 300 and 350 circle sizes. This suggests that overall performance of the system will be poorer at larger circle sizes. The inter-operator differences also suggest that further definition of the encoding rules is required.

Environment

The environmental factors studied concerned the ambient lighting required to concentrate on the CCTV display with a minimum of discomfort, the local noise associated with the various subsystems and the heat levels generated by the electronic components.

Our experience indicates that even with the sloping monitor screen and the polarized face plate, glare becomes a negative factor in the operation of the equipment. To alleviate this situation we generallv operate with the rear window blinds in the closed position. We have found that the most comfortable overhead lighting is to backlight the equipment with all other room lighting off.

The noise level of the SAFES equipment is fairly high. We have installed the vacuum card hold-down system in a remote location to alleviate a local noise problem. There have been no negative comments on the noise factor from operators.

Although the equipment does not require a specially air-conditioned room, a slightly lower than normal ambient temperature is desirable to compensate for the heat generated by the components.

<u>Equipment</u>

<u>Overall System Considerations</u>

The SAFES System major subassemblies each have an ON/OFF switch. There is also a main power switch. Through experience we have found it necessary to turn on the main system switch with the camera control unit in the OFF position. This guarantees that the display system will be in sync. When power has stabilized we then turn on the camera control unit.

The camera console-table was supplied with the air circulators of the digitizer electronics and camera control electronics. During our operational tests we determined that heat buildup in the console was significant and was the cause of display problems with the sync generator electronics. This has been rectified by modifying the rear grill door to house a 300cfm electronic fan operating off the main power switch. This fan draws ambient air from the rear of the unit and discharges it through grill work in the camera control unit and the bottom front of the console.

We have also modified the spacer in the tape recorder rack to include air escape holes, since the air moved by the tape recorder fan was not escaping from the console.

Display Subsystem

Prior DCJS studies indicated that a high resolution TV system would be necessary to display fingerprints in a manner that would be sensitive to human factors.

During the project we trained 6 operators to encode fingerprints. As a result of this experiment, we found that the image quality of the fingerprints at the nominal 10:1 enlargement is entirely adequate for minutiae encoding. For latent prints both available illuminating lamps are generally utilized to bring out required details.

In experiments utilizing good quality inked fingerprints the number of display adjustments for different fingers on the same card was minimal. As expected, the frequency of these adjustments increased when coding latents.

The major drawback noted is in the quality of the special effects generated as aids to the operators. For instance, with the monitor phosphor used there is a noticeable flicker in the encoding circle. In addition, certain hardware and software limitations cause a blinking effect in the memory spots when two minutiae appear on the same "X" scan line. This blinking increases as the number of points increases.

The special function switches ("positive/negative" and "image reverse") are extremely useful for non-standard size inked cards and latents developed with white powder.

The vacuum pump card hold-down is an important part of the display subsystem. With this mechanism, movement of the card between fingers is accomplished manually by the operator. The SAFES System, as delivered, contained a foot treadle for deactivating the vacuum system between fingers. This has proved unnecessary in operational use for the following reasons:

1. The amount of resistance to movement introduced by the low vacuum levels needed for card hold-down does not hinder the operator in moving the card.
2. The activation of the foot treadle introduces a large "transient" into the electronic circuits. This leads to many problems with respect to data acquisition.

As mentioned previously, a major drawback of the vacuum pump arrangement for card hold-down is the noise of the system. To lessen this problem, we have mounted the pump in a remote location (with adequate air flow), to minimize the local noise problem.

Stylus/Digitizer/Cursor Subsystem

An important characteristic of the operation of the

SAFES equipment is the eye and hand coordination required to move a stylus on the digitizer platen and simultaneously follow the cursor across the screen. We have found this to be an easy to learn task since the stylus has free motion and the interface of stylus movement with cursor movement is one to one.

The standard function switches on the stylus were originally activated to enable the operator to encode minutiae location and direction from the stylus. However, due to the electronic "noise" introduced into the system by these switches, they have been deactivated except for the system origin switch. Operational use has identified no problems in using one hand to move the stylus and the other hand to encode minutiae from the keyboard.

Encoding Keyboard

The SAFES encoding keyboard was specifically designed for this project. Key/switch location was determined through an analysis of function, frequency of use, and operating sequence. Key spacing and action have been found to be no problem for the operator. Key/switch arrangements are detailed in Section 3, Figure 3.

The only difficulties encountered with the keyboard have arisen as a result of decisions made early in the design phase. We originally anticipated that all procedural error checking would be controlled by the computer software. However, estimates of computer time required to include error checking indicated that procedural error checking would not be possible within the program. Because of this, all error checking was incorporated as a hardware function for the keyboard. This decision has caused a number of operational problems.

1. Due to the increased electronic logic necessary for error checking, there was no room in the keyboard to include logic for justification of ID input. Therefore, all ID numbers must be entered by the operator in a non-standard right to left sequence.

2. Because of the hard wired error checking, the keyboard can be "out of sync" with respect to the operational program.

This situation is not a major problem as long as the operators are fully trained in the normal operating procedures for the minutiae encoding program. A greater problem exists with respect to encoding latents.

Latents do not occur in 10 finger sequences. Since the hardware error checks require the coding of a 10 finger sequence, we had to develop a way to disable the error checking circuitry to allow single finger encoding.

To accomplish this, a switch was placed on the back edge of the keyboard. An operator can perform any program compatible function in a non-standard way as long as the error circuitry is disabled. For instance, if the program is expecting finger number 1, the operator may enter finger number 2 without having entered finger number 1. Upon completing the entry of the non-standard data, the switch may be disabled thereby arming the error circuit for monitoring of the subsequent encoding procedure.

This so called "flexibility" switch has been extremely important in our research studies, since these studies have required extensive non-standard operation.

3. The height of the front edge of the keyboard is approximately 1/2" higher than accepted human engineering standards. This

causes hand and arm discomfort to some operators when encoding minutiae over a long period of time.

We have noted that an inordinate number of replacements of encoding keys has been necessary. Theoretically, the keys utilized are highly reliable. We have found, however, that the more commonly used switches fail quite frequently. The cause of the failures may be attributed to the need for a "bounce" suppression circuit which was not included in the initial SAFES design.

<u>Teletype Input-Output</u>

There are no major problems with the use of the ASR33 Teletype as the I/O device in daily encoding operations. It is possible, however, to "bomb" the program by initiating a keyboard interrupt while the teletype is operating in the print mode.

The 10 character/sec speed of the teletype reader causes time delays in compiling and loading operating programs. This drawback could easily be removed by interfacing a high speed paper tape reader/punch or by utilizing the read head on the recorder for program input.

VI

ALTERNATE SYSTEMS CONFIGURATIONS

VI

ALTERNATE SYSTEMS CONFIGURATIONS

As noted in Section III, the SAFES equipment is a batch processing system. That is, fingerprints are encoded for output to a magnetic tape recorder for later processing by a large-scale, general-purpose computer. This is not the only configuration that can be envisioned for a latent fingerprint processing system using SAFES-type equipment as an input device.

The overall system configuration depicted in Figure 1 (p. II-1) was chosen for the following reasons:

- The prototype SAFES System is a batch processing machine.
- A scanner for inked-type fingerprints was not available.
- We were limited in our candidate retrieval function by the available microfilm equipment.

The purpose of this section is to outline alternate configurations for a minutiae-based, latent system incorporating SAFES-type hardware.

The particular minutiae-based, latent system configuration implemented by an agency is dependent upon the operational goals of that agency and workload of its arrest/identification function. For example:

- A state-wide latent system such as can be postulated for DCJS would have a tremendous input workload. This workload refers to the arrest fingerprint data that would have to be coded for addition to the latent fingerprint system base file. The DCJS criminal fingerprint input volume is approximately 850 cards per day. Even accounting for the fact that only a sub-set of these cards would be added to the latent system base file, it would be an impossible task to encode minutiae data from this volume of prints using the SAFES equipment.

- If a minutiae based latent system were to be implemented for a large city police department, the input workload would be smaller.
- The future implementation of an FBI-FINDER System whether as an FBI internal system or using a local terminal oriented approach could lead to a different latent fingerprint processing configuration than that of the DCJS pilot system.*

*The characteristics of these Systems are described in detail in the article, The FBI's Approach to Automatic Fingerprint Identification; Banner, Conrad S. and Stock, Robert M., FBI Law Enforcement Bulletin, January and February 1975.

Following are descriptions of four potentially viable systems configurations utilizing SAFES equipment, reflecting the above-enumerated considerations:

<u>Alternate Systems Configuration 1</u>

Alternate configuration 1 Figure 7 (p. VI-5) eliminates the batch processing characteristic of SAFES. In this configuration, the SAFES tape recorder is replaced by an interface between the SAFES mini-computer and the general-purpose processor. This configuration has the advantage of eliminating many of the clerical and tape handling procedures necessary in the DCJS pilot system.

This configuration also assumes that the system has large base file requirements necessitating an FBI FINDER-type scanner to obtain the inked print data. Therefore, only poor quality inked and actual latents would be SAFES encoded. All other inked prints would be scanned. If the basic system were to be implemented in a city with substantially smaller input (base file coding) requirements, it would be possible to operate with multiple SAFES encoders, thereby eliminating the requirement for a FINDER System.

<u>Alternate Systems Configuration 2</u>

This configuration Figure 8 (p. V-6) assumes that the SAFES System is implemented as a stand-alone processing system at the local level. The mini-computer that processes the input is used off-hours to perform the search function possibly utilizing a special purpose hardwired matching system.

<u>Alternate Systems Configuration 3</u>

This configuration Figure 9 (p. VI-7) assumes the implementation of the FINDER System by the FBI and the willingness of the FBI to provide data tapes of a particular state or region's arrest fingerprint cards after they have been FINDER scanned,

Alternate Systems Configuration 4

This configuration Figure 10 (p. VI-8) assumes the development of an economical FINDER-type terminal that could be installed at the local level for input fingerprint scanning.

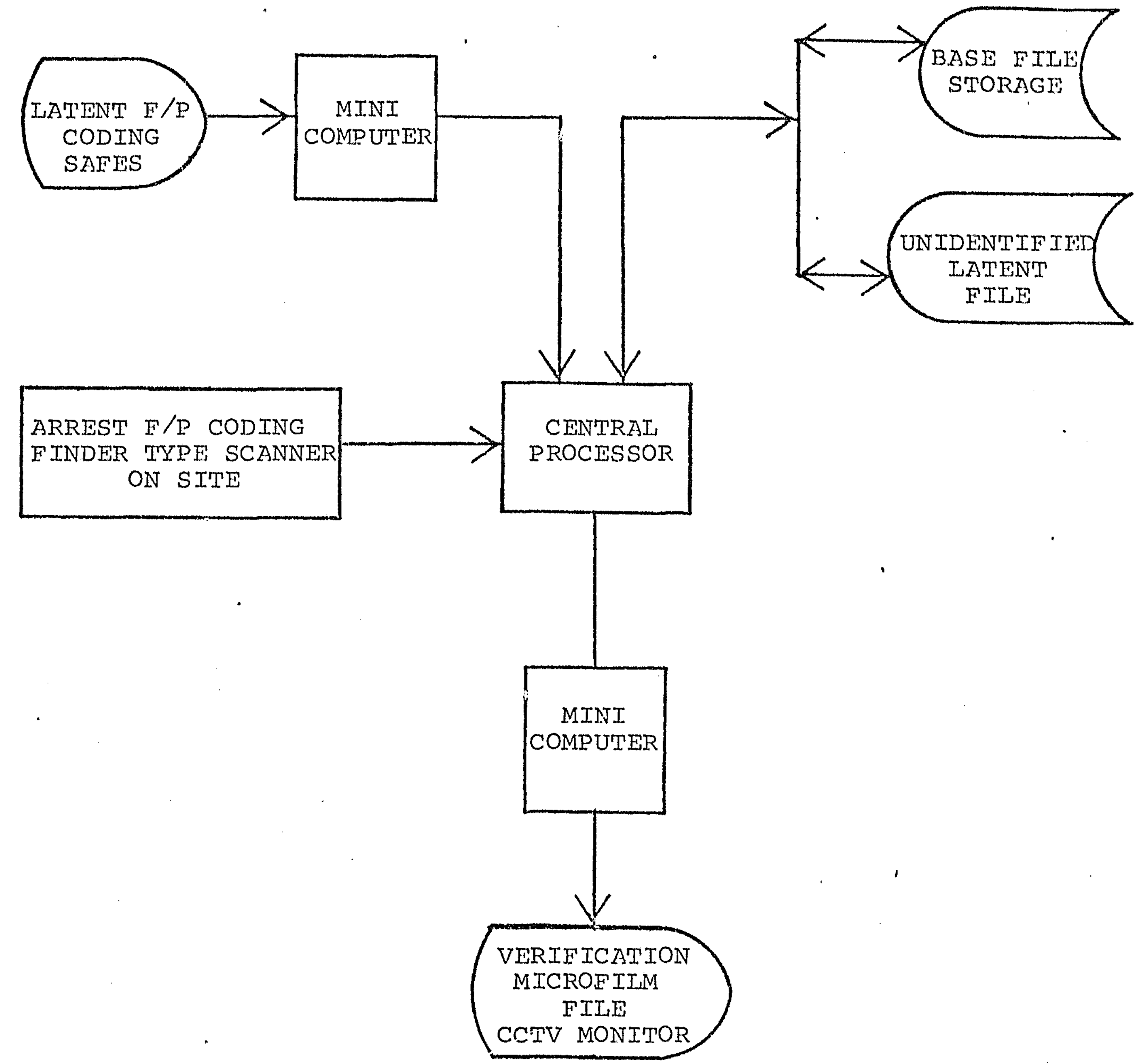

FIGURE 7

ALTERNATE SYSTEMS CONFIGURATION 1

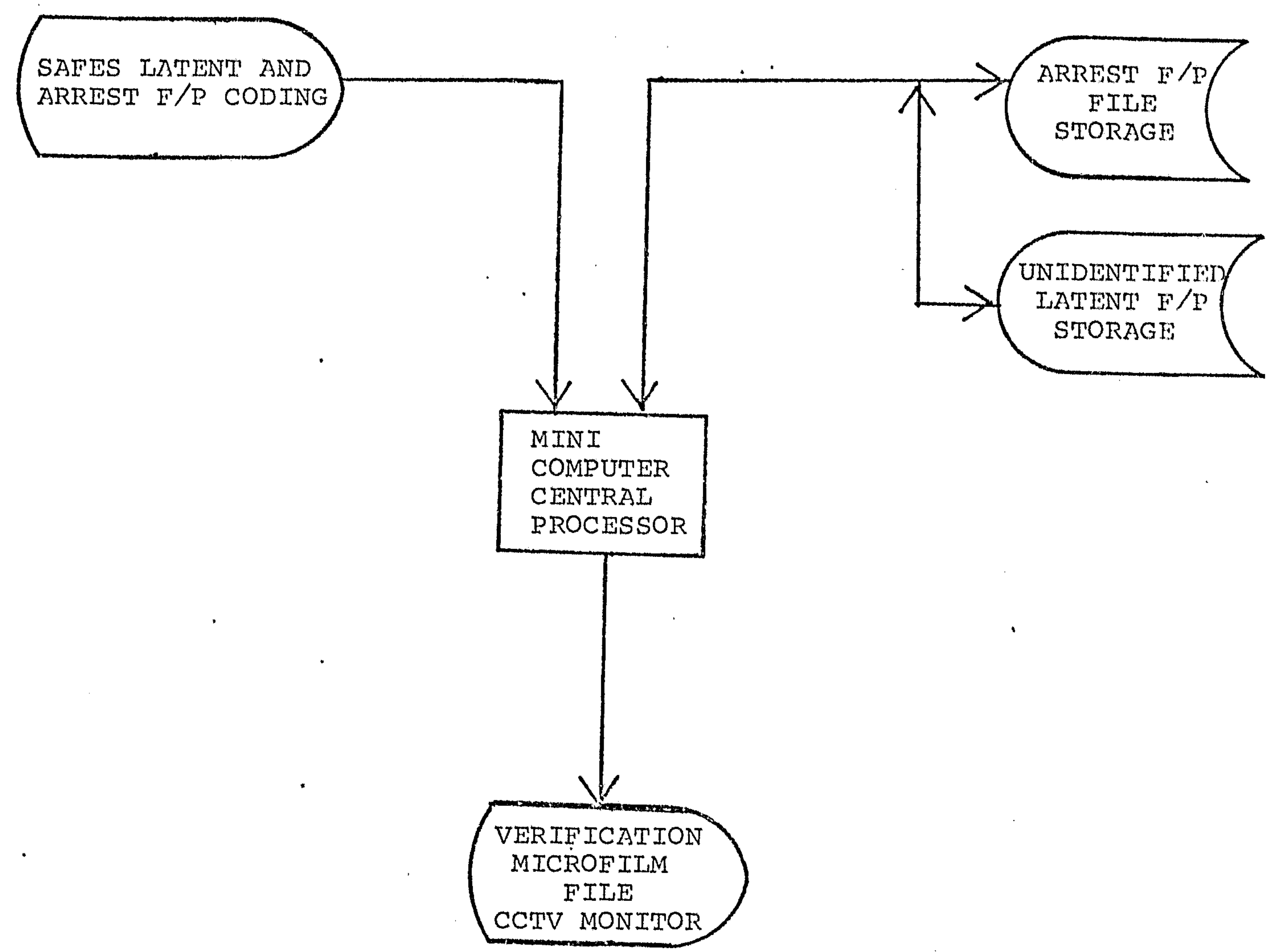

FIGURE 8

ALTERNATE SYSTEMS CONFIGURATION 2

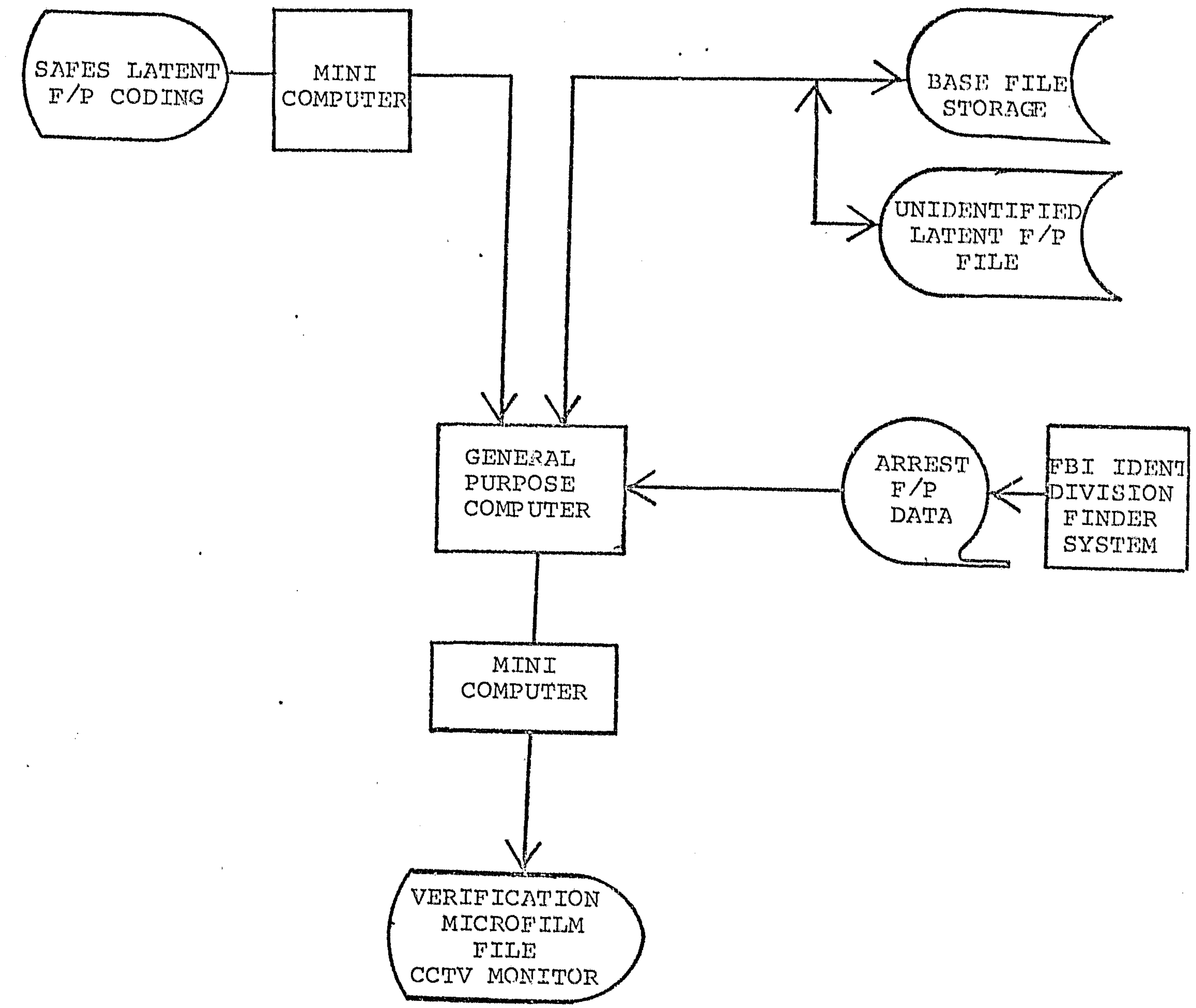

FIGURE 9

ALTERNATE SYSTEMS CONFIGURATION 3

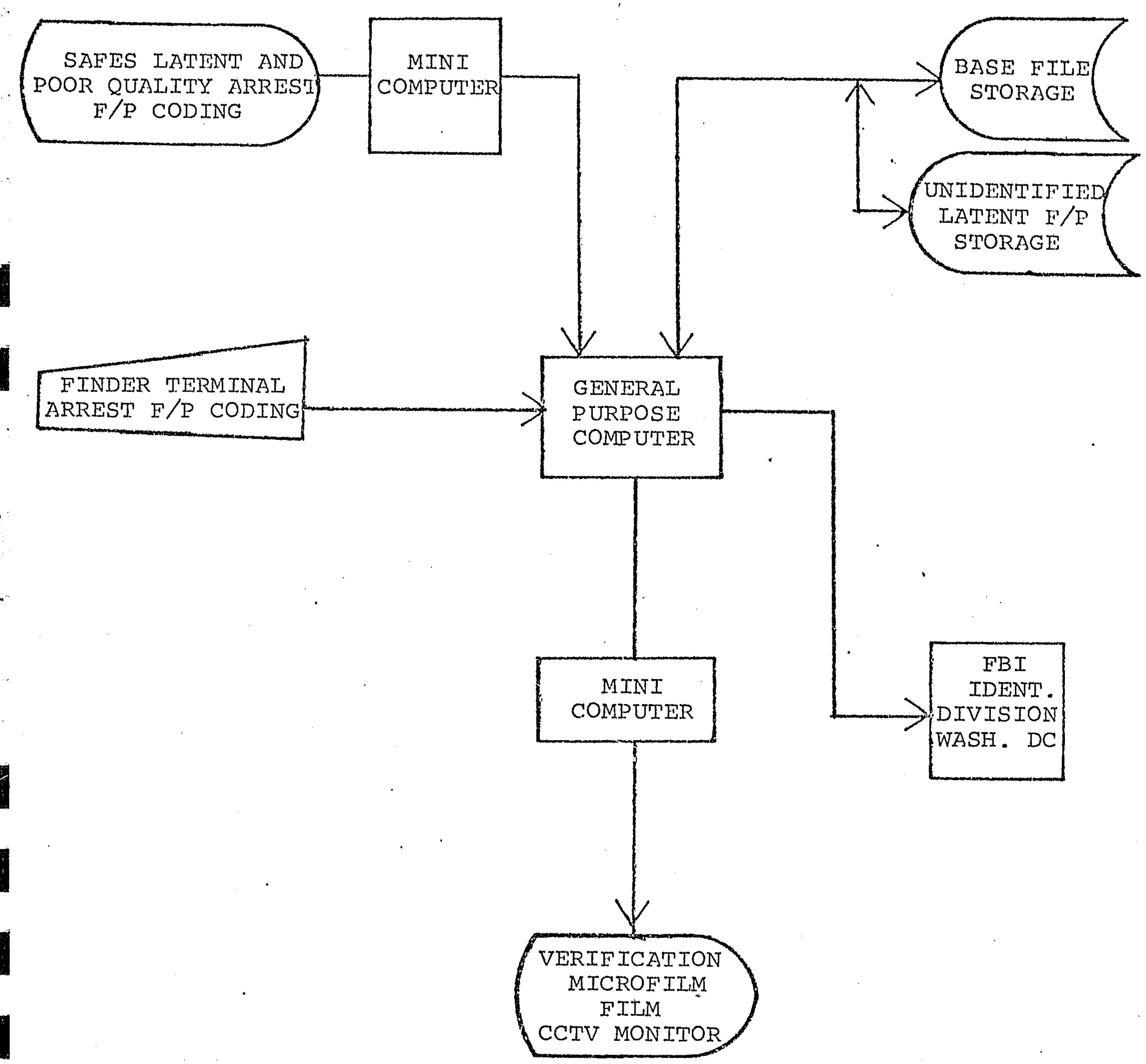

FIGURE 10

ALTERNATE SYSTEMS CONFIGURATION 4

The retrieval of candidate identifications from the file is a vital part of any latent system whether SAFES orientated or manually orientated. Each of the above configurations has the common element of verification. The time required to locate and verify candidate identifications represents a significant workload on the system.

In the pilot system, we are utilizing a Kodak Miracode System. This microfilm-based system is more efficient than retrieving large numbers of candidates in a manual hard copy file. However, there are several drawbacks to rear projected microfilm images of fingerprints:

- The image quality is marginally adequate for comparing latents with base file fingerprints.
- The fixed microfilm image does not enable the examiner to re-orient the fingerprint on the screen.
- It is difficult to place a magnifying glass on the screen to observe detailed features of the fingerprint.
- Reflected glare from room lights causes eye fatigue.

A more desirable system would retain a microfilm file storage capability. However, the image would be displayed to the examiner by a CCTV monitor. Each of the alternate system configuration flow charts assumes an improved retrieval unit with call-up-under computer control. Call-up could also be accomplished locally to the retrieval unit. A split screen could be used allowing the operator to display the suspect or latent fingerprint along side the fingerprint from the file.

Each proposed configuration also provides for a search of all input fingerprints at the time of coding against a stored file of unidentified latent fingerprints. Experience has shown that this type of search is very productive. Studies have shown that there is a strong possibility that a perpetrator may not be in the base file for the following reasons:

- No previous arrest in the jurisdiction
- Juvenile offender*

The "incoming arrest" search of latents provides an opportunity to identify latents of these types of perpetrators at the time of receiving their first fingerprint card.

*Latent Value Study, Kingston, Charles R., Madrazo, Frank G., NYSIIS, 1968.

VII

FBI/SAFES COMPATIBILITY STUDIES

VII

FBI/SAFES COMPATIBILITY STUDIES

An important question with respect to the potential utility of SAFES-type equipment is its compatibility with the FBI FINDER. There are two reasons for this:

1. As mentioned in Section VI, it is conceivable that a FINDER scanner will be one component of a minutiae-based latent fingerprint processing system for regional, large city or state oriented Bureaus of Identification.
2. SAFES equipment will be required by the FBI for processing of fingerprint cards of marginal quality.

In view of the mutual interest of the FBI and DCJS in the future applicability of the SAFES equipment in fingerprint processing systems, a study has been initiated to determine the compatibility of the SAFES output with FINDER-type output.

The first problem to be overcome is the difference between FINDER and SAFES in registration (orientation) of the fingerprint data. This refers to the fact that with available search algorithms, it is necessary to register the data from each FINDER scan or SAFES encoding of a fingerprint in a standard way with respect to itself. This is to compensate for differences in placement of the fingerprint on the card from inking to inking. Registration is also of paramount importance in coding latent fingerprints.

As mentioned previously, the SAFES computer program and hardware has been designed to implement the DCJS registration technique consisting of rotation of all data about a defined core ridge direction point. The location of the core direction point is determined by the operator using the core circle generated by the program and specific rules based on the core configuration. This method was chosen because of the lack of information generally available in the latent fingerprint and the need to determine an orientation point quickly in the context of operational time for coding.

The FBI orientation scheme is based on the more extensive ridge angle data derived from the FINDER scan. The details of the technique are presented in NBS Technical Note 730, "Manual and Automated Fingerprint Registration," by J.H. Wegstein.

Wegstein also describes a semi-automated implementation of the FINDER registration (orientation) technique in Technical Note 730. It is this method that we are hoping to implement in our compatibility project.

An overlay was designed (see Figure 11, p. III-3) to conform with suggestions made by Wegstein. A line with six equally spaced points on either side of a central point was utilized. When the center point is placed on the core, an operator can encode six (in our initial studies, five points were used) points on or between ridges which intersect the line. A direction point is then encoded to define the ridge flow at each of the overlay points. From this data, a ridge flow angle is calculated for the left and right sides of the fingerprint pattern. As delineated in Technical Note 730, the angles to the left of center and to the right of center are averaged.

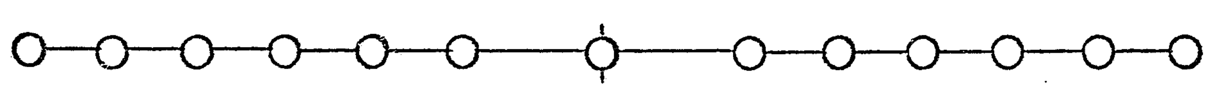

FIGURE 11

TEMPLATE USED TO SIMULATE FBI FINDER SYSTEM REGISTRATION

A grand average is then determined according to the relationship $V = \frac{-R-L}{2}$. This grand average is the registration angle for the fingerprint.

Operationally, SAFES software was modified to allow us to calculate the sine and cosine of the registration angle. These values were then used by the rotation and translation subroutine in the minutiae encoding program to recalculate new coordinates for each minutia point for the fingerprint. The output tape contains the coordinates of minutiae points after they have been rotated through the registration angle. Our studies to date have been directed toward specifying tape data formats, agreeing on common definitions, determining inter and intra operator precision in locating points and determining agreement in orientation angle for different fingerprint pattern types.

Our initial data file consis s of two inkings of eleven fingerprints distributed across the various pattern types. The FBI first scanned the 22 (two sets of 11 prints) fingerprints using FINDER. As per standard procedures, the ridge angle data from the FINDER scan was then subjected to the registration program. Tapes containing data from the scan and registered data were provided to DCJS for analysis. Two DCJS SAFES operators then coded the two sets of fingerprints.

Table 5 (p. VII-5) summarizes intra-operator consistency for two encodings of the same set.

Table 6 (p. VII-6) summarizes inter-operator consistency between two operators coding the same set.

TABLE 5

INTRA-OPERATOR CONSISTENCY

OPERATOR 1

Set Card Number	Finger Number	Pattern Type	Registration Angle Coding 1	Registration Angle Coding 2	Δ Angle
70101	7	Left Slant Loop	7	6	1
	8	Left Slant Loop	1	2	1
	9	Left Slant Loop	-6	-5	1
70102	1	Double Loop Whorl	-14	-7	7
	2	Plain Whorl	4	2	2
	3	Right Slant Loop	-16	-14	2
	4	Left Slant Loop	-8	-7	1
70103	2	Right Slant Loop	-11	-8	3
	3	Right Slant Loop	-6	-3	3
	8	Left Slant Loop	0	6	6
70104	6	Plain Arch	1	0	0

TABLE 6

INTER-OPERATOR CONSISTENCY

Set Card Number	Finger Number	Pattern Type	Registration Angle Operator 1	Registration Angle Operator 2	Δ Angle
70101	7	Left Slant Loop	6	-4	10
	8	Left Slant Loop	2	7	5
	9	Left Slant Loop	-5	-7	2
70102	1	Double Loop Whorl	-7	-6	1
	2	Plain Whorl	2	2	0
	3	Right Slant Loop	-14	3	17
	4	Left Slant Loop	-7	-13	6
70103	2	Right Slant Loop	-8	3	11
	3	Right Slant Loop	-3	-10	7
	8	Left Slant Loop	6	-4	10
70104	6	Plain Arch	0	-3	3

Since it is not possible to establish a "theoretically correct" orientation angle, we are seeking to determine the extent of compatibility between the two techniques by examining the performance of the fingerprint match routines. For instance, Table 7 (p. VII-8) summarizes the results of matching 11 SAFES encoded fingerprints against the same prints scanned by FINDER. A rank of 1 in the table indicates that the particular fingerprint scored highest with its corresponding match in the file.

The relatively low number of minutiae points is caused by the limitation of SAFES coding to a circle of 4 inch diameter on a nominal 10x enlargement.

Table 8 (p. VII-9) illustrates the results of another variation in searching SAFES VS FINDER data. DCJS set 1 was matched with FINDER set 2 (different inking of the same fingerprints) plus the data from an additional 30 FINDER scanned prints. Again, the rank of each print subjected to the matcher is the evaluation criterion.

On the basis of these limited studies, we have made the following observations:

1. Core placement criteria between the SAFES operation (manual) and the FINDER System (programmatically derived) appear to be compatible.
2. The range of differences between SAFES and FINDER orientation angles appears small enough for search purposes.

TABLE 7

DCJS SAFES SET 1 VS FBI FINDER SET 1

FN	No. of Minutiae Latent	Base	Matches	Match Score	Top Score	Rank
1	19	16	15	111.40	111.40	1
2	15	8	9	42.22	42.22	1
3	11	12	15	75.60	75.60	1
4	23	20	26	178.73	178.73	1
5	21	14	23	100.22	100.22	1
6	14	22	19	83.79	83.79	1
7	20	13	13	60.69	60.69	1
8	8	7	6	15.83	17.33	2
9	18	9	9	39.00	52.47	2
10	10	11	6	26.00	26.00	1
11	21	16	21	87.52	87.52	1

TABLE 8

DCJS SAFES SET 1 VS FBI FINDER SET 2 & 30 FINDER PRINTS

FN	No. of Minutiae					
	Latent	Base	Matches	Match Score	Top Score	Rank
1	19	13	20	85.80	85.80	1
2	15	11	12	77.42	77.42	1
3	11	12	16	61.00	61.00	1
4	23	19	22	92.18	92.18	1
5	21	16	17	81.53	81.53	1
6	14	17	13	64.62	64.62	1
7	20	14	18	40.56	40.69	2
8	8	6	4	10.00	16.83	3
9	18	10	15	44.00	44.00	1
10	10	9	9	41.00	41.00	1
11	21	13	14	51.21	51.21	1

3. Individual minutiae location and direction rules for SAFES must be studied to obtain better correspondence with the FINDER'S programmatic data reduction procedures.

The foregoing represents only a small portion of the types of compatibility studies currently being pursued. In the future we hope to collect data using more extensive base and suspect files.

VIII

LATENT IDENTIFICATION PROFILE

VIII

LATENT IDENTIFICATION PROFILE

One of the objectives of Grant NI70-095 was to model an improved latent fingerprint processing system through interaction with a law enforcement agency of a large metropolitan area in upstate New York.

The design of the project was relatively simple. The law enforcement agency would make a conscientious effort to obtain latent fingerprints at the scenes of all Burglaries reported for a given time period in a high crime area of the city. DCJS would then attempt to identify the latent fingerprints utilizing the SAFES equipment.

Because of the delay in receiving the SAFES equipment, we were not able to fulfill our objective of modeling the system. However, the law enforcement agency submitted the latents and the DCJS Latent Section continued its routine manual efforts to affect identification. As an alternative to modeling the latent system, we decided to develop information on certain characteristics of the latents identified during the grant period. We have termed this information a latent identification profile. Basically, we collected data on identified latent cases along with the arrest records of the individuals identified. We believed that this information would be useful in determining base file and search strategies.

During the period of the study, the DCJS Latent Section made latent fingerprint identifications in 41 cases submitted by the cooperating law enforcement agencies. Following is a summary of the data obtained from these cases.

Multiple Identifications

Thirty-four (34) individuals were identified by lifts from the 41 cases. One individual was identified with lifts from 4 latent cases, another individual with lifts from 3 latent cases, and 3 other individuals were identified with lifts from 2 latent cases. One latent case with multiple lifts resulted in the identification of 2 individuals.

Latent Crime Type

When latents are sent to DCJS, a Latent Fingerprint Evidence Form is attached. On this form, the type of crime being investigated is reported. An account of the 41 cases by type of crimes is as follows:

BURGLARY	35
GRAND LARCENY (GL)	2
BURG & GL	1
GL & STOL AUTO	1
STOLEN PROPERTY	1
THEFT	1

Probable Fingers and Location of Lifts

The Latent F/P Evidence Form also provides spaces for listing the probable fingers (a guess of the fingers lifted by the evidence technician), and also the object on which the latents were found. The following results indicate the reliability of these estimates.

No Guess	30 Lifts
Correct Guess-Fingers	18 Lifts
Correct Guess-Hand Only	4 Lifts
Incorrect Guess-Fingers	1 Lift
Incorrect Guess-Hand	1 Lift

The incorrect finger latent contained 2 fingers while the incorrect hand latent had 3 fingers.

The above lifts were found on the following objects:

Glass (broken glass from point of entry, mirrors, car windows)	21
Plexiglass	2
Bottles	3
Window Sill	2
Coin Box	3
Jewel Box	1
Metal Box	1
Cardboard Money Box	1
Drawer	2
Metal Can	1
Plasterboard	1
Safe	1
Plastic (Cash Register)	1

Date of Crime - Date of Identification (DOC-DOI)

In most latent systems identifications can be broken down into two categories:

1. Base File Identifications: A latent is received by the Latent Section and immediately searched against a fingerprint file of potential perpetrators. An identification results from this base file search or the latent is added to an unidentified latent file.

2. Incoming Search Identifications: All new arrests are searched against the unidentified latent file mentioned above. In this case, the identification cannot occur until the perpetrator of the latent crime has been arrested.

Table 9 (p. IX-4) illustrates the elapsed time between the date the crime was committed and the date the identification was made by the Latent Section. The statistics for the latent profile resulted mainly from incoming search identifications.

TABLE 9

ELAPSED TIME FROM DATE OF LATENT CRIME TO DATE OF IDENTIFICATION

MONTHS ELAPSED	NUMBER OF IDENTS	CUM %
1-3	18	44
4-6	6	59
7-9	5	71
10-12	1	73
13-15	5	85
16-18	3	93
19-24	-	93
25-30	2	98
31-36	-	98
37-42	1	100
TOTAL	41	

Perpetrator Age Related Data

The following two tables illustrate the ages of individuals at the time the identifications were made (Table 10, p. VIII-6) and their ages at the time the crime was committed (Table 11, p. VIII-7). Table 10 only contains 34 entries because all multiple identifications for one individual occurred at the same time. Table 10 has 41 entries because the dates are different for each crime. Therefore, a perpetrator of multiple crimes could appear in multiple age brackets.

Arrest Data

A study was made of the arrest records of those individuals identified with each latent case.

Table 12 (p. VIII-8), lists the frequency of arrests for each crime type for the 34 individuals idented. In this data, if an individual was arrested 5 times for a particular crime type, it was tallied as 5 arrests under that crime type.

The following general observations emerge from analysis of the latent/arrest data:

A. For 30 of the 41 cases, no immediate identification was possible because the perpetrator had not been arrested in New York State for any crime before the latent crime was committed. Under the present selected crime categories used for the DCJS latent base file, resisting arrest would not be added to the file. Therefore, an additional case would not be immediately identifiable. If we look back at the age data section, we find that 8 individuals were still minors (under 16) at the time the latent crime was committed. These 8 individuals are included in the 30 mentioned above.

TABLE 10

PERPETRATOR AGE AT TIME OF IDENTIFICATION

AGE	NO. OF IDENTS.	CUM %
16	12	35
17	7	56
18	6	74
19	2	79
20	–	79
21	1	82
22	–	82
23	–	82
24	–	82
25	2	88
26	1	91
27	1	94
28	2	100
	TOTAL 34	

TABLE 11

PERPETRATORS AGE AT DATE OF CRIME

AGE	NO. OF IDENTS.	CUM %
14	2	5
15	6	20
16	15	56
17	8	76
18	1	78
19	1	80
20	–	80
21	1	83
22	–	83
23	1	85
24	–	85
25	–	85
26	3	93
27	1	95
28	2	100
TOTAL	41	

TABLE 12

FREQUENCY OF ARRESTS BY CRIME TYPE

OFFENSE	NUMBER OF OCCURRENCES	PERCENT OF TOTAL
Assault	19	9.6
Murder	-	-
Rape/Sodomy	3	1.5
Kidnap	-	-
Burg/Tresp	66	33.3
Misc/Tamp	9	4.5
Arson	-	-
Grand Larceny	24	12.1
Robbery	15	7.6
Auto Larc	4	2.0
Narcotics	16	8.1
Weapons	2	1.0
Petit Larceny	17	8.6
Escape	4	2.0
Resisting Arrest	7	3.5
Dis Conduct	3	1.5
Loitering	2	1.0
V & T	1	0.5
DWI	1	0.5
Obst Gov't Admin	1	0.5
Forgery	2	1.0
Harassment	1	0.5
Menacing	1	0.5
TOTAL	198	

The data from this sample of latent cases suggests that more than 70% of the latent cases submitted cannot be immediately identified against a file, because the perpetrator of the crime has not been arrested previously.

B. If 70% of all possible latent identifications cannot be made because of no existing arrest record, then how much time passes before an arrest of the perpetrator makes an identification possible? Table 13 (p. VIII-10) contains the elapsed time from the date of the latent crime to the date of the first/next arrest for the sample latent identifications. In other words, the table illustrates the potential latent system performance if an incoming system (unidentified latents searched against incoming arrest cards) had been in operation. Of the 5 cases in which the first or next arrest came more than 12 months after the latent crime:

- -2 individuals were 14 years old when the crime was committed
- -2 individuals were 15 years old when the crime was committed

C. One of the main objectives in collecting this data was to determine a strategy for eliminating certain categories of arrests from the latent base file. Theoretically, if all fingerprintable arrests are added to a base file, a latent identification cannot be missed unless the perpetrator was not in the file. However, using any existing latent search, manual or computerized, as the file size increases so do the number of false retrievals. As the false retrievals increase, the potential for misses increases because of examiner fatigue and failure of the search algorithm.

TABLE 13

ELAPSED TIME FROM DATE OF LATENT CRIME TO DATE OF FIRST/NEXT ARREST

MONTHS	NUMBER ARREST	CUM %
1	18	43.9
2	4	53.7
3	4	63.4
4-6	5	75.6
7-9	4	85.4
10-12	1	87.8
13-18	1	90.2
19-24	2	95.1
25-36	2	100.0
TOTAL	41	

The size of the file also limits the number of latent searches that can be performed by one examiner. For example, if the file size can be cut by 50 percent (through selective additions to the file) without substantially increasing the miss rate, the examiner can search twice as many latents in the same amount of time. The examiner should, therefore, make many more idents with the same amount of effort. Identifications are the main objective in any latent system, not a zero percent miss rate.

Analysis of the arrest data associated with the sample of 41 latent cases does not provide any basis for rejecting f/p cards based on crime types. When developing criteria for eliminating cards from the base file by crime type, it would seem that concentration should be put on the less serious crime types which represent a substantial number of cards in the file.

For instance, a tally of arrests for the geographical area associated with this study, from May, 1973 thru August, 1973, shows that Petit Larceny alone represents 20 percent of all arrests. Eliminating these arrests would, of course, substantially reduce the file size. This has to be balanced against the average age of the perpetrators (see Table 10) and their arrest records. The data in this sample of latent identifications indicates that inclusion of Petit Larceny arrests in the base file would assist in identifying perpetrators earlier.

The situation with serious crimes is different. For instance, neither Kidnapping nor Arson were contained in any of the arrests associated with this sample. However, they account for a small percentage of all arrests and the importance of solving a Kidnapping or a string of Arsons with a latent, justifies these charges being included in any file.

Another important factor in file design strategy concerns the expected ages of criminals who leave latents. None of the perpetrators associated with this sample of latent cases was over 30 years old. Therefore, consideration should be given to limiting additions to the base file to arrestees under 30 years of age.

The file size could also be controlled by including only males in the base file. If, however, latent base file coding and searching were accomplished as a by-product of an on-going arrest print system, a code could be entered for females or the females could be segregated into a separate file. Hence, if a female was listed as a possible suspect this category could be searched.

IX

PROJECT CONCLUSIONS

IX

PROJECT CONCLUSIONS

The conclusions to be derived from the preceding sections must be viewed from the perspective of the length of time between project inception and official termination. Grant NI70-095 began in July 1970 and was originally scheduled for completion in December 1971. The equipment design and development stage was originally to be a 6-month effort with a 12-month systems installation and evaluation period.

HOwever, due to numerous administrative and technical problems the project did not end until December 1974. What was originally to be a turn-key delivery of the SAFES equipment required numerous hardware and software modifications before the system could be considered operational for data gathering purposes. It must be emphasized that there existed no equipment of the SAFES configuration commercially available at the time the project was begun.

During the period of time we were attempting to bring the SAFES equipment to an operational status, research external to DCJS was continuing in the area of minutiae level encoding. For instance, the FBI was continuing studies on the FINDER System. Also, during the latter part of the project, commercial vendors were developing off-the-shelf minutiae-oriented latent fingerprint systems.

The lengthy period of design, development and construction was not without certain benefits. For instance, we quickly determined the short-comings of certain hardware decisions.

We also gained a great deal of knowledge concerning the operation of the mini-computer and its interaction with the TV hardware. We were able to discuss these problems and our operational experiences with both the FBI and commercial vendors. This process most likely resulted in improved products being offered today.

With the above perspectives in mind, following are the conclusions that we have drawn as a result of the SAFES project:

1. Technical Feasibility

   As a result of the studies and experiences documented in the preceding sections, we have concluded that the prototype SAFES equipment has demonstrated the technical feasibility of the semi-automatic encoding of fingerprints at the minutiae level. The prototype SAFES equipment with its human operator is capable of obtaining minutiae data with a precision and accuracy sufficient to allow the searching of fingerprints. The compatibility studies with the FBI, although not concluded, strongly indicate that SAFES-type equipment will become a complementary hardware configuration to the FINDER-type automated fingerprint reader.

2. Human Factors

   The use of closed circuit TV with a suitable input device and computer processing proved to be a great improvement over alternative methods of displaying the fingerprint to the human operator.

Other alternatives such as optical rear projection, although offering improvements over the fingerprint glass, proved less-desirable than the closed circuit TV approach. Our work during this project confirmed the previous studies that led to the basic SAFES hardware configuration.

The superiority of the closed circuit TV approach was definitely demonstrated in the case of latent fingerprint encoding. The TV system has been used on numerous occasions off-line to assist examiners in verifying identifications made as a result of routine DCJS Latent Section processing.

3. Hardware/Software

The main conclusion to be derived from the hardware/software evaluation is that the SAFES prototype can continue to provide valuable service as a research tool. Our evaluation of the prototype served to identify the following areas for improvement in subsequent generations of similar equipment.

First, the SAFES hardware is relatively inflexible and the short-comings noted in the previous sections mitigate against daily, routine production usage.

Second, software development is a tedious task with the 3-pass assembly language programming required for the computer system.

Third, the SAFES maintenance history, especially the computer subsystem, has not been consistent with routine usage.

Problems in the above mentioned areas are not insurmountable. All the technology required to produce high-quality graphic aids along with fingerprint images currently exist in off-the-shelf hardware. Additionally, the control functions performed by the mini-computer can be implemented in either mini-computers with high-level programming languages and operating systems or through micro-processor technology.

Presumably, the maintenance problems experienced with SAFES would not occur with a production-oriented hardware system. Serving to confirm these observations is the fact that at least two manufacturers currently market latent fingerprint systems designed around the minutiae concept.

Additionally, the FBI is continuing its design activities for a semi-automated device to handle these fingerprints unable to be scanned by the FINDER System.

4. <u>FBI/SAFES Compatibility</u>

As mentioned above, we consider that we have demonstrated the first level of compatibility between the SAFES and the FBI FINDER System. That is, the core locations as determined by the SAFES operator and the FINDER System appear to be relatively consistent and the simulated registration angles derived by the two techniques appear to be in sufficient agreement to allow effective matcher operation.

5. <u>Project Spin-Off</u>

Although the main objective of this project was to evaluate the SAFES hardware/software system in context with latent fingerprint operations, another important benefit was derived.

During our studies using the RIDGE COUNT PROGRAM, it became obvious that SAFES-type hardware could be utilized as an on-line classification system for routine DCJS 10-print processing. The RIDGE COUNT PROGRAM enabled us to simulate all the operations necessary to fully classify a set of fingerprints for direct input into the DCJS automatic fingerprint search system.

The current system is traditional in nature with respect to the manual classification of fingerprints by a classifier utilizing a fingerprint magnifying glass. However, subsequent to classification, the fingerprint card is transported to a data entry clerk who enters the pattern and ridge count type data through CRT hardware into the main DCJS processing computer.

It was clear, as a result of our studies, that the SAFES System with appropriate software and human factors engineering could be utilized to handle the input of the DCJS automated fingerprint search system or could, at minimum, complement an automated classification system.

As a result of this conclusion, DCJS has obtained Safe Streets Act Block Grant funding to design and install an on-line fingerprint classification system. The design specifications for the system were derived directly from experience gained and experiments performed using the SAFES System as delivered under Grant NI70-095.

As a result of the above conclusions, DCJS intends to continue its use of the SAFES equipment as a research tool. It is important to reiterate that as a result of the SAFES project, commercial suppliers, as well as the FBI, continue their interest in the semi-automated encoding of minutiae characteristics for both latent and arrest fingerprint processing.

END