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HIGH SPEED PARALLEL SENSING SCHEME

Pi Fuay Chen and William W. Seemuller

DECEMBER 1977

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ERRATA SHEET: The original photographs of figures 8 through 11 and 14 are 8 by 8 inches. However, to be able to incorporate the photographs into the size of this report, a slight reduction was made to figures 8 through 11 and 14.

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

A high speed parallel scanning scheme is described that uses high density linear sensor arrays to convert optical images into electrical signals for computer processing or storage.
By using two 1,024-element linear arrays in a staggered line and x-y translational stages, a 9- by 9-inch transparency can be scanned and digitized into 8.5 × 10 pixels in 1 minute. Scan time can be reduced by increasing the slew rate of the stage or by increasing the scan line by using additional

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arrays. Since each array produces four simultaneous video signals, the system could be utilized as an input device for a parallel processor such as the STARAN. The video signals can be multiplexed onto a single line if desired.

PREFACE

This work was authorized by the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia under DA Project-Task Area Work Unit No. 4A161102B 52C/ 1752CS20002, entitled "Application of Sensing Arrays to Mapping."

In this report, the final results are presented on the high speed parallel sensing scheme, which uses high density linear sensor arrays.

The authors extend thanks to Mr. R. Nelson for all the mechanical work involved in setting up the stage and modifying the heavy optical table, and to Mr. C. Johnson for constructing portions of the electronic hardware used for this experimentation. We are also grateful to Mr. R. Marth for reconstructing images from data tapes on the microdensitometer, to Mr. J.F. Merkel for reconstructing images from data tapes on the electron beam recorder, and to Mr. W. Daniels for the photographic work.

Conversion Factors: U.S. Customary Units to SI Metric

MULTIPLY	BY	TO OBTAIN
Inch	2.54	centimeter
mil	.0254	millimeter

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HIGH SPEED PARALLEL SENSING SCHEME

INTRODUCTION

The major objective of this investigation was to devise a system that could increase the digitizing speed of photographs for mapping applications. Solid state sensor arrays were chosen as the system transducer because of the fixed and accurate position of the photosensitive elements comprising an array and because of the rapid scanning speed possible with these devices.

For our study and experimentation, two linear arrays consisting of 1,024 elements each were positioned in a staggered line to achieve even pixel separation in the x-scan direction. Nine staggered arrays would be needed for scanning a 9- by 9-inch photographic transparency. An Aerotech two-dimensional, 10- by 10-inch, translational stage* was used to scan the transparencies over the arrays. The stage was controlled by both the special purpose hardware and the minicomputer to give three modes of scanning operation.

The digital hardware controller and the electronic interface between the array and minicomputer were designed and built with commercially available TTL components. Software was developed in both assembly and Fortran languages to implement stage control and signal processing.

The overall system was tested in three modes of operation using the in-house designed digital electronic hardware or the minicomputer as the system controller.

Good results were obtained in relation to the scan time and quality of the reconstructed imagery. The scheme proved to be encouraging for mapping applications.

INVESTIGATION

System Description. The block diagram of the total system is shown in figure 1. The system was designed to operate in three modes as described below.

1. In the first mode of operation, two staggered Reticon linear arrays consisting of 1,024 elements each were used to produce eight simultaneous video signals. A white light source powered by a variable d.c. supply was positioned under the center of an Aerotech two-dimensional translational stage as shown in figure 2. The stage was used to hold the imagery, which was a 9- by 9-inch photographic transparency. The stage was capable of moving in both x and y directions approximately 10 inches. A mir-

*For an explanation of the translational stage, see the *Aerotech Unidex D C Position Servo Instruction Manual*, Aerotech Inc., Allison Park, Pa., nd.

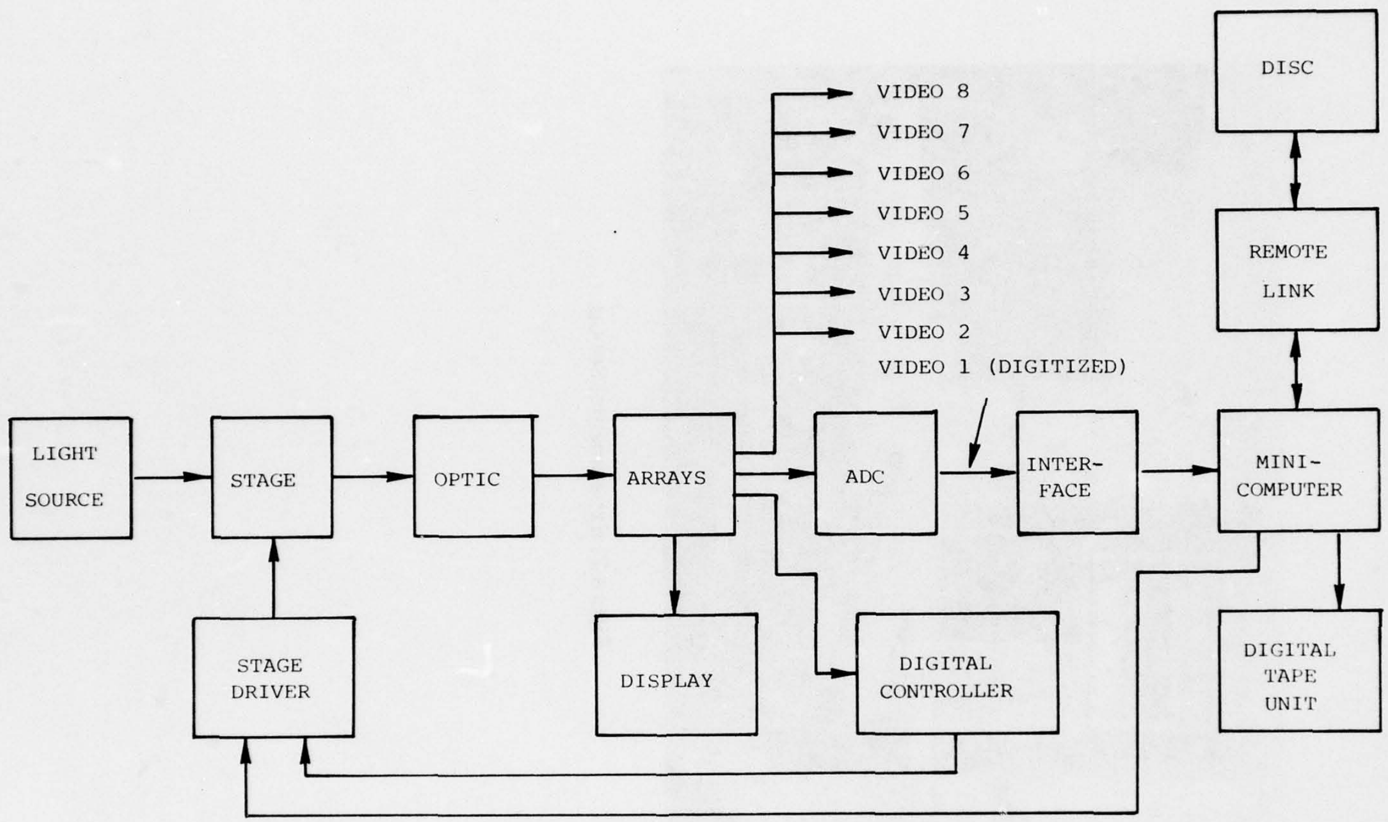

Figure 1. System Block Design

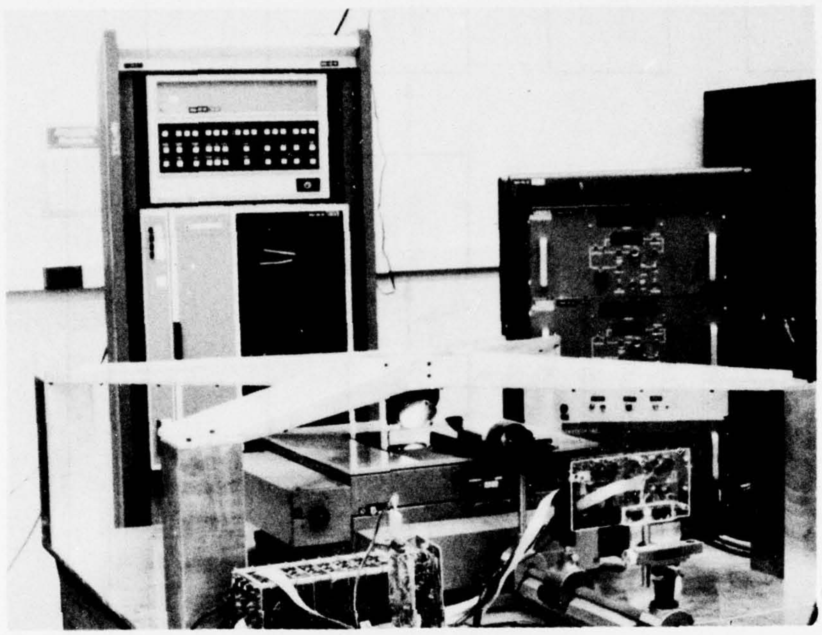

Figure 2. Experimental Set-up.

ror was mounted at a 45 angle just above the transparency (see figure 2). The portion of the imagery illuminated by the light source was reflected by this mirror and imaged onto the surface of the arrays with a lens. The lens and the arrays were mounted on a triangular optical bench, which was in turn mounted on a heavy optical table. The translational stage was also mounted on this optical table to minimize relative motion between the imagery and the arrays during scanning. The position of the lens between the imagery and the arrays was adjusted by a micrometer attached to the lens mount to produce one-to-one imaging. The stage was driven by digital electronics to scan a 2-inch, vertical strip across the arrays. This digital controller will be described in detail later. After scanning one strip, the stage changed direction and the next adjacent strip was scanned in the opposite direction. The scanning path of the stage with respect to the arrays is shown in figure 3. As mentioned earlier, each array produced four simultaneous video channels. The sequence of the video signals with respect to the physical position of the array elements is shown in figure 4. The eight video channels from two arrays can be interfaced to a parallel computer through ADCS (analog to digital converters). To facilitate experimentation, only one video channel was interfaced. All video channels were displayed on an oscilloscope for visual inspection.

2. For the second mode of operation, only one linear array was used for sensing. One of the four video channels was digitized by a DATEL, Model HV-100 ADC before being sent to the HP-2100 minicomputer as shown in figure 1. In this mode of operation, the minicomputer was used as both the signal processor and the stage controller. The digitized data were processed by the minicomputer and stored onto magnetic tape using a HP-7970B digital tape unit. The stored data were then reconstructed offline using the DICOMED system* and the microdensitometer. The undesirable dark noise of the array was removed in the computer. The same light source, stage, and optics used in Mode 1 were used in this case.

3. In the last mode of operation, a remotely located disc was used to store the digitized data. This was done so that a final data tape could be written in a true 9- by 9-inch raster scan from the data stored in strip fashion on the disc. However, the serial link to the remote disc greatly increased the total data acquisition time.

DIGITAL HARDWARE CONTROLLER

The digital hardware was designed and built to move the two-dimensional translation stage in the scan path shown in figure 3. The schematic of this controller is shown in figure 5. The controller consists mainly of two sets of counters for motor step count indexing and other circuits for direction drive, pulse gating, and timing. The operation of this controller is described below.

*Registered trademark for DICOMED, Inc.

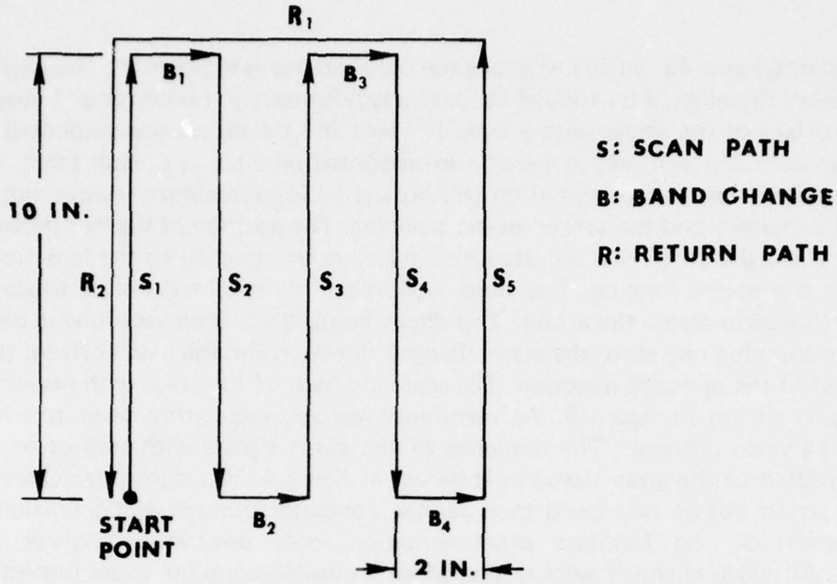

Figure 3. Scan Path for Mode 1 Operation.

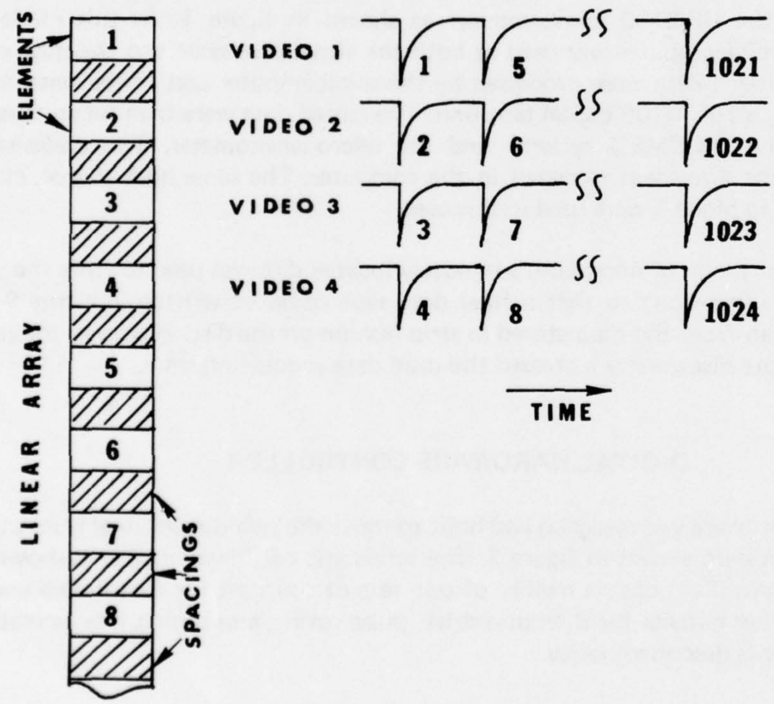

Figure 4. Video Sequence and Array Element Configuration.

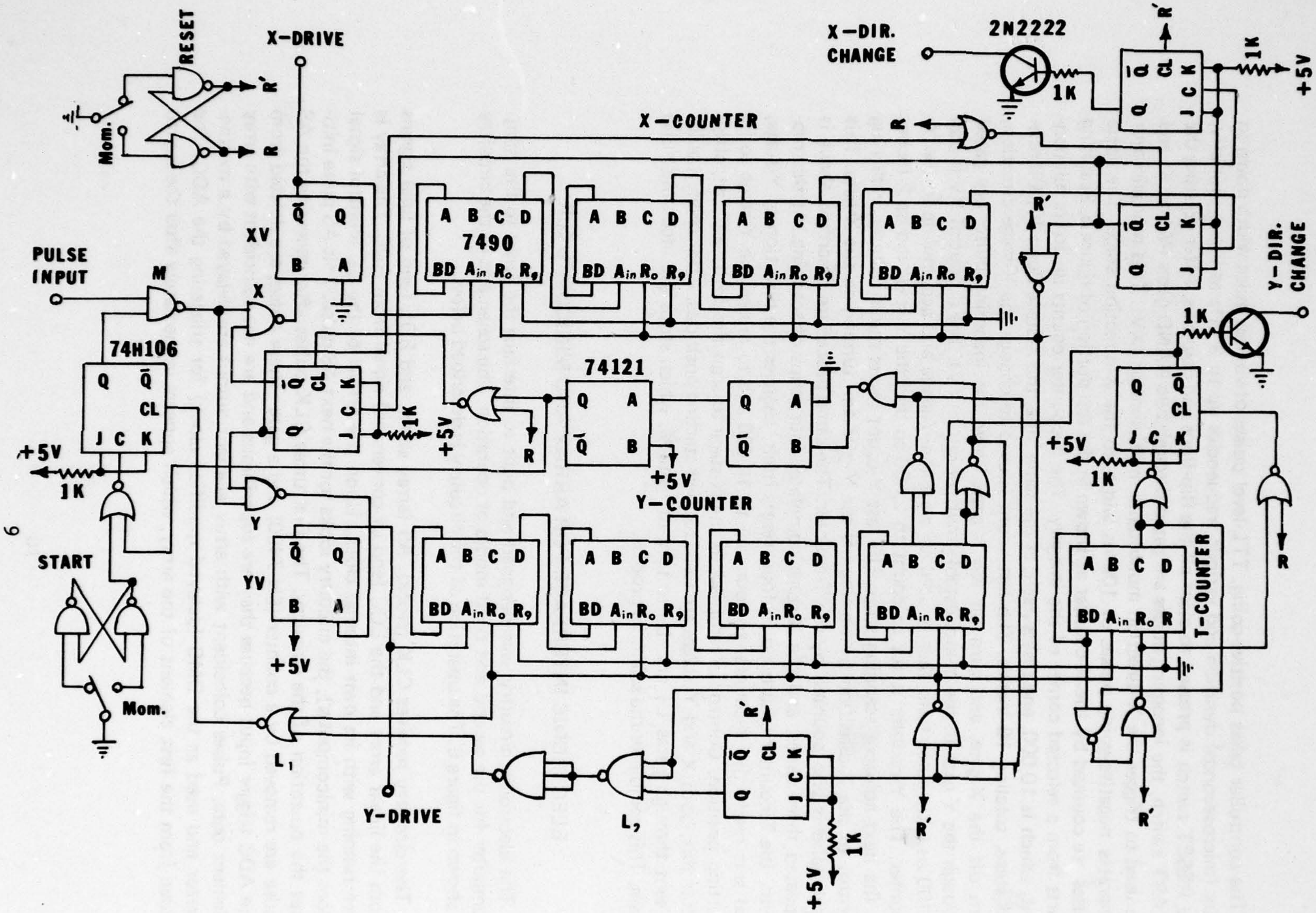

Figure 5. Schematic of System Controller for Mode 1 Operation

The controller takes positive-going, TTL-level pulses of various pulse width down to 1 μs (microseconds) duration and various frequencies up to 3 kHz as input. Initially, the RESET switch is pressed to clear all the flip-flops and counters. After pressing the START switch, the incoming pulses are gated through two NAND gates (M and X) and are used to trigger the X-direction monostable multivibrator (XV). This multivibrator generates negative-going pulses of 100 μs width to the X-direction stage. The same pulses are counted by the X-counter as shown in the top portion of figure 5. Scanning starts from a selected corner of the imagery. The X-counter counts up to its full content, which is 10,000, and resets itself; at the same time, the X-stage slews 10,000 one-mil steps, totaling 10 inches. The last count is used to change the X-stage direction, turn off the X-gate, and turn on the Y-gate. Now, the incoming pulses are gated through the Y-gate to the Y-monostable multivibrator (YV). The output of YV is also a 100 μs-wide-pulse train that is used to slew the Y-stage and accumulate in the Y-counter. The Y-counter is set to count to 2,000 so that the Y-stage moves 2 inches to the next adjacent scanning strip. The last Y-count resets the Y-counter, returning control to the X-direction by turning off the Y-gate and turning on the X-gate. This reset pulse is also counted by the T-counter. The same procedure described above is repeated three times, and the X-stage completes four strips of scanning. At this moment, the T-counter counts up to four, resets itself, changes the direction of Y-stage, and sets ready the Y-counter to count up to 10,000 and to return the Y-stage to its starting position. Control is returned to the X-stage to scan the fifth, and last, strip. After this, both X and Y stages are reset to their starting positions. After reset, a pulse is sent through gates L_1 and L_2 to turn off gate M, which stops the incoming pulse train. This completes the scanning process.

ELECTRONIC INTERFACE FOR ARRAY AND MINICOMPUTER

The electronic circuitry was designed and built to interface the array to the minicomputer for the second and third modes of operation. The schematic of the circuitry is shown in figure 6. The operation of the circuitry is described below.

The circuitry receives CLK (clock), AS (array start), and EOL (end of line) signals from the linear array and the EOC (end of conversion) signal from ADC. The array is free running with its own internal clock. Upon the arrival of the CC (control signal from the minicomputer), the circuitry looks for the next AS pulse. This AS pulse initiates the operation of the circuitry. The first three CLK pulses after receiving the AS pulse are removed by a counter (SN 7490) and a gate. These pulses are deleted from the ADC trigger input because they are superfluous and are not coincident with array element data. Pulses coincident with array element output are delayed by a multivibrator and used as the DMC (delayed modified clock) for triggering the ADC. The video from the first element of the array, which appears immediately after the fourth

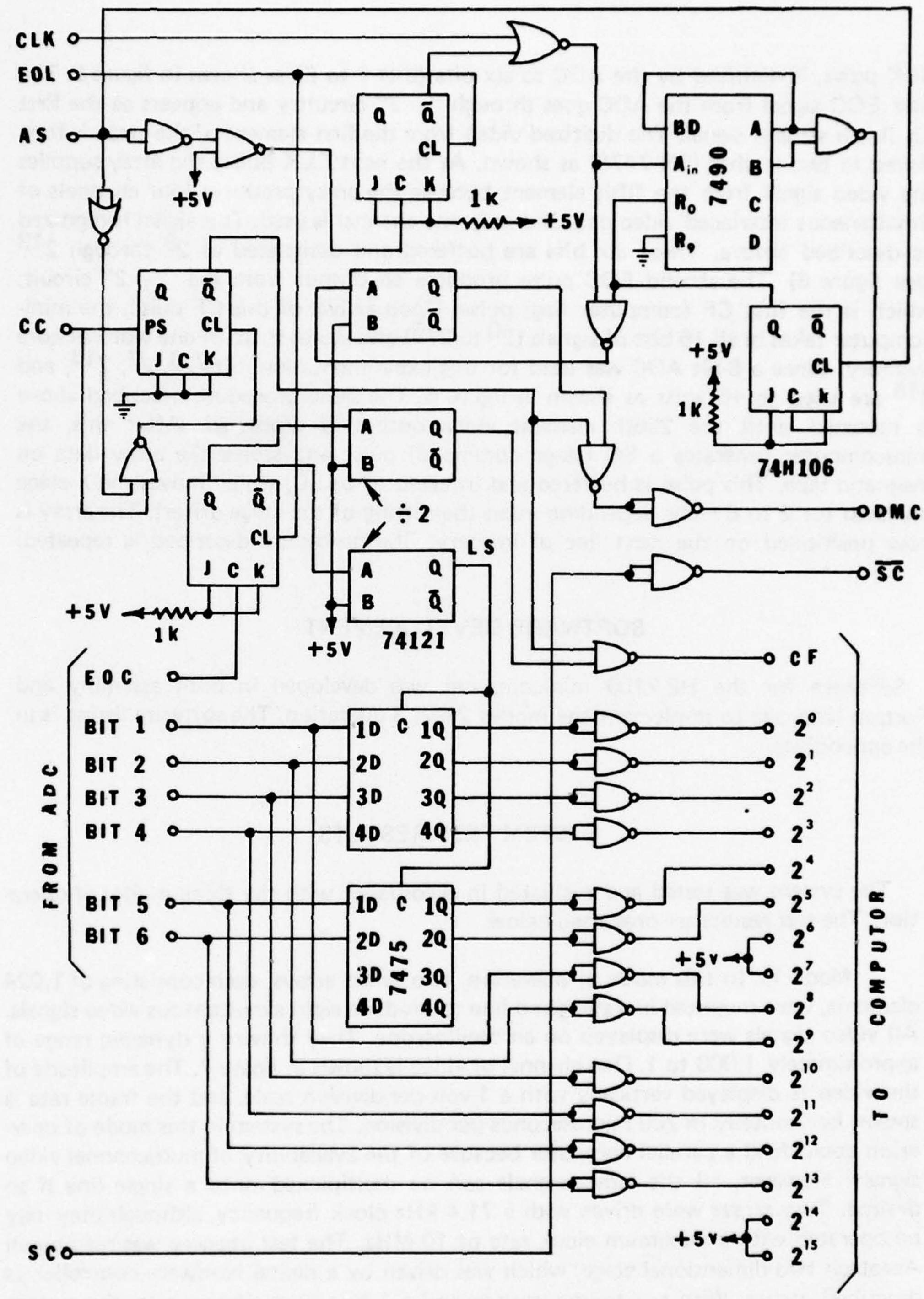

Figure 6. Schematic of Interface Electronic for Modes 2 and 3 Operations

CLK pulse, is digitized by the ADC to six bits (bits 1 to 6) as shown in figure 6. The first EOC signal from the ADC goes through "÷ 2" circuitry and appears as the first LS (latch strobe) signal. The digitized video from the first element of the array is then stored in two latches (SN 7475) as shown. At the next CLK pulse, the array supplies the video signal from the fifth element because the array produces four channels of simultaneous interlaced video data and only one channel is used. This signal is digitized as described before. These six bits are buffered and designated as 2^8 through 2^{13} (see figure 6). The second EOC pulse produces an output from the "÷ 2" circuit, which is the first CF (computer flag) pulse. Upon arrival of this CF pulse, the minicomputer takes in all 16 bits of signals (2^0 to 2^{15}) and stores them in one word of core memory. Since a 6-bit ADC was used for this experimentation, bits 2^6, 2^7, 2^{14}, and 2^{15} are tried to +5 volts as shown in figure 6. The same procedure described above is repeated until the 256th element video output is processed. After this, the minicomputer generates a SC (stage command) pulse and stores the array data on magnetic tape. This pulse is buffered and inverted to be $\overline{SC}$, which moves the X-stage one step (or 2 to 8 steps depending upon the setting of the stage driver). The array is now positioned on the next line of imagery. The procedure described is repeated.

SOFTWARE DEVELOPEMENT

Software for the HP-2100 minicomputer was developed in both assembly and Fortran language to implement the modes 2 and 3 operation. The software listing is in the appendixes.

SYSTEM TEST RESULTS

The system was tested and evaluated in accordance with the three modes of operation. The test results are presented below.

Mode 1. In this mode of operation, two linear arrays, each consisting of 1,024 elements, were mounted in a staggered line to produce eight simultaneous video signals. All video signals were displayed on an oscilloscope. They showed a dynamic range of approximately 1,000 to 1. One channel of video is shown in figure 7. The amplitude of the video is displayed vertically with a 1-volt-per-division scale, and the frame rate is shown horizontally in 200 microseconds per division. The system in this mode of operation could feed a parallel computer because of the availability of multichannel video signals. However, all the video signals can be multiplexed onto a single line if so desired. Two arrays were driven with a 71.4 kHz clock frequency, although they may be operated with a maximum clock rate of 10 MHz. The test imagery was held by an Aerotech two-dimensional stage, which was driven by a digital hardware controller as described earlier. With one-to-one imaging and a 1-kHz-stage slewing rate, the system scanned and digitized a 9- by 9-inch photo-transparency into 84,934,656 pixels of 1

Figure 7. CRT Display of Video Signal.

mil by 1 mil, each consisting of 256 gray shades, in 58 seconds. The system was tested with various stage slewing rates, and a very linear relationship was obtained, up to 3 kHz driving frequency (see table 1). Overslewing of the stage occurred when the driving frequency was raised beyond 3.5 kHz. Smaller pixel size is possible with greater image magnification and with an increase in scan time. The converse is true if a larger pixel is desired. The best scanning scheme for 9- by 9-inch transparencies would be to use nine staggered linear arrays and a single direction translational stage.

Mode-2. In this mode ot operation, one channel of video was digitized by a 6-bit ADC, before being sent to the minicomputer for storage on magnetic tape. Since the dynamic range of the video signal is approximately 1,000 to 1, the video data may be digitized to 8 or 10 bits for applications requiring more gray shades. In our system, the digital data from two adjacent pixels were packed into one 16-bit word before being sent to the minicomputer. The images on the tapes were then reconstructed by a remotely located DICOMED system or a microdensitometer. To match the format of the DICOMED device, only an 8- by 8-inch area was scanned from the 9- by 9-inch photo transparencies. It took approximately 16 minutes to scan and store the digital data for the 8- by 8-inch area of transparency. The increase in the system operation time compared to that of the Mode-1 is mainly due to the slow writing speed of the digital tape unit.

Two aerial photographs from the Baltimore area, a photographic plate of an Oklahoma scene, and a grid plate were scanned and stored on magnetic tapes using this mode of operation. The contents of the tapes were reconstructed into hard copies 3 5/8 by 3 5/8 inches. The original 8- by 8-inch photographs were developed from these hard copies (See figures 8 through 11). The aerial photographs from the Baltimore area (figures 8 and 9) and the scene from Oklahoma (figure 10) were reconstructed by using the mocrodensitometer, and the grid photograph (figure 11) was reconstructed by the DICOMED system. Each figure shows good resolution and contrast, and accurate pixel position. The pixel size for these figures is 4 by 4 mil. The lines between each scan strip are due to uneven illumination from the light source. This also caused the sudden gray shade change of some patterns overlapping two adjacent scan strips. The undesirable black lines in figure 11 are due to scratches on the original imagery.

A 2- by 2-inch section from the first aerial photograph of the Baltimore area and the photographic plate of Oklahoma were magnified four times in both the X and Y directions and were scanned and stored on magnetic tapes as before. The contents of the tapes were reconstructed by the DICOMED system, and phtotgraphs of original size were developed (See figures 12 and 13). Comparison of these photographs with corresponding sections in figures 8 and 10 clearly indicates that much higher resolution was obtained. The pixel size for figures 12 and 13 is 1 by 1 mil. Only 2-inch-square images

Table 1

Stage Drive Frequency versus Scan Time

Stage Drive Frequency (Hz)	Scan Time (Sec)
100	580
200	290
300	193
500	116
1000	58
2000	29
3000	19.3

were selected for this demonstration because of the limitation of the DICOMED system (maximum number of pixels is 2,048 by 2,048). Resolution exactly equal to that shown in figures 12 and 13 can be obtained by multiplexing four simultaneous video channels electronically without magnifying the images.

Mode-3. To produce a data tape with a true 9- by 9-inch raster compatible with the EBR (Electron Beam Recorder), the software was modified to store the digitized data onto a remotely located disc through a communication link. The data on the disc in strip mode were rearranged in the format of the EBR and stored on magnetic tape through the same communication link. The system's operation time was not reduced because the digitized data had to be converted to a serial string to pass through the communication link. This effort was unsuccessful from the point of view of saving system operation time. However, if a disc were located online with the array scanner and the minicomputer, a reduction factor of 16.6 in system operation time is possible. This will again reduce the 16 minutes operation time of the Mode 2 into less than 1 minute. Figure 14 shows the preliminary result of the reconstructed image of the Oklahoma area by the EBR operated in the analog mode. The pixel size is 4 by 4 mil.

CONCLUSIONS

1. High speed scanning of photographic transparencies was successfully demonstrated using high resolution, solid state, linear arrays as the optical transducer.

2. With this method, a 9- by 9-inch photographic transparency can be scanned and digitized into 84,934,656 pixels of 1 mil by 1 mil each consisting of 256 gray shades, in 58 seconds.

3. High resolution, good contrast, and accurate pixel position were obtained in the reconstructed images scanned by this method.

4. The scheme also offers simultaneous parallel outputs that can readily be connected to a parallel processor for rapid processing.

Figure 8. Reconstructed Image of the Baltimore Area 1.

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Figure 9. Reconstructed Image of the Baltimore Area 2.

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Figure 10. Reconstructed Image of the Oklahoma Area.

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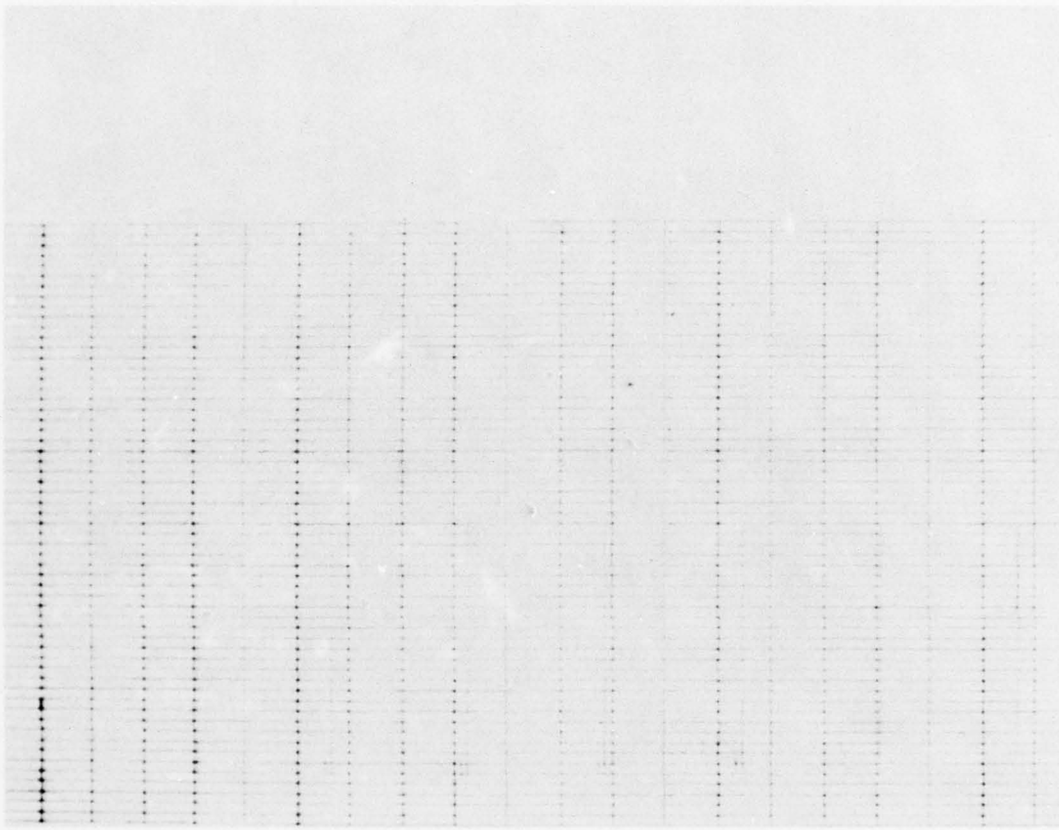

Figure 11. Reconstructed Grid Image.

Figure 12. Reconstructed Image for a Section of the Baltimore Area 1.

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Figure 13. Reconstructed Image for a Section of the Oklahoma Area.

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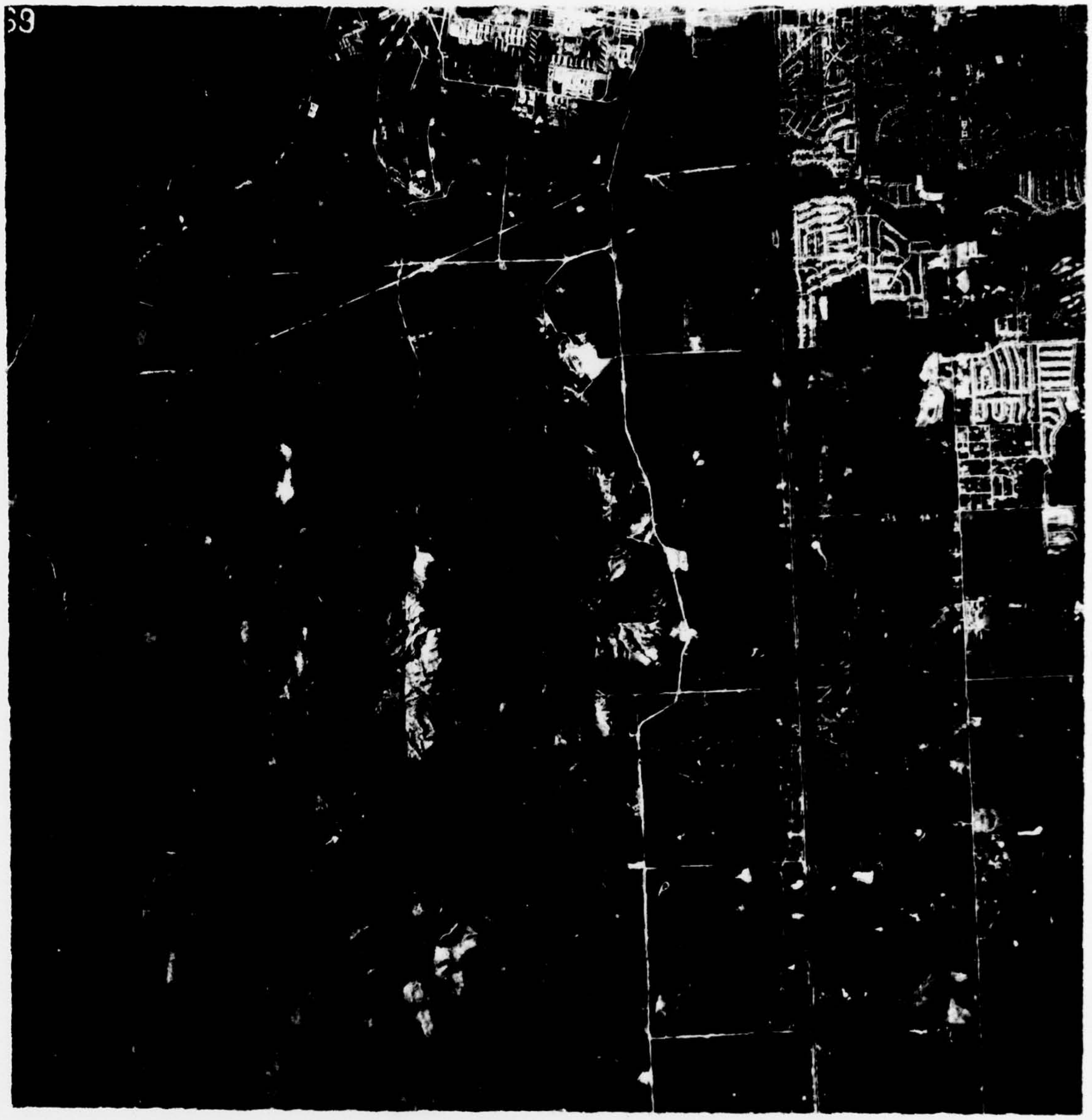

Figure 14. Reconstructed Image of the Oklahoma Area with EBR.

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APPENDIX A

A PROGRAM TO STORE BINARY IMAGE ON MAG TAPE FOR PLAYBACK ON THE DICOMED


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*
*                  PROGRAM TO STORE BINARY IMAGE ON MAG TAPE FOR
*                  PLAYBACK ON THE DICOMED.
*
*
      00000                    NAM ISCAN
                               ENT ISCAN
                               EXT .IOC.,ASOUT,NUMIN,FINPT
                               EXT UNPAC,MMOVE
                               EXT DELAY
      00000 000000  ISCAN      NOP
      00001 063206R            LDA =B10
      00002 007400             CCB
      00003 016004X            JSB FINPT       INPUT DARK LEVELS
      00004 000406R            DEF BUFER
      00005 000326R            DEF N
*
      00006 062326R            LDA N
      00007 001200             RAL
      00010 066161R            LDB BUFAD
      00011 016005X            JSB UNPAC       UNPACK INTO DARK BUFFER
      00012 000606R DKADR      DEF DARK
*
      00013 062326R            LDA N
      00014 001200             RAL
      00015 003004             CMA,INA
      00016 072364R            STA CNT1
      00017 066012R            LDB DKADR
      00020 160001             LDA 1,I         MAKE DARK
      00021 003004             CMA,INA          LEVELS
      00022 170001             STA 1,I           NEGATIVE
      00023 006004             INB
      00024 036364R            ISZ CNT1
      00025 026020R            JMP *-5
*
      00026 002400  L0         CLA
      00027 102601             OTA 1
*
      00030 063207R LL1        LDA =B2000
      00031 043210R            ADA =D14
      00032 066337R            LDB MAD1
      00033 016002X            JSB ASOUT       ASK FOR NO. OF STRIPS
      00034 000151R            DEF RETRN
      00035 026147R            JMP END
      00036 016003X            JSB NUMIN       INPUT NO. OF BLOCKS
      00037 000151R            DEF RETRN
      00040 026147R            JMP END
      00041 026030R            JMP LL1
      00042 067211R            LDB =D2048
      00043 002020             SSA           NEG. X MOTION?
      00044 007004             CMB,INB       YES, STORE
      00045 076370R            STB BSTEP      NEG. BLOCK STEPS
      00046 002021             SSA,RSS
      00047 003004             CMA,INA
      00050 072372R            STA NBLKS
      00051 043206R            ADA =D8
      00052 002020             SSA             MORE THAN 8?
```

PAGE 0003 #01

```
00053 026030R       JMP LL1
*
00054 063207R L1    LDA =B2000
00055 043212R       ADA =D18
00056 066347R       LDB MAD2
00057 016002X       JSB ASOUT       ASK FOR NO. OF LINES
00060 000151R       DEF RETRN
00061 026147R       JMP END
00062 016003X       JSB NUMIN
00063 000151R       DEF RETRN
00064 026147R       JMP END
00065 026054R       JMP L1
00066 067206R       LDB =D8
00067 002020        SSA           NEG. Y MOTION?
00070 007004        CMB,INB        YES, MAKE -1
00071 076367R       STB LSTEP
00072 002021        SSA,RSS
00073 003004        CMA,INA
00074 072371R       STA NLINS
00075 002400        CLA
00076 072373R       STA XSET        SET STAGE POSITIONS
00077 072374R       STA YSET         TO ZERO
00100 003000        CMA
00101 072402R       STA LASTX
*
00102 002400  L2    CLA           SET X
00103 072375R       STA XSTEP     STEPS = 0
00104 062367R       LDA LSTEP      SET Y STEP
00105 072376R       STA YSTEP      =+-1
00106 062371R       LDA NLINS
00107 072365R       STA CNT2        LINE COUNTER
00110 102501  L3    LIA 1
00111 002020        SSA            ABORT?
00112 026137R       JMP START
00113 016155R       JSB READ        INPUT AND ROTATE
00114 016316R       JSB WRITE       WRITE ON MAG TAPE
00115 036365R       ISZ CNT2        ALL LINES DONE?
00116 002001        RSS
00117 026122R       JMP *+3
00120 016246R       JSB SLEW        MOVE TO NEXT LINE
00121 026110R       JMP L3
00122 036372R       ISZ NBLKS       ALL STRIPS DONE?
00123 002001        RSS
00124 026133R       JMP EOF         YES, WRITE EOF, REWINDE
00125 062374R       LDA YSET        RESET TO
00126 072376R       STA YSTEP        TO TOP LINE
00127 062370R       LDA BSTEP      MOVE TO
00130 072375R       STA XSTEP      NEXT STRIP
00131 016246R       JSB SLEW
00132 026102R       JMP L2
*
00133 016001X EOF   JSB .IOC.
00134 030103        OCT 30103
00135 000000        NOP
00136 016331R       JSB WAIT
00137 016001X START JSB .IOC.
00140 030403        OCT 30403
```

```
00141 000000          NOP
00142 062373R         LDA XSET
00143 072375R         STA XSTEP
00144 062374R         LDA YSET
00145 072376R         STA YSTEP
00146 016246R         JSB SLEW           SLEW BACK TO START
00147 102077   END    HLT 77B
00150 026026R         JMP L0
*
*
00151 000000   RETRN  NOP
00152 102501          LIA 1
00153 013213R         AND =B100000
00154 126151R         JMP RETRN,I
*
00155 000000   READ   NOP
00156 063206R         LDA =B10
00157 007400          CCB
00160 016004X         JSB FINPT
00161 000406R  BUFAD  DEF BUFER
00162 000326R         DEF N
00163 062326R         LDA N
00164 003004          CMA,INA
00165 072364R         STA CNT1
00166 062012R         LDA DKADR
00167 072366R         STA CNT3
00170 066161R         LDB BUFAD
00171 160001   L4     LDA 1,I
00172 001727          ALF,ALF
00173 013214R         AND =B377
00174 142366R         ADA CNT3,I      SUB. DARK LEVEL
00175 002020          SSA            MAKE 0
00176 002400          CLA              IF NEG.
00177 072405R         STA TEMP
00200 102501          LIA 1       IF BIT 0=1
00201 002011          SLA,RSS       CLIP VIDEO DATA
00202 026214R         JMP L5
00203 062405R         LDA TEMP
00204 003004          CMA,INA
00205 042362R         ADA CLIP
00206 002020          SSA
00207 026212R         JMP *+3
00210 002400          CLA
00211 026213R         JMP *+2
00212 062363R         LDA MAX
00213 072405R         STA TEMP
00214 036366R  L5     ISZ CNT3
00215 160001          LDA 1,I
00216 013214R         AND =B377
00217 142366R         ADA CNT3,I
00220 072361R         STA TMP
00221 102501          LIA 1
00222 002011          SLA,RSS
00223 026233R         JMP L6
00224 062361R         LDA TMP
00225 003004          CMA,INA
00226 042362R         ADA CLIP
```

```
00227 002021           SSA,RSS
00230 026235R          JMP **+5
00231 062363R          LDA MAX
00232 026236R          JMP **+4
00233 062361R L6       LDA TMP
00234 002020           SSA
00235 002400           CLA
00236 001727           ALF,ALF
00237 032405R          IOR TEMP
00240 170001           STA 1,I
00241 006004           INB
00242 036366R          ISZ CNT3
00243 036364R          ISZ CNT1
00244 026171R          JMP L4
00245 126155R          JMP READ,I
*
*
00246 000000  SLEW     NOP
00247 062402R          LDA LASTX
00250 022375R          XOR XSTEP
00251 002020           SSA
00252 026257R          JMP DIROT
00253 062403R          LDA LASTY
00254 022376R          XOR YSTEP
00255 002021           SSA,RSS
00256 026272R          JMP MOVE
00257 063215R DIROT    LDA =B77774
00260 066375R          LDB XSTEP
00261 006020           SSB
00262 002004           INA
00263 066376R          LDB YSTEP
00264 006020           SSB
00265 033216R          IOR =B2
00266 102621           OTA 21B
00267 016007X          JSB DELAY
00270 000272R          DEF **+2
00271 000401R          DEF MASK
00272 016006X MOVE     JSB MMOVE
00273 000303R          DEF RTN
00274 000375R          DEF XSTEP
00275 000376R          DEF YSTEP
00276 000377R          DEF RATE
00277 000400R          DEF PAUSE
00300 000401R          DEF MASK
00301 000401R          DEF MASK
00302 000404R          DEF CHAN
00303 062375R RTN      LDA XSTEP
00304 072402R          STA LASTX
00305 003004           CMA,INA
00306 042373R          ADA XSET
00307 072373R          STA XSET
00310 062376R          LDA YSTEP
00311 072403R          STA LASTY
00312 003004           CMA,INA
00313 042374R          ADA YSET
00314 072374R          STA YSET
00315 126246R          JMP SLEW,I
```

```
*
*
00316 000000  WRITE NOP
00317 026322R       JMP *+3
00320 016001X       JSB .IOC.
00321 000007        OCT 7
00322 016001X       JSB .IOC.
00323 020103        OCT 20103
00324 026320R       JMP *-4
00325 000406R       DEF BUFER
00326 000200  N     DEC 128
00327 016331R       JSB WAIT
00330 126316R       JMP WRITE,I
*
*
00331 000000  WAIT  NOP
00332 016001X       JSB .IOC.
00333 040003        OCT 40003
00334 002020        SSA
00335 026332R       JMP *-3
00336 126331R       JMP WAIT,I
*
00337 000340R MAD1  DEF *+1
00340 047117        ASC 7,NO. OF STRIPS?
00341 027040
00342 047506
00343 020123
00344 052122
00345 044520
00346 051477
00347 000350R MAD2  DEF *+1
00350 047117        ASC 9,NO. OF SCAN LINES?
00351 027040
00352 047506
00353 020123
00354 041501
00355 047040
00356 046111
00357 047105
00360 051477
00361 000000  TMP   NOP
00362 000040  CLIP  DEC 32
00363 000077  MAX   DEC 63
00364 000000  CNT1  NOP
00365 000000  CNT2  NOP
00366 000000  CNT3  NOP
00367 000000  LSTEP NOP
00370 000000  BSTEP NOP
00371 000000  NLINS NOP
00372 000000  NBLKS NOP
00373 000000  XSET  NOP
00374 000000  YSET  NOP
00375 000000  XSTEP NOP
00376 000000  YSTEP NOP
00377 000144  RATE  DEC 100
00400 000000  PAUSE NOP
00401 000017  MASK  OCT 17
```

```
0272  00402 000000  LASTX NOP
0273  00403 000000  LASTY NOP
0274  00404 000021  CHAN  OCT 21
0275  00405 000000  TEMP  NOP
0276  00406 000000  BUFER BSS 128
0277  00606 000000  DARK  BSS 256
      01206 000010
      01207 002000
      01210 000016
      01211 004000
      01212 000022
      01213 100000
      01214 000377
      01215 077774
      01216 000002
0278                      END ISCAN
**  NO ERRORS*
```

APPENDIX B

PROGRAM ARSCN

```
FTN,B
          PROGRAM ARSCN
          DIMENSION IBUF(1025),NAME(3)
          DIMENSION IDARK(256)
          DIMENSION LU(2),IO(2),IPIXL(2)
C
C         GET LU AND CHANNEL OF THE MCI CARDS.  THE
C         FIRST CARD IS USED FOR DATA INPUT AND
C         THE SECOND CARD IS USED TO SLEW THE STAGES.
C
          CALL LUNIT(14B,LU,IO)
          IF (LU.NE.0)GO TO 6
          WRITE(2,5)
5         FORMAT("D.14 NOT PRESENT")
          CALL IDLE
C
C         INPUT THE NUMBER OF BITS IN THE DATA.  THE HARDWARE
C         REVERSES THE THE ORDER OF THE TWO 8 BIT PIXELS IN
C         THE 16 BIT INPUT WORD.  ACCORDING TO THE HIGHEST
C         SIGNIFICANT BIT DESIRED IN THE DATA, THE SIX BIT
C         PIXEL FROM THE A/D CONVERTER(RIGHT JUSTIFIED IN
C         8 BITS), IS ROTATED TO THE LEFT BY
C         NBITS. (NBITS=-6 FOR AN 8 BIT RANGE).
C
6         WRITE(2,7)
7         FORMAT("NO. OF BITS?")
          READ(1,*)I
          IF (IRANG(6,8,I))6,8
8         NBITS=I-14
C
C         SET THE DARK LEVLES TO 0
C
          DO 9 I=1,256
9         IDARK(I)=0
C
C         INPUT THE ARRAY DARK LEVELS IF TTY RESPONSE > 0.
C
10        CALL IOUT(0,1)
          WRITE(2,11)
11        FORMAT("INPUT DARK LEVELS? (INPUT>0)")
          READ(1,*)I
          IBUF=0
          IF (I.LT.1)GO TO 12
          CALL DMAIN(IBUF(2),128,LU)
          CALL ROTAT(IBUF(2),IBUF(2),128,NBITS)
          CALL UNPAK(IBUF(2),IDARK,256)
C
C         CREATE DATA FILE OR OPEN EXISTING FILE
C
12        WRITE(2,20)
20        FORMAT("CREATE FILE? (INPUT>0)")
          READ(1,*)I
          WRITE(2,30)
30        FORMAT("FILE NAME?")
          READ(1,40)NAME
40        FORMAT(3A2)
          IF (I.GT.0)GO TO 60
          CALL ROPEN(ISTAT,IERR,NAME)
          GO TO 70
```

```
60   CALL RCRET(ISTAT,IERR,NAME,-1,1,0,-22)
70   CALL FILER(ISTAT,IERR,IF)
     IF (IF.EQ.-1)GO TO 1000
C
C    INPUT SCAN PARAMETERS.  A NEGATIVE ENTRY FOR SIZE
C    CAUSES REVERSE STAGE MOTION.
C
     WRITE(2,75)
75   FORMAT("STAGE SPEED?")
     READ(1,*)IRATE
     WRITE(2,80)
80   FORMAT("STRIP SIZE?")
     READ(1,*)IWDTH
85   WRITE(2,90)
90   FORMAT("NO. OF STRIPS?")
     READ(1,*)NSTRP
     IF (IRANG(1,8,NSTRP))85,95
95   WRITE(2,100)
100  FORMAT("Y STEP SIZE?")
     READ(1,*)LSIZE
     WRITE(2,110)
110  FORMAT("NO. OF LINES?")
     READ(1,*)NLINS
C
C    INITIALIZE PARAMETERS
C
     IXSET=0
     IYSET=0
     N=1
     NUM=1
C
C    TAKE ARRAY DATA, ROTATE TO CORRECT BIT POSITIONS,
C    UNPACK, SUBTRACT DARK LEVELS, RE-PACK
C    AND STORE ON REMOTE DISK FILE FOR ONE STRIP
C
115  DO 120 I=1,NLINS
     IF (ISSW(15))1010,130
130  CALL DMAIN(IBUF(2),128,LU(1))
     CALL ROTAT(IBUF(2),IBUF(2),128,NBITS)
     CALL UNPAK(IBUF(2),IBUF(130),256)
     DO 131 J=1,256
131  IBUF(J+1)=IBUF(J+129)-IDARK(J)
     CALL IPACK(IBUF(2),IBUF(2),256)
     CALL RWRIT(ISTAT,IERR,NAME,IBUF(2),128,NUM)
     CALL FILER(ISTAT,IERR,IF)
     IF (IF.EQ.-1)GO TO 1000
     NUM=NUM+1
     IF (I.EQ.NLINS)GO TO 120
     CALL STAGE(0,LSIZE,IXSET,IYSET,IRATE,IBUF,IO(2))
120  CONTINUE
C
C    CHECK FOR END OF DATA TAKING.  IF NOT FINISHED,
C    SLEW OVER TO NEXT STRIP AND TAKE DATA IN OPPOSITE
C    SCAN DIRECTION.
C
     IF (N.EQ.NSTRP)GO TO 1010
     N=N+1
     CALL STAGE(IWDTH,0,IXSET,IYSET,IRATE,IBUF,IO(2))
     LSIZE=-LSIZE
     GO TO 115
```

```
C
C      REMOTE FILE ACCESS ERROR
C
1000   CALL IOUT(100000B,1)
C
C      CLOSE THE FILE AND RESET STAGES
C
1010   CALL RCLOS(ISTAT,IERR,NAME)
       CALL STAGE(IXSET,IYSET,IXSET,IYSET,IRATE,IBUF,IO(2))
       IF (ISSW(15))10,135
C
C      THIS SECTION WRITES THE DATA ON DISK TO MT
C      IN THE CORRECT SCANNING SEQUENCE(RASTER)
C
135    LEN=128*NSTRP
       CALL IOUT(0,1)
       REWIND 3
       CALL ROPEN(ISTAT,IERR,NAME)
       CALL FILER(ISTAT,IERR,IF)
       IF (IF.EQ.-1)GO TO 1000
C
C
       DO 140 I=1,NLINS
       DO 141 J=1,NSTRP
       IF (ISSW(15))190,180
180    IF (J.EQ.1)GO TO 150
       J2=J/2
       IREM=J-2*J2
       IF (IREM.EQ.1)GO TO 160
       NUM=2*J2*NLINS-I+1
       GO TO 170
160    NUM=2*J2*NLINS+I
       GO TO 170
150    NUM=I
170    CALL RREAD(ISTAT,IERR,NAME,IBUF((J-1)*128+1),N,NUM)
       CALL FILER(ISTAT,IERR,IF)
       IF (IF.EQ.-1)GO TO 1000
141    CONTINUE
       CALL BFOUT(3,IBUF,LEN)
142    IF (IUNIT(3))142,140
140    CONTINUE
C
C
       ENDFILE 3
190    REWIND 3
       CALL RCLOS(ISTAT,IERR,NAME)
       PAUSE
C
C      IF SW BIT 0=1 AFTER RUN IS PUSHED, THE DATA
C      ON MAG TAPE IS READ RECORD BY RECORD AND PRINTED
C      ON THE TTY TO CHECK THE OPERATION OF THE SYSTEM
C      SW BIT 15=1 ABORTS TO STATEMENT 10.
C
       IF (ISSW(0))200,10
200    CALL BFINP(3,IBUF,LEN)
210    IF (IUNIT(3))210,220
220    DO 230 I=1, LEN
       IF (ISSW(15))10,225
225    CALL UNPAK(IBUF(I),IPIXL,2)
       WRITE(2,226)IPIXL(1)
```

```
            WRITE(2,226)IPIXL(2)
      226   FORMAT(I4)
      230   CONTINUE
            GO TO 200
            END
            END$
```

**END-OF-TAPE
*

Chen, Pi-Fuay
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