MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

LEVEL II

RADC-TR-80-198
Final Technical Report
July 1980

AD A089952

DATA HANDLING RECORDING SYSTEM (DHRS)

Harris Corporation

Dr. W.E. Taylor

DTIC
SELECTED
OCT 6 1980

A

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

80 10 6 078

This report has been reviewed by the RADC Public Affairs Office (PA) and
is releasable to the National Technical Information Service (NTIS). At NTIS
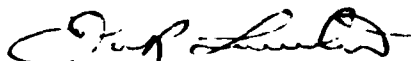it will be releasable to the general public, including foreign nations.

RADC-TR-80-198 has been reviewed and is approved for publication.

APPROVED:

ANDREW R. PIRICH
Project Engineer

APPROVED:

OWEN R. LAWTER, Colonel, USAF
Chief, Intelligence and Reconnaissance Division

FOR THE COMMANDER:

JOHN P. HUSS
Acting Chief, Plans Office

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
RADC-TR-80-198	AD-A089953	

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
DATA HANDLING RECORDING SYSTEM (DHRS)	Final Technical Report 1 Oct 79 — 31 Mar 80
	6. PERFORMING ORG. REPORT NUMBER N/A

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Dr. W.E. Taylor	F30602-79-C-0268

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Harris Corporation PO Box 37 Melbourne FL 32901	63208F 665A0003

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Rome Air Development Center (IRRE) Griffiss AFB NY 13441	July 1980
	13. NUMBER OF PAGES 66

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
Same	UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Andrew R. Pirich (IRRE)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Real-Time Processing   Digital Imagery
Detection   Enhancement
Identification
Reporting

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

The final technical report submitted by Harris Corporation contains a brief synopsis of the preliminary design criteria for the fabrication of the DHRS during Phase II. An analysis is presented of the hardware design to handle 10^{12} bits of digital imagery data. Harris Corporation provides a hierarchical software technique in handling the voluminous amount of imagery data without degradation to the imagery and employing a single (MTU) magnetic tape unit.

DD FORM 1473   EDITION OF 1 NOV 65 IS OBSOLETE

TABLE OF CONTENTS

EVALUATION

The DHRS (Data Handling Recording System/Phase 1) effort was offered as a dual award to two contractors to provide the Air Force with the best technical design and cost criteria.

Harris Corp was one of the two contractors. The Harris Corp portion of the effort succeeded in providing a technically feasible design for the DHRS.

Harris Corp provided sound technical solutions to the many design problem areas designated within the SOW, e.g., handling 10^{12} bits of data, storage and retrieval, automatic detection and classification of targets from FLIR (Forward Looking IR) and DLIR (Downward Looking IR) imagery, and image interpretation (IR) functions for generating tactical reports.

The DHRS design appears to be technically feasible and cost effective, and is a primary thrust in developing an all digital multi-sensor tactical ground exploitation system.

ANDREW R. PIRICH
Project Engineer

I. ABSTRACT

This final report presents the results of the Data Handling Recording System (DHRS) study effort to define and specify an architecture for the purpose of ingesting, storing, exploiting, and verifying reconnaissance imagery. The defined architecture consists of four functional modules: Sensor Input Module (SIM), Storage and Retrieval Module (S/RM), Real-Time Processing Module (RTPM), and Near Real-Time Exploitation Module (NRTEM). These functional modules and the associated hardware subsystems will perform the ingest, handling, and display of the required sensor data types. To obtain a more detailed description of any particular facet of the DHRS, refer to one of the following applicable documents:

"DHRS System/Subsystem Specification," Harris Corporation GCSD, March 1980.

"DHRS Functional Description," Harris Corporation GCSD, March 1980.

"DHRS Data Base Specification," Harris Corporation GCSD, March 1980.

"DHRS Data Requirements Document," Harris Corporation GCSD, March 1980.

"DHRS Technical Proposal," Harris Corporation GCSD, March 1980.

RADC Contract "DHRS #F30602-79-C-0268," dated 28 September 1979, Unclassified.

II.   STATEMENT OF THE PROBLEM

Since World War II, commanders have lost opportunities to destroy enemy targets because of the delay between target observation and dispatch of weapon systems. To this day, that delay is several hours, plenty of time for enemy aircraft, tanks, ships, and convoys to relocate. The Harris/WEC DHRS allows real-time target reporting and increased utilization and efficiency of deployed forces.

Only a few frames are needed by the Image Interpreter (I/I) to locate all the targets in a 2-minute mission covering four target sites. Yet, today the I/I examines all the collected frames.

The Harris/WEC DHRS, the unique solution to the reconnaissance cycle problem, reduces processing time from several hours to several minutes.

After proof of concept using the DHRS advanced development model has been demonstrated, the far term solution will utilize an airborne screener. Airborne screening allows only that small portion of the sensed imagery containing targets to be transmitted, thus realizing a tremendous reduction in required data link bandwidth. Sufficiently low data rates permit the use of anti-jam equipment in hostile environments or HF over-the-horizon data links, thus eliminating the need for expensive data relay aircraft.

The Harris/WEC DHRS Configuration evolved through a series of baseline iterations. The resulting configuration may be easily adapted to a hostile environment or to a scenario utilizing real-time "on-board" screening of target data.

III.   TECHNICAL OBJECTIVE

The need for the DHRS is based on decreasing the time delay associated with the reconnaissance cycle. The problem of decreasing this time delay can be solved in several ways. This paragraph will describe the reconnaissance cycle time problem, an assumed reconnaissance scenario, and potential solutions.

The efficiency with which the Tactical Air Forces deliver weapons on enemy targets is determined, in part, by data collected by reconnaissance aircraft. If the location of tanks, trucks, aircraft, and armored vehicles are unknown, they cannot be destroyed.

During the past three decades, substantial progress has been made in collection instruments; infrared sensors are capable of day and night sensing of enemy targets. The instrument measurements are recorded directly via magnetic tape, thereby eliminating the need to develop film. The technology of electro optics has also been applied to image collection and the quality of collected data has been constantly improved.

Yet, the process by which image interpreters extract targets from images has changed little since World War II. While it is true that neither infrared imagery not tape recording of images existed at that time, the manual image interpretation process was similar.

Present day reconnaissance consists of four steps:

1. Aircraft mission to collect imagery on video tapes.
2. Off load the recorded imagery.
3. Interpret the contents of the recorded imagery.
4. Generate and distribute reports of target locations.

These steps normally take several hours even to process a 2 minute mission. Processing time is long because of data management, not because of target identification. Two minutes of collected FLIR data amounts to 3600 frames of data. Because many of the frames do not contain targets, the job of detection and classification is a long, slow process.

Summarizing, the reconnaissance cycle time problem consists of the transportation delay associated with carrying the video tape from the target site to the image interpreter, and the interpretation delay associated with detecting and classifying target.

In the future the reconnaissance cycle time problem will be solved with an airborne screener/classifier. The airborne screener/classifier will remove subframes containing targets. These subframes will then be transmitted to a ground-based exploitation system via a data link. The reconnaissance cycle time problem is reduced to a verification problem with the human image interpreter being the sole source of delay.

Until airborne screener/classifiers become a reality, the solution to the reconnaissance cycle time problem will evolve to a point such that transportation and processing delay is minimized through the use of the DHRS and a wide band data link. The data link will be used to transmit imagery data from the aircraft to the DHRS. The data link will be able to support both analog and digital data, and the DHRS will perform the same functions as described in the executive summary. This solution to the reconnaissance cycle time problem will consist of a RF link and automated image interpretation, i.e., automatic detection and classification of targets, supplemented by computer assisted verification.

The proposed DHRS will provide a solution to the reconnaissance cycle time problem similar to the intermediate solution. The current solution differs from the intermediate solution only in the delay associated with the transportation of the video tape to the image interpreter. There is a natural evolution from the DHRS to the far term solution.

For the purposes of developing the requirements for the DHRS, tne assumed reconnaissance scenario shall be as follows. A typical mission will be two minutes in duration. The mission will consist of a reconnaissance aircraft visiting four target sites, and collecting 30 seconds of imagery at each site. Figure 1 shows a time line corresponding to this mission scenario. The contents of each 30 second data segment consist of frames containing targets, surrounded by frames containing no targets. The number of frames containing targets will vary. For the purposes of computation only, it will be assumed that there exists one frame containing targets midway between the ends of the 30 second segment.

4
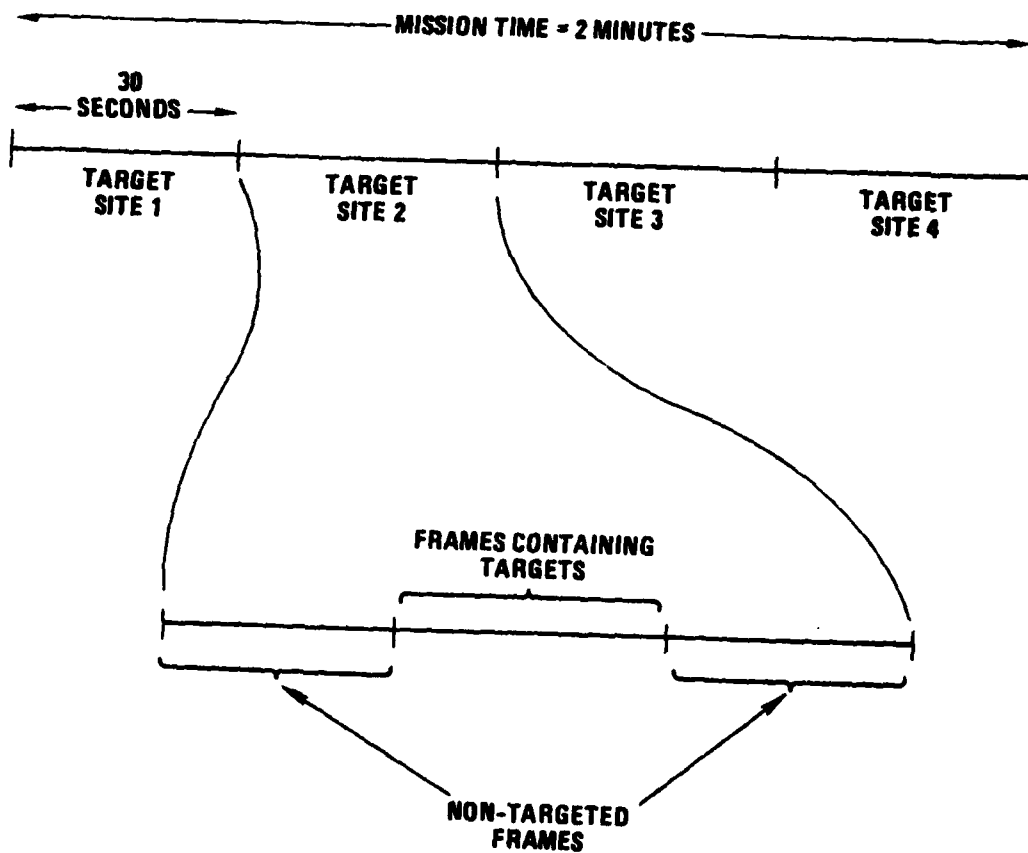
Figure 1. Assumed Typical Mission Scenario

The DHRS considerations discussed in this section lay the groundwork for the design by developing the implied system and subsystem requirements. These implied requirements in conjunction with the specific requirements of the Statement-of-Work form the basis for designing DHRS.

This section presents an evolution of DHRS as a solution to the reconnaissance problem. The DHRS functional partitioning is presented and the subsystems are described. The impact of present and future sensor characteristics upon the system is discussed in terms of data rates and image segmentation. The various contributors to system throughput delay are presented and the computationally intensive navigation and rectification functions are discussed.

The problem as defined by Harris is to provide a system configuration composed of the following functional modules comprising the Data Handling and Recording System.

Either recorded data from the video tapes or real-time data from a data link receiver will be directed to the Sensor Input Module (SIM).

1. The Sensor Input Module must be able to:
   a. Accept video tape data from the recorders of (Pave Tack) FLIR and AN/AAD-5 sensors
   b. Accept direct analog data or direct digital data from the same when it becomes available with minimal modification to the SIM
   c. Provide appropriate a/d conversion for utilizing the analog data in a digital environment
   d. Accept digital data rates of up to 140 Megabits/second
   e. Accept and route navigation, timing, and sync data
   f. Accept preprocessed data
   g. Format image data for storage or "real-time" processing

From the SIM, the formatted digital data will be routed to two modules simultaneously: the "Real-Time" Processing Module (RTPM) and the Storage and Retrieval Module (S/RM).

The RTPM implements the target detection/classification function within the DHRS. The necessary requirements for performing the target screening include, but are not limited to, the RTPM real-time enhancement techniques given in the SOW.

2. The Real-Time Processing Module must perform the following tasks.
   a. Automatic Target Screening
   b. "Real-Time" Image Enhancements
   c. "Real-Time" Target Detection
   d. "Real-Time" Target Identification
   e. Image Segmentation

The output of the RTPM will be a list of target frames, used by the Near Real Time Exploitation Module (NRTEM) to retrieve display size images from the S/RM.

3. The Storage and Retrieval Module must have the following Characteristics:
   a. Equivalent of 10^{12} bits of storage
   b. Ability to input and output data at more than 140 Mb/sec
   c. Image decimation
   d. Image Segmentation for Storage and Display

Two of these characteristics are specified in the SOW as RTPM functions (i.e., decimation and segmentation) but are more efficiently implemented in the S/RM.

From the S/RM, a decimated full-frame image (DLIR), a segmented subframe image (DLIR), or a full-frame full resolution image (FLIR) is routed to the Image Queue, residing in the Near Real Time Exploitation Module (NRTEM).

The NRTEM will provide the Man-Machine Interface and the overall system control for the DHRS, translating target frame cues to retrieval requests from the ingested image data and providing an interactive image evaluation and processing capability.

7

4. The Near Real-Time Exploitation Module provides the following capabilty:
    a. System Control
    b. Image Display and Storage (including Image Queue)
    c. Automatic Retrieval of Cued Subimages
    d. Voice Input and Communications Interface
    e. Image enhancements (including rectification and pixel mensuration)
    f. Data Management with Action/Interaction reporting capability
    g. Exploitation Output Capability
    h. Coordinate Conversion

The modules are connected by a network or bus structure which provides an efficient, low risk method for transferral of image data and system control commands.

5. Internal Distribution Subsystem
    a. Full-Frame Image Transfer
    b. Subframe or Display Image Transfer
    c. System Control and Status

The Function partitioning and module interconnection is shown in Figure 2.

Operational Modes (User Scenario)

The DHRS will provide three modes of operation for the image interpreter (I/I). These modes consist of:

1. Pre Mission or Configuration Mode
2. Auto Q or Mission Mode
3. Post Mission Mode

The premission mode will consist of initialization of the DHRS modules. The SIM initialization will consist of selecting the sensor type for a given mission. The I/I will then initialize the application processors which are part of the S/RM, the display and the Target Screener. The S/RM initialization

8

FULL FRAME IMAGE BUS

SUBFRAME IMAGE BUS

COMMUNICATIONS PORT

INPUT DATA

SIM

S/RM

NRTEM

RTPM

SYSTEM CONTROL BUS
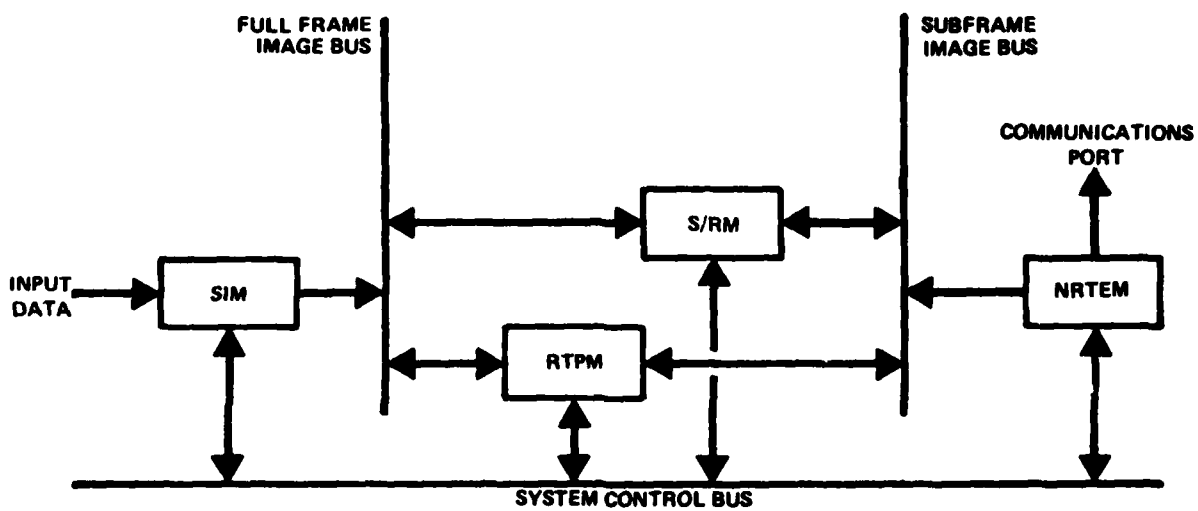
10760—8

Figure 2.   DHRS Functional Partition

9

will consist of moving the tape to the next available location for recording and transferring the mission report identification to the tape as a header. The mission report identification will not only be sent to the S/RM, but also it will be saved by the SCM as part of the report generation function. The System Control Module will be responsible, during the premission mode, for checking the S/RM tape footage count and reporting this to the I/I. The operator voice characteristics will be down-loaded to the voice recognizer. Target priorities may be selected for the auto retrieval of targets, and finally if LORAN navigation calculations will be necessary, the LORAN station coordinates will be selected. The Image Display will be initialized by clearing the display screens, resetting image queue, setting the cursor location and down-loading of any function tables for table lookup.

The Auto Q or mission mode can be divided into two distinct operations. The first will consist of the ingest of data, formatting and routing to the S/RM and RTPM, and the screening of images. The second operation will consist of automatic retrieval of targeted frames and the verification of the target classifications.

The first operation of ingest, format, store, and screen will be done automatically, without I/I assistance. The ingest function will include header extraction and routing, A/D conversion, formatting for storage and processing, rectifying DLIR imagery, and packing the data (for transfer efficiency). The storage of digital data will be performed simultaneously with screening of the imagery. The storage of the digital data consists of transferring image frames, documentation, and sync and search headers to the S/RM magnetic tape. The screening will consist of detecting targets within image frames, classifying detected targets and routing information to the SCM for storage on the data base.

The second operation will consist of image retrieval, queue loading, and I/I exploitation. The image retrieval will occur automatically, and will provide for down-loading of image frame numbers from the SCM to the S/RM control processor. The S/RM control processor will translate the frame number into an actual tape location using auxiliary track information. The resolution/subframe control is loaded with the tape location. As the image is extracted from the tape, the navigation data is sent to the SCM for processing and eventual display. The image queue loads the display with images until the queue is nearly empty. At this time more frames are requested from the S/RM.

10

Once the image is displayed, along with annotation, the I/I may perform any number of image enhancements and rectification processes. As each target is verified, the I/I will be provided with an automatic target reporting facility. The report generation is in key-entry format with as much data transfer directly from the target verification activity as possible. As targets are exploited, the queue empties. When the queue reaches a specified level, the S/RM will ship additional frames to the image queue. The frame retrieval, image queue loading, and image exploitation continues until all frames collected have been serviced.

The post-mission mode will be used for re-processing or enhancement/exploitation of images. The I/I can manually retrieve and route specific imagery data from the S/RM to the image queue, and to the display. Once in the image display, the I/I may perform enhancements, rectification, or restoration processing functions. The I/I may re-route frames to the screener for reevaluation (just as in the mission mode).

Sensor Characteristics

The Data Handling Recording System (DHRS) will necessarily accept the required sensor data types and format this data for real-time processing and/or storage. Initially, the DHRS will accept image data from the recorders of Pave TACK FLIR and AN/AAD-5 data in analog form. The preliminary data will be stored in video form on a standard video cassette recorder for the FLIR and in analog form on the RCA Advisor-62 VTR for the AN/AAD-5. Future data types include Second Generation FLIR, downward looking IR (DLIR), and ESSWACS sensor data. The acceptance of these varied sensor data types reflects the need for a flexible, reconfigurable architecture such that the same hardware may be used for most of the conditioning functions.

The current sensors impacting the design of the SIM include:
1. AN/AAQ-9 Forward looking infared (FLIR) sensors
2. AN/AAD-5 Downward looking infared (DLIR) sensors
3. Electronic Solid State Wide Angle Camera System (ESSWACS)
   Downward looking Visible sensor

Each of the sensor types and their particular characteristics are discussed in the following paragraphs. A description of the implementation method for the ingest of each sensor data type is provided in Paragraph 4.1 of the Technical Proposal.

1. AN/AAQ-9 PAVE TACK FLIR

The FLIR sensor is an analog TV compatible sensor which is sensitive in the 8 - 14 micron spectral band (i.e., passive infrared). The data is in the form of conventional video, presented at 60 fields/second interlaced to give 30 frames/second. The FLIR data is available in either 525 line or 875 line resolution. The required bandwidth of the current FLIR sensor is determined by the IR detector resolution. The actual required data rate, however, is determined by the number of successive frames of video data which must be examined to perform the auto cueing/autodetection of targets. Current detector resolution and sensor operation mode indicate a maximum effective data rate of up to 28.8 megasamples/sec. This can be reduced further by examining the actual required scene "update" rate.

The data format for the conventional video form of the FLIR sensor is shown in Figure 3. The sensor characteristics (i.e., resolution, field of view, data rates, and frame sizes) are shown in Table 1.

Also available on separate channels will be the positional information derived from the ARN-101 system or the LORAN-D time difference information which can be used to determine geographical location of targets. The ability to convert and display the geographical location of targets will exist as part of the System Control Module (SCM) Software.

2. AN/AAD-5 DLIR

The DLIR AN/AAD-5 is a high resolution down-looking IR sensor whose bandwidth is controlled by the aircraft V/H ratio. The sensor consists of 12 paralleled, overlapping channels, each with a bandwidth of 1.2 Megahertz (MHz). The channels are utilized in such a manner that as the V/H factor increases, additional channels are engaged to assure overlapping coverage of the ground swath. Thus, with all 12 channels providing data in parallel, the equivalent bandwidth is 18 MHz. This dictates a Nyquist sampling rate of 36 megasamples/sec. However, the method with which the multiple channels are time multiplexed for recording on the RCA Advisor 62A tape recorder reduces the actual bandwidth of each channel to 1.0 Megahertz. This reduction in channel bandwidth results in the reduction of the required sample rates.
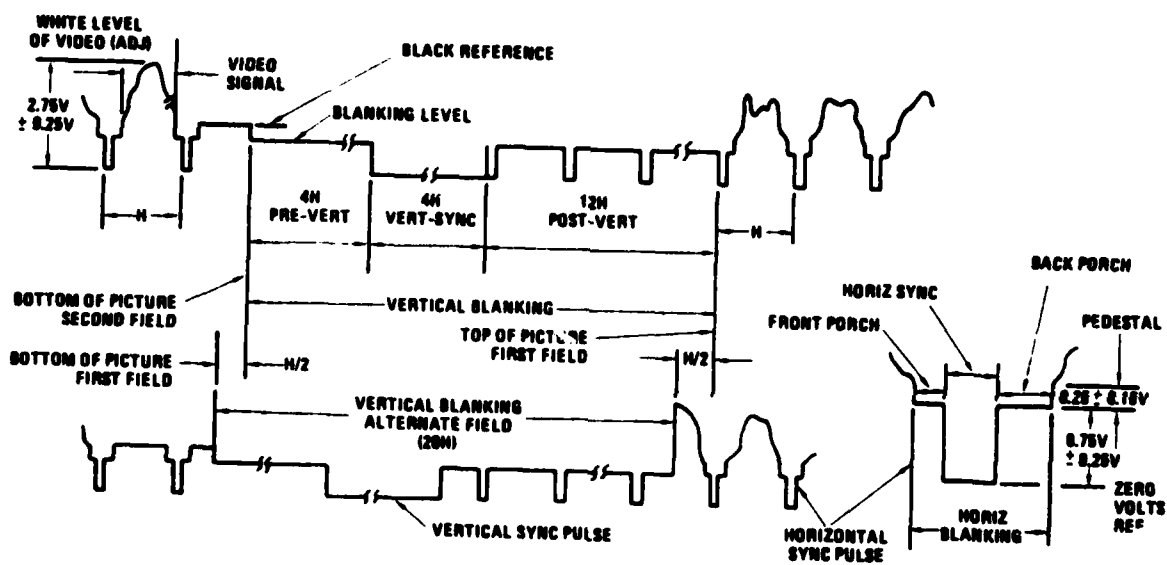
Figure 3. FLIR Composite Waveform

Table 1. FLIR Data Rate Characteristics

SENSOR TYPE	ACTIVE LINES PER FRAME	LINE SCAN TIME (10^{-6} SEC)	MONITOR BANDWIDTH (MHz)	PIXELS/ LINE AT NYQUIST	PIXELS/ LINE GIVEN	MAXIMUM SAMPLE RATE FOR PIXELS GIVEN (10^6 SAMPLES/SEC)	PIXELS PER TRANSFER	SYNC BITS/LINE	TRANSFERS PER SECOND TO TAPE (10^6)	SENSOR BANDWIDTH AT GIVEN SAMPLE RATE AT NYQUIST (MHz)
875	809	TOTAL 38.09 ACTIVE 31.09	17.2	1069	896	28.82	4-6 BIT PIXELS	96 BITS (4 WORDS)	3.91 *	14.41
525	480	TOTAL 63.50 ACTIVE 51.00	4.5	477	512	9.66	4-6 BIT PIXELS	432 BITS (18 WORDS)	2.299 *	4.83
							3-6 BIT PIXELS		2.986	4.81

* CALCULATION OF TRANSFERS/SECOND TO TAPE: $\dfrac{\left(\dfrac{\text{(No. pixels/Line)}}{\text{No. of pixels/Transfer}}\right) + \text{(No. sync words/line)}}{\text{TOTAL LINE SCAN TIME}}$

14

Six channels of the AN/AAD-5 are recorded sequentially on the recorder. Channels 4,5,6,7,8, and 9 are recorded with the format shown in Figure 4.

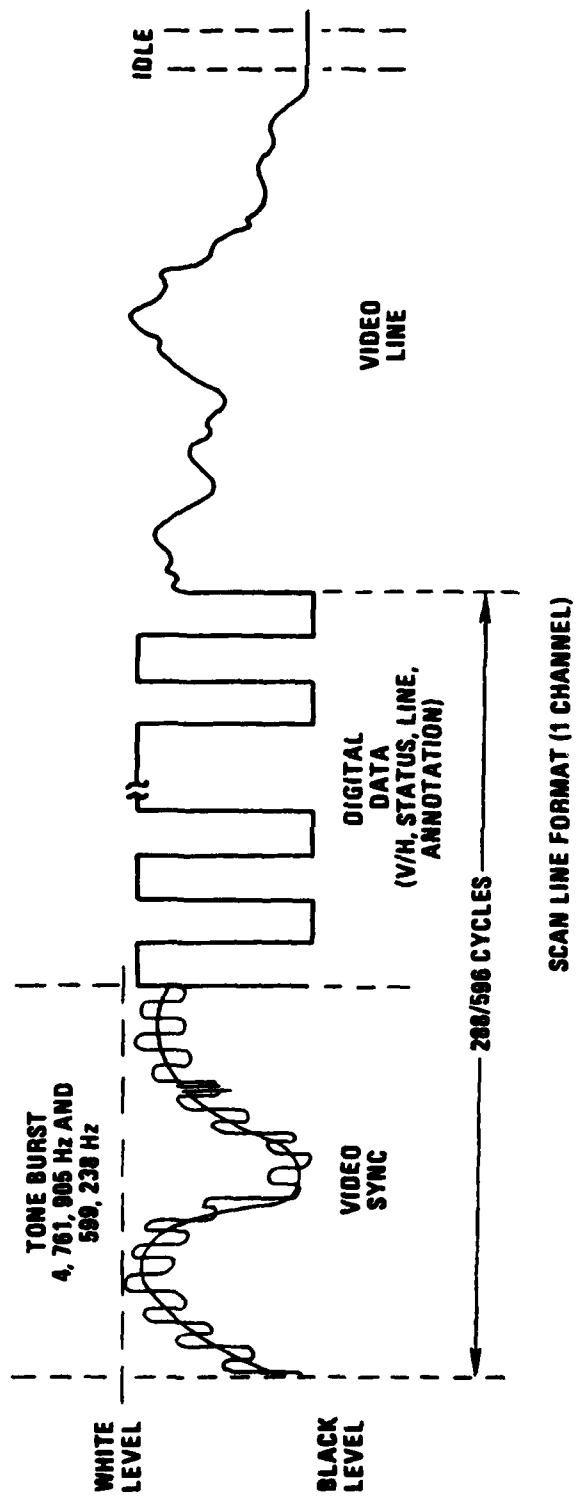THE NOMINAL* DLIR TIMING CHARACTERISTICS ARE AS FOLLOWS:

MODE	LINE RATE LINES/SEC	PERIOD* SEC	TONE SEC	DATA SEC	VIDEO SEC	IDLE* SEC
WFOV	2400	416.66	26.88	33.6	350.0	6.19
NFOV	1200	833.33	53.76	62.7	700.0	12.37

* CHANGES WITH ROLL

The tone burst is 4,761,905 HZ ± 5 PPM. A second tone, equal in amplitude, exists at 595,238 Hz. The digital data is in NRZ format. The first word in channel 4 is a 13 bit barker code (if inverted it means that the next word of the ADAS is the first in the block). ADAS will occur over approx 4 scans. The ADAS is comprised of ninety-six (96) six bit words for a total of 576 bits. Each word consists of one identification bit in the first position, four data bits coded in excess three binary coded decimal plus one parity bit. The data matrix coding is specified in specification MIL-STD-820, and is shown in Figure 5.

Three types of rectification will be provided by the SIM for the AN/AAD-5 sensor data. These include:

1. Pixel skew - The adjacent channels of the AN/AAD-5 sensor are off set and will be realigned in the SIM by regeneration of line sync.

2. V/H Overlap - At V/H crossover points (i.e., when addition of channels are enabled) complete overlap of terrain coverage exists. The V/H values will be read and a determination made in real time to keep all data or to drop alternate lines to avoid processing redundant data.

3. Crosstrack geometric warp - The geometric distortion introduced by the AN/AAD-5 crosstrack scan is shown in Figure 6. This distortion will be corrected using look-up table techniques implemented in the format generator of the SIM. Given a particular pixel, and the aircraft roll angle the associated correction factor is addressed in the look-up table. The values loaded into the look-up table are calculated during pre-mission configuration and down-loaded to the SIM for the particular sensor type.

15

Figure 4. AN/AAD-5 Scan Line Format (1 Channel)

16

MAJOR COLUMN Z

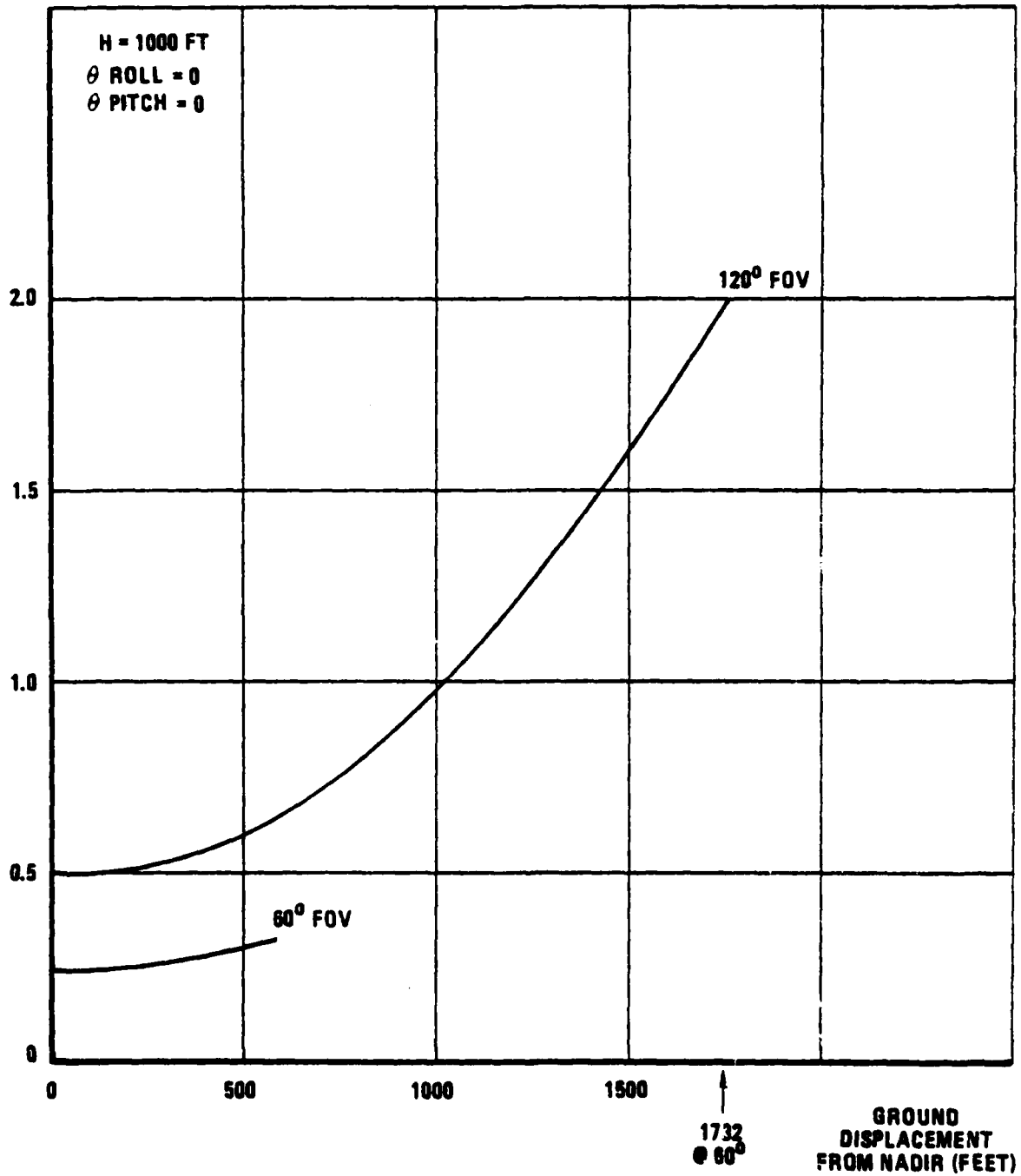| C	P	1	2	4	8	I		
	●	●	●	●	●	●	1	
UNITS DAY						●	2	
TENS OF DAY						●	3	
UNITS MONTH						●	4	DATE
TENS OF MONTH						●	5	
UNITS YEAR						●	6	
TENS OF YEAR						●	7	
●	●	●	●	●		●	8	
UNITS (DETACH)						●	9	
TENS (DETACH)						●	10	
UNITS (SQUAD)						●	11	TAKING UNIT
TENS(SQUAD)						●	12	
HUNDREDS (SQUAD)						●	13	
THOUSANDS (SQUAD)						●	14	
●	●	●	●	●		●	15	
UNITS						●	16	
TENS						●	17	
HUNDREDS						●	18	
THOUSANDS						●	19	
●	●	●	●	●		●	20	
UNITS						●	21	
TENS						●	22	
HUNDREDS						●	23	
●	●	●	●	●		●	24	
UNITS						●	25	
●	●	●	●			●	26	
V/H						●	27	
FOV						●	28	ELRAC
●	●	●	●	●		●	29	
						●	30	
						●	31	
●	●	●	●	●		●	32	

SLAR SENSOR SORTIE OR MODE IDENT PROJECT NO.

MAJOR COLUMN Y

P	1	2	4	8	I		
●	●	●	●	●	●	1	
UNITS					●	2	
TENS					●	3	
HUNDREDS					●	4	BAROMETRIC ALTITUDE (FT)
THOUSANDS					●	5	
TENS OF THOUSANDS					●	6	
●	●	●	●	●	●	7	
TENTHS OF DEGREES					●	8	
UNITS OF DEGREES					●	9	
TENS OF DEGREES					●	10	HEADING
HUNDREDS OF DEGREES					●	11	
●	●	●	●	●	●	12	
SIGN, + OR-					●	13	
TENTHS OF DEGREES					●	14	DRIFT
UNITS OF DEGREES					●	15	
TENS OF DEGREES					●	16	
●	●	●	●	●	●	17	
SIGN, + OR -					●	18	
TENTHS OF DEGREES					●	19	ROLL
UNITS OF DEGREES					●	20	
TENS OF DEGREES					●	21	
●	●	●	●	●	●	22	
SIGN, + OR -					●	23	
TENTHS OF DEGREES					●	24	PITCH
UNITS OF DEGREES					●	25	
TENS OF DEGREES					●	26	
●	●	●	●	●	●	27	
					●	28	
					●	29	ELRAC
					●	30	
					●	31	
●	●	●	●	●	●	32	

MAJOR COLUMN X

P	1	2	4	8	I			A
●	●	●	●	●	●	1		
TENTHS OF SECONDS					●	2		
UNIT SECONDS					●	3		
TENS OF SECONDS					●	4	TIME (GMT)	
UNIT MINUTES					●	5		
TENS OF MINUTES					●	6		
UNIT HOURS					●	7		
TENS OF HOURS					●	8		
●	●	●	●	●	●	9		
SIGN, + OR -					●	10		
TENTHS OF MINUTES					●	11	LATITUDE	
UNIT MINUTES					●	12		
TENS OF MINUTES					●	13		
UNIT DEGREES					●	14		
TENS OF DEGREES					●	15		
●	●	●	●	●	●	16		
SIGN, + OR -					●	17		
TENTHS OF MINUTES					●	18		
UNIT MINUTES					●	19	LONGITUDE	
TENS OF MINUTES					●	20		
UNIT DEGREES					●	21		
TENS OF DEGREES					●	22		
HUNDREDS OF DEGREES					●	23		
●	●	●	●	●	●	24		
UNITS					●	25		
TENS					●	26	RADAR ALTITUDE (FT)	
HUNDREDS					●	27		
THOUSANDS					●	28		
TENS OF THOUSANDS					●	29		
●	●	●	●	●	●	30		
UNITS					●	31	B/N MODE ALTITUDE (FT)	
●	●	●	●	●	●	32		

C — 0.534" ± 0.060 — D

0.018" ± 0.003(TYP)   0.036" ± 0.006(TYP)   B

0.331 IN. ± 0.037

P90431-80

Figure 5. ADAS Binary Data Block

17

CELL SPACING ON GROUND (FEET)

Figure 6.   AN/AAC-5 DLIR Sensor Image Distortion Characteristics

18

The DLIR AN/AAD-5 sensor data rate characteristics are summarized in Table 2.

3. Electronic Solid State Wide Angle Camera System (ESSWACS)

The airborne sensor employs 140 degree ground swath. Resolution from 1000 feet in a push broom mode is 0.75 foot. This corresponds to 5210 feet of ground coverage with a ground resolution of 1.5 ft/1p when flying at an altitude of 1000 feet and at 480 knots (Mach 0.8). Data from the five arrays and synchronization, V/H and roll data are multiplexed into a single data line for airborne storage or direct transmission to the ground. To achieve the desired resolution, 8640 elements (five 1728 element arrays) are used. These arrays are read at a 10.5 megasamples/second (MS/s) rate corresponding to a 1081 scan/sec line rate. The data from the five arrays is time division multiplexed to a common data line by array block; synchronization information and V/H and roll data are interleaved in the data stream as shown in Figure 7.
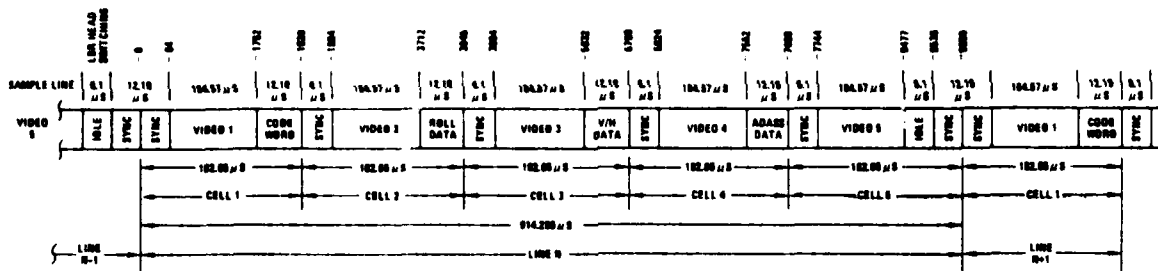
Figure 7. Composite Video Signal

The ground coverage of the ESSWACS sensor is provided as shown in Figure 8.
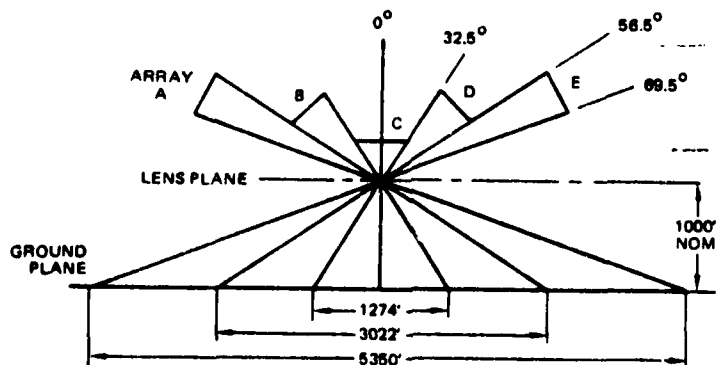
Figure 8. System Coverage

19

Table 2. DLIR Sensor Characteristics

Information Provided With
Technical Proposal

20

The tilted lens system of Figure 8 introduces the image distortion shown in Figure 9.
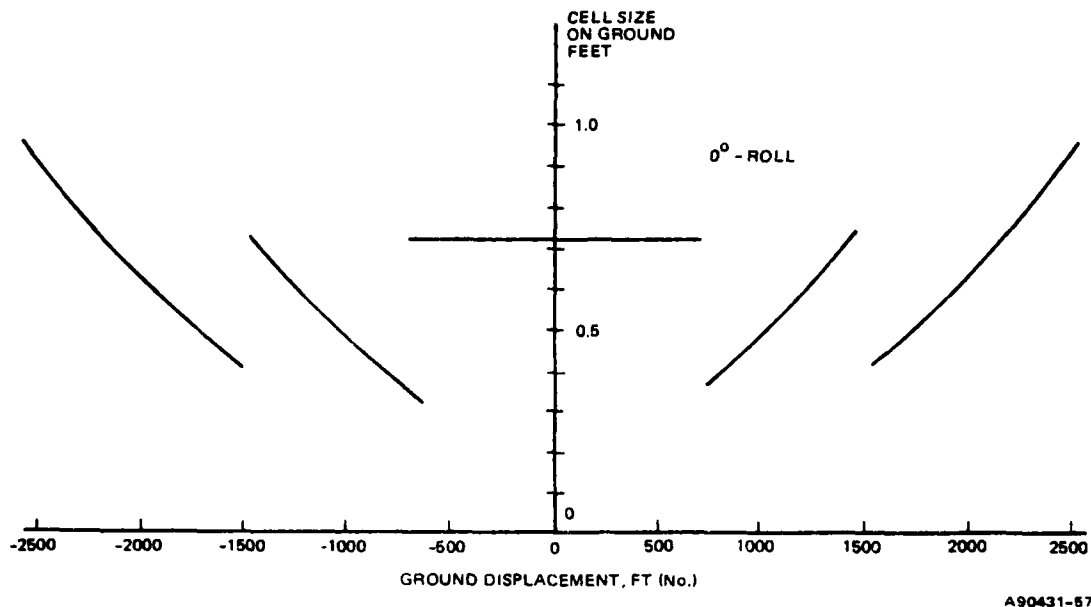
Figure 9. Image Distortion Characteristics

To provide a configuration easily modified to accept future data, additional sensors have been investigated. These include:

1. Long Range Electro-Optical Reconnaissance System (LOREORS) - Another sensor which might be considered is the Long Range Electro-Optical Reconnaissance System, a single-frame visible scanner. This sensor, like the ESSWACS sensor, utilizes multiple integrated CCD arrays. Eighteen 64 x 1024 CCD arrays provide an 18,432 pixel/line x 13,563 line/frame image at a 10 second/frame rate. The LOREORS sensor was not identified in the SOW but has been considered in the definition of the system configuration to provide maximum system flexibility.

2. Future FLIR sensors - These improved sensors will encompass improved performance over the current FLIR sensors, but should not impact the SIM configuration.

3. Future Downward Looking Infrared (DLIR) - Future DLIR sensors will likely be IR versions of the ESSWACS (visible) sensor. The ESSWACS sensor is a down looking, push broom-type charge-coupled device (CCD) sensor composed of five 1728 element arrays which are read at a 10.5 Megasamples/second rate.

21

System Throughput Delay Considerations

The maximum tolerable time delay associated with DHRS-assisted image exploitation is specified as 10 minutes, with a design goal of 5 minutes.

For the purposes of this discussion, DHRS throughput delay is defined so as to exclude the time required by the human operator, i.e., the I/I, to evaluate/verify/correct or otherwise exploit the displayed imagery. Our real concern here is only with the delay associated with the DHRS hardware and software. For missions containing many target frames it is expected that the overall exploitation delay using the Harris/WEC baseline will be due almost wholly to the human operator.

It is readily established that time delay associated with the data recording and playback function of the SRM is the dominant machine-related contributor to DHRS throughput delay for the Harris/WEC baseline. This is because of the poor random-access time of the only viable storage medium, magnetic tape. (Magnetic tape is the only medium that can cost-effectively meet the 10^{12} storage requirement and the 5-minute frame retrieval design goal.) The impact of using image compression upon system throughput delay is briefly discussed in this subsection. The relationship between mission length and random frame retrieval time is illustrated and the effect of nonreal-time screening upon system throughput delay is then described. Note that the WEC screener is a real-time machine.

Simple calculations show that the image throughput delays associated in the SIM, RTPM, and NRTEM are all well under two seconds for either FLIR or DLIR imagery; thus, only the considerably longer delay associated with the S/RM will be considered further.

Recall that in the assumed typical mission scenario the sensor visits four target sites. At each target site the pilot turns on the sensor somewhat prior to encountering the target and turns off the sensor sometime just after leaving the target. The four-target mission scenario will yield a mission data record with target information located as shown in Figure 10.

22

TARGET
SITES

NO. 1   NO. 2 NO. 3   NO. 4   RECORD

T_M

NO. 4   NO. 3   NO. 2   NO. 1
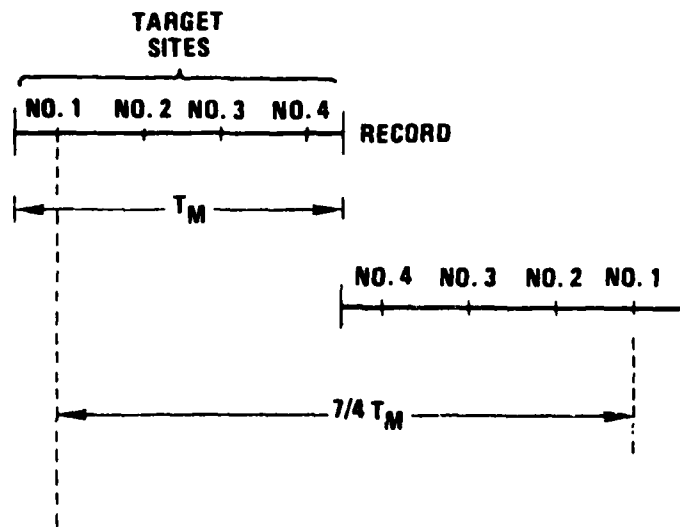
7/4 T_M

T_M = MISSION DATA RECORD DURATION
T_G = 5 MINUTES

GOAL:

$T_G = 7/4\ T_M \Rightarrow T_M = 4/7\ T_G \doteq 2.85$ MINUTES

A90431-81

Figure 10.   Permissible Mission Length for Meeting Throughput Delay Design Goal

23

Recall that the target frames are assumed to be located at the center of each 30 second segment of the mission data. The computations in the figure show that the design goal specification of 5 minutes for throughput delay between ingest of the first target frame and display of at first target frame can be met for mission lengths of 2.85 minutes. Recall that the assumed mission length is two minutes. It should be pointed out that the permissible mission lengths increase significantly if throughput delay is interpreted as being the interval between ingest of the first target frame and the first display of any target frame. This latter interpretation seems to be more reasonable.

Image Data Compression Impacts

Compression of the input imagery data will impact several constraints of the Data Handling and Recording System (DHRS). Among these are:

1. Mass Storage Capacity
2. Mass Storage Access Latency
3. Mass Storage Spooling Rates
4. Sub Frame Address Generation

Entropy reducing techniques introduce significant image degradation to achieve increased compression.

Entropy-preserving techniques produce variable length codes, which necessitate variable data rates, huge buffers, or variable file size for image storage.

Image compression is only feasible for reduction of the required mass storage capacity. Clearly, the random access of compressed data from the high-speed store is not practical since each access would require a "back-track" through memory to facilitate decoding. The use of entropy-preserving codes would compound the problem since the exact memory location of each pixel value is indeterminate. The necessity to channelize the processor pipeline to facilitate growth potential and flexibility eliminates any compression technique which utilizes an "intelligent" search of the high-speed store.

24

The variable record length creates software problems in retrieval of a requested file, since exact location of any particular file is indeterminate. This indeterminancy means that meeting the 5 minute random frame retrieval goal could not be guaranteed. In the front end, access times are critical and an extensive record search would violate data retrieval time constraints. The records must be easily located, requiring constant record length and simple file search algorithms.

After thoroughly investigating several techniques from each of the two compression categories and evaluating the constraints necessarily dictated by the implementation of each, it was decided that conventional data compression schemes seriously impact hardware and software management of the S/RM. The attainable compression ratios do not significantly reduce the total on-line capacity of the S/RM and do significantly impact access/retrieval timelines and the software data base management problem. Therefore, image bandwidth compression is inappropriate for DHRS.

The Throughput Delay Impact of a Single-Pass DHRS Approach Using a Nonreal-Time Classifier

A single-pass DHRS approach using a nonreal-time classifier requires ping pong recorders in the S/RM. In addition to the expense associated with the added recorder, there is a serious operational implication of using ping pong tape recorders with a one pass nonreal-time classifier approach. This problem is illustrated in Figure 11; it might be referred to as "ping pong runaway". The figure shows the time location and duration of the recording operation for each of the tapes, A and B. While one tape is recording the other tape is playing back images at reduced speed into the nonreal-time classifier. The figure reflects the following two assumptions:

(1) no "fast" rewind exists for the very high speed tape recorders required in DHRS -- must rewind at normal speed.

(2) the target classifier operates at one-half real time, i.e., it takes the target classifier two seconds to operate on one seconds' worth of real-time data.
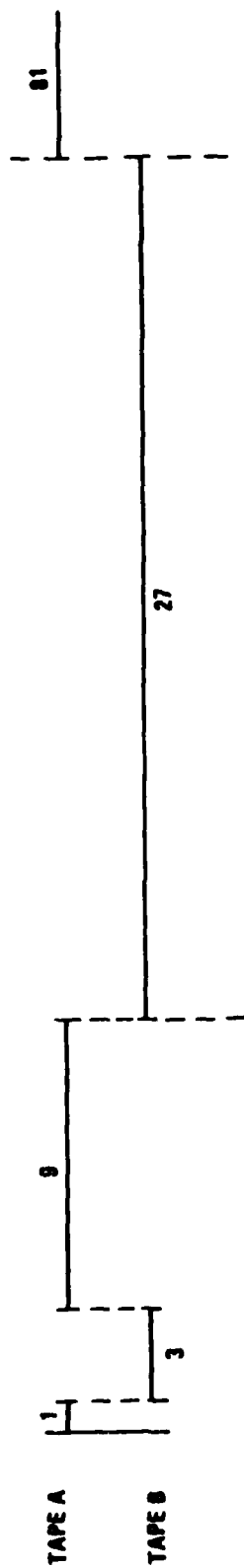
Figure 11. Tape Recording Ping Pong Sequence

Referring to the tabulated record times for each recorder in Figure 11 it may be concluded that the record and playback time intervals increase exponentially, and that for relatively long missions the nonreal-time exploitation delay goal of five minutes is unattainable. The problem is worse for slower classifiers.

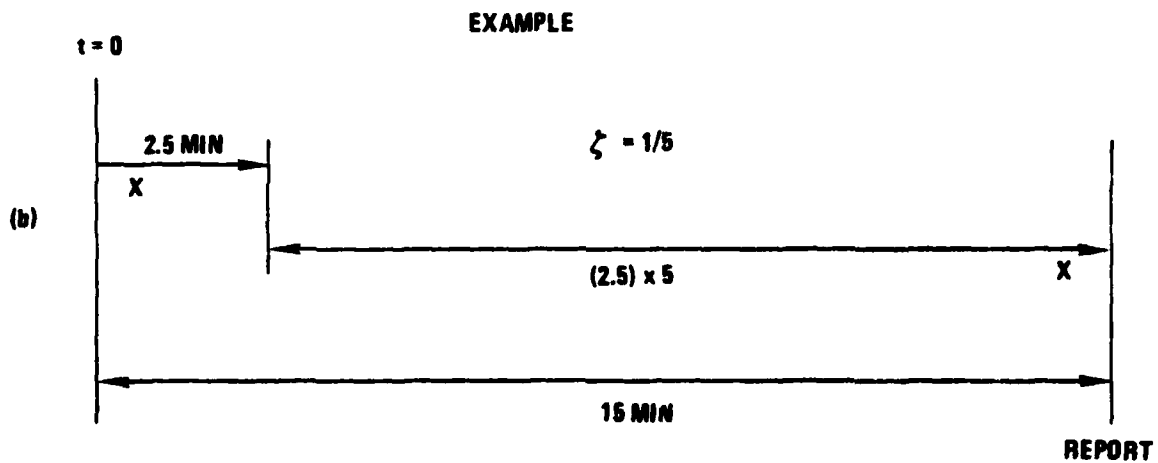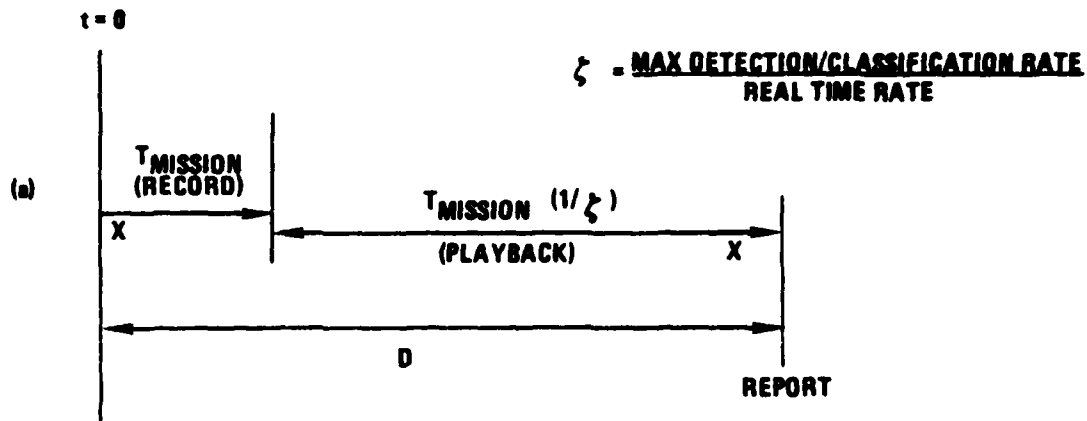### The Disadvantage of a Two-Pass DHRS Approach Using a Nonreal-Time Classifier

The Harris/WEC baseline DHRS is a two-pass approach using a <u>real-time</u> classifier on the imagery data during the <u>first</u> pass. A nonreal-time classifier requires that the image data be simply recorded on the first pass and then played back at a slower rate into the nonreal-time classifier during the second pass. Since no fast rewind capability is available on the very high speed tape recorders, the images are played back backwards in the second pass to save time. The disadvantage of using a nonreal-time classifier in a two pass approach is illustrated in Figure 12. In the figure the "x" corresponds to the first target encountered during the mission. The $(1/\zeta)$ in the figure is the expansion factor associated with the reduced-speed playback into the classifier, where

$$\zeta = \frac{\text{maximum detection/classification rate}}{\text{real time rate}}$$

The specific example shown in Figure 12 illustrates the case of a 2.5 minute mission duration and a 5:1 expansion factor; the result is that there is a 15 minute delay to exploit the first target frame. Figure 13 shows exploitation delay versus mission length with ζ as a parameter. This figure shows that even for $\zeta = 1/2$ the exploitation delay exceeds the 5 minute design goal if mission length exceeds 2 minutes.

System FAR Impact Upon Throughput Delay

A system false alarm occurs when an image frame not containing a target is automatically displayed to the I/I. This can only occur if the target screener within the RTPM false alarms and the RTPM erroneously reports to the NRTEM that a target exists within a frame that contains no targets.
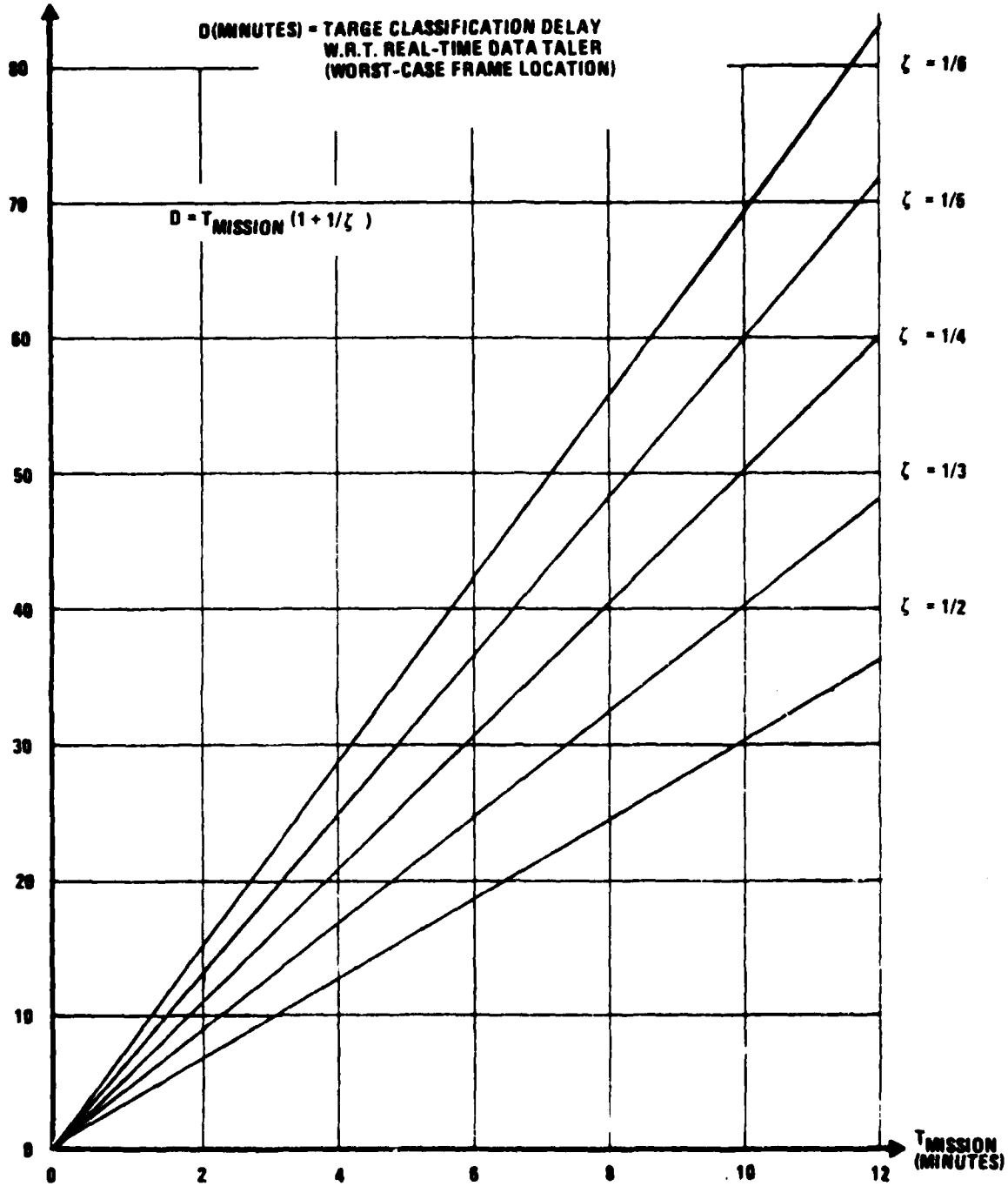
Figure 12. Nonreal-Time Target Detection/Classification Approach

28

Figure 13. Target Classification Delay WRT Real-Time Data Rate
(Worst Case Frame Location)

29

The false alarm rate (FAR) is a very important system parameter since the system throughput delay can be seriously degraded if the FAR is sufficiently high. In order to derive the maximum tolerable FAR for the RTPM two assumptions are required regarding:

(1) False alarm dismissal time – the time required for the image interpreter to dismiss a displayed image that does not contain a target.

(2) The total time allocated per mission for the operator to dismiss false alarms.

The maximum tolerable FAR may then be determined as follows:

$$\text{FAR} = \frac{\text{total time allocated for dismissing false alarms}}{(\text{total number of frames})(\text{false alarm dismissal time per frame})}$$

Human Operator Throughput Delay

The amount of time the image interpreter devotes to a displayed target frame depends upon many factors:

(1) Number of targets
(2) Size of targets
(3) Distribution of target types
(4) Number of misclassified, unclassified or undetected targets in the frame
(5) Quality of target images: SNR, contrast ratio, thermal noise, time-of-day, sun-angle, local weather at time-of-mission
(6) Skill of image interpreter
(7) Urgency of mission
(8) Prior knowledge regarding geography, expected targets, etc.

In view of the large number of factors affecting the required display time of an image it is difficult to estimate it; only experience gained from operation of the DHPS with typical input tapes will be useful in predicting the system throughput delay due to the human operator (I/I).

30

3.5   Target Detection and Classification Performance Considerations

In this subsection a discussion of the performance of the Westinghouse
AUTO-Q system in relation to such key parameters as video signal-to-noise ratio,
target size in resolution elements, and system sensitivity threshold is
presented. This performance evaluation is facilitated by a comparison of the
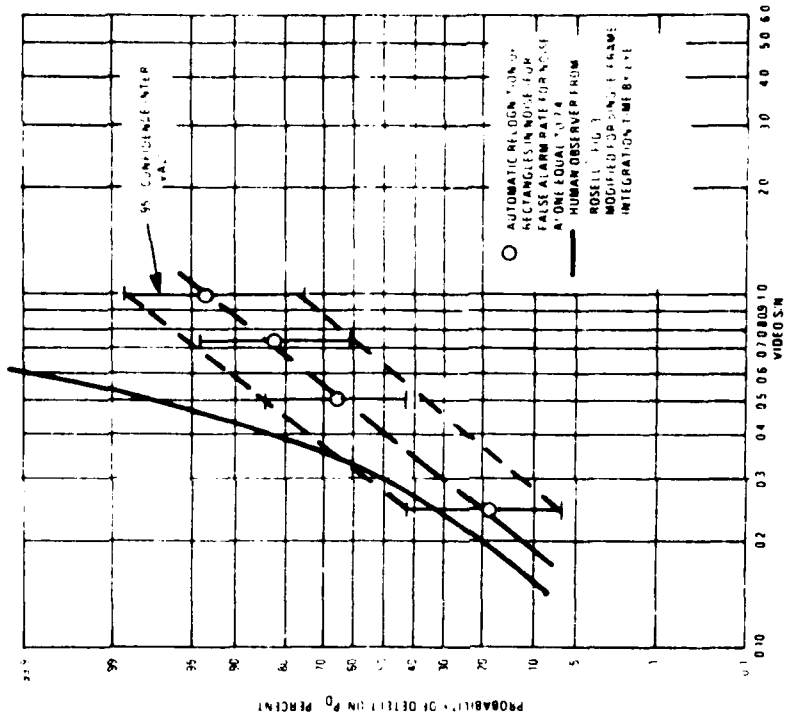AUTO-Q performance with human detection performance.

A comparison of human and machine recognition of rectangles imbedded in
noisy backgrounds as a function of video SNR has been conducted. The test images
are shown in Figure 14(a). Nine rectangles are shown here, each of which must be
recognized by shape, and discriminated from the noise background. The human is
presented with an analogous situation, presented by a TV display, as described in
the reference. A comparison of AUTO-Q and human performance for this test is
shown by Figure 14(b).

At the low signal-to-noise values, the machine performance approaches
human performance within the 95 percent confidence intervals of the experiment.
Such high noise conditions are probably typical of much FLIR Imagery.
Furthermore, the human performance measured in the laboratory can be expected to
deteriorate in an aircraft cockpit. Thus, one can reasonably argue that
recognition machines can compete favorably with humans under difficult conditions.

For signal-to-noise ratios above 0.9, the probability of detection for
the rectangle exceeds 90 percent. Thus, the performance requirements of the SOW
can be met if an adequate signal-to-noise ratio exists.

Every recognition system offers a tradeoff between detection
probability and false alarm rate, as determined by a detection threshold, For the
same test data used in obtaining Figure 14(b) these tradeoffs are shown as a
function of signal-to-noise ratio in Figure 15. Note that with a threshold of 17
or greater, and a zero false alarm rate, the detection probability approaches 89
percent for very high S/N. On the other hand, with a threshold of 6 or greater,
and a 7.4 percent false alarm rate, the detection probability approaches 100
percent. Clearly, high detection (or recognition) probabilities can be associated
most readily with low false alarm rates when the signal-to-noise ratios are high.

Detection of Rectangles by Auto-Q

Machine Recognition of Rectangles

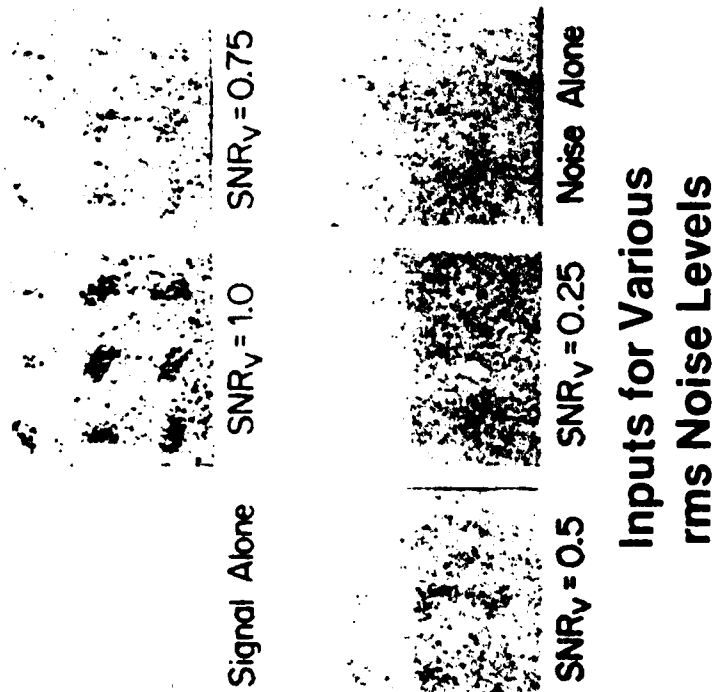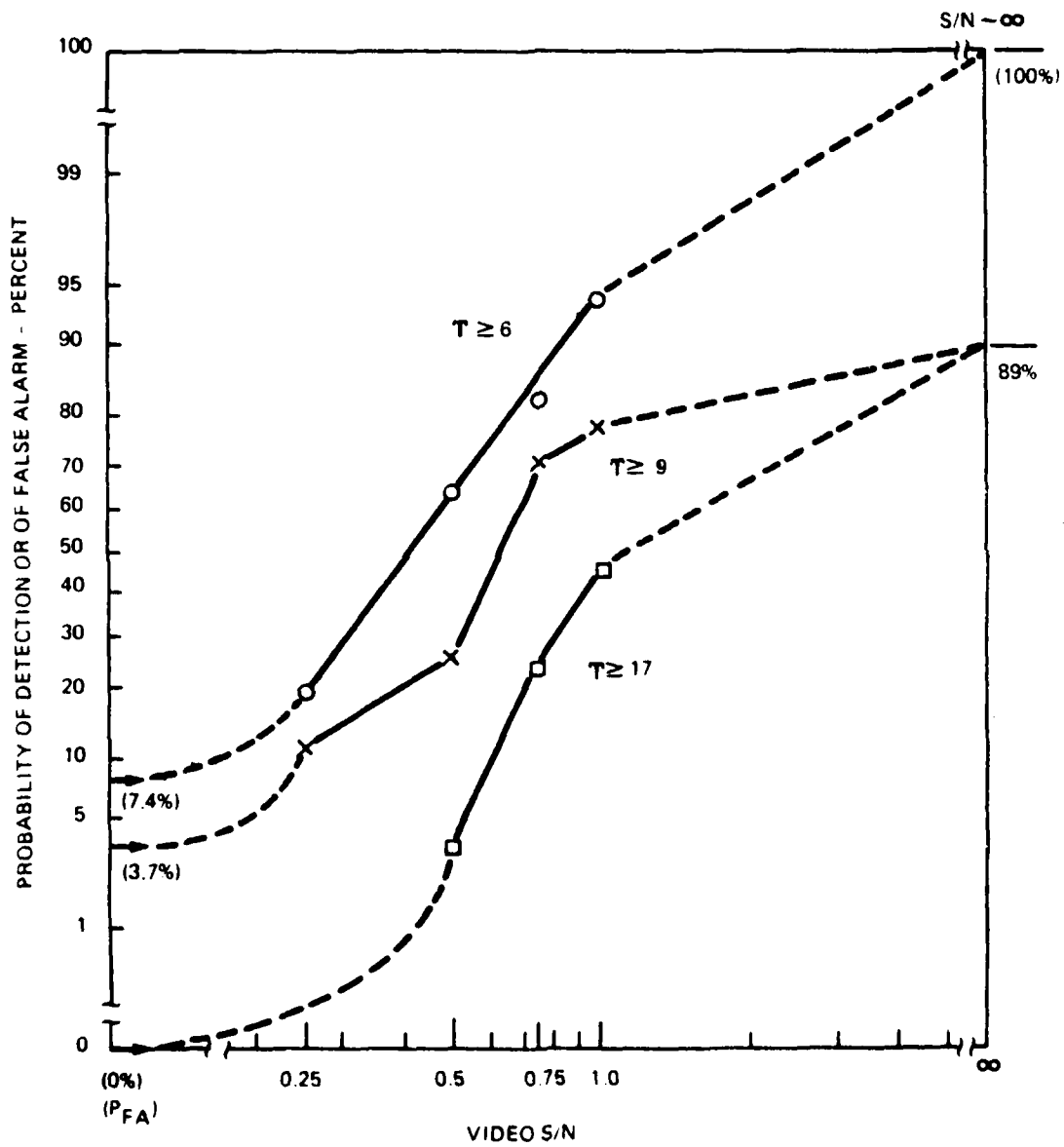79-0345 V 14

Signal Alone $SNR_v = 1.0$ $SNR_v = 0.75$ Noise Alone

$SNR_v = 0.5$ $SNR_v = 0.25$

Inputs for Various rms Noise Levels

Figure 14.   Detection of Rectangles by AUTO-Q

Figure 15. Effect of Detection Threshold on Performance

79-0345-V-47

33

It is well known that recognition performance depends on the target size in resolution elements. A variety of experience on this subject is summarized in Figure 16. The well-known Johnson criteria for human detection, recognition, and identification at the 50 percent probability level are shown, together with human experience with various military targets. In addition, curves for detection, acquisition, and classification have been added from the AUTO-Q test data from the Army programs. Acquisition is defined by the screening of detected target samples by size and shape so as to improve the probability of their inclusion in the full set of target classes. Both the acquisition and classification probabilities relate to the original number of test samples involved; the values would be higher if they related instead to the number of samples detected. In any case, it is apparent that the 90 percent probability will be reached for detection, and 80 percent probability for classification as image resolution is increased.
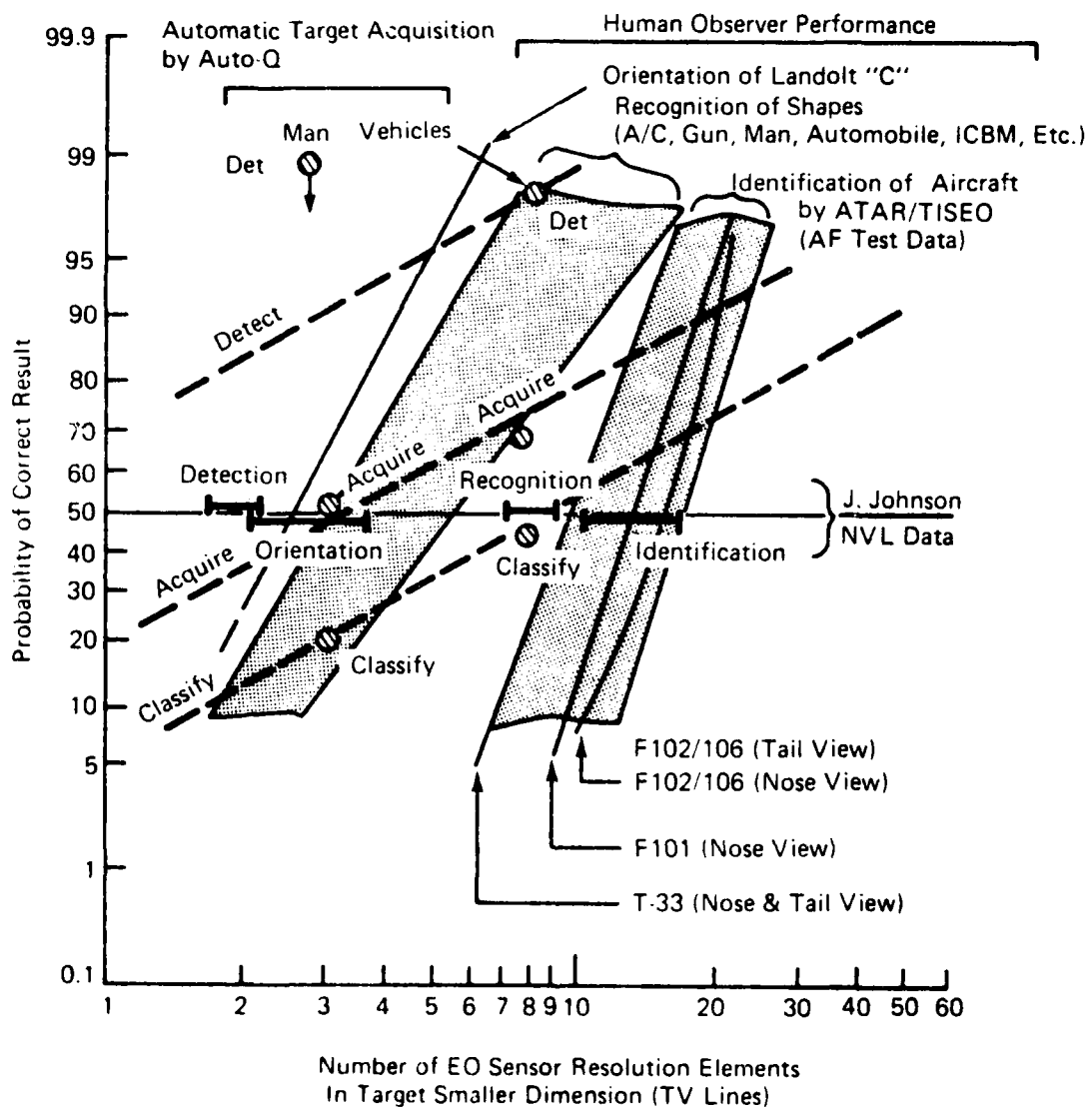
A final comparison is made in Figure 17 between AUTO-Q performance on the synthetic imagery of Figure 14 and on the real FLIR imagery of Figure 16 for three levels of system sensitivity. The similarity between these curves suggests that the WEC understanding of AUTO-Q performance is valid.

From the foregoing discussion it may be concluded that the design goals of the SOW can be met under favorable conditions of signal-to-noise ratio, sensitivity threshold, and target size in resolution elements. Further discussion on each of the detailed requirements now follows.

The WEC AUTO-Q will offer specified performance in target detection, classification, and misclassification. The WEC response to each of the performance guidelines is as follows:
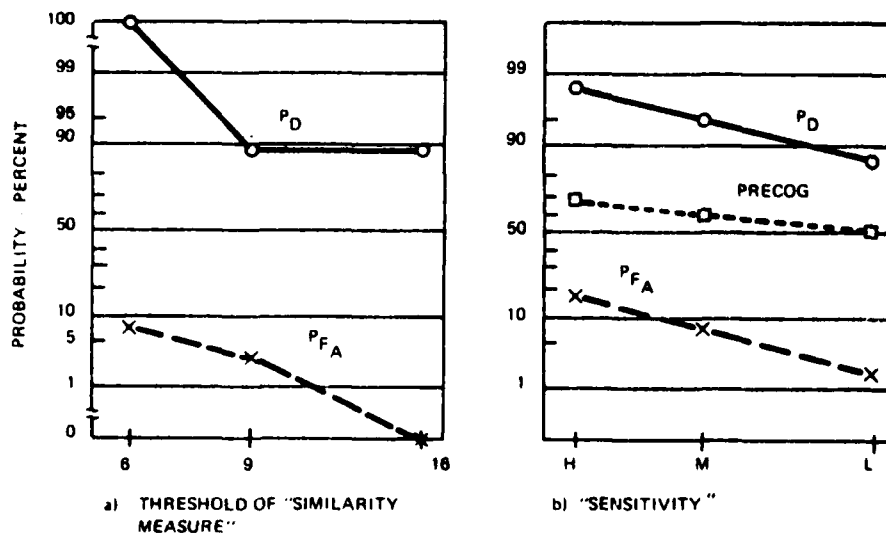
    a.   Use of Range Data or Other Aids
        Westinghouse has completed statistical performance tests of
        autoscreening on FLIR imagery both with and without the
        availability of range information. In the laboratory breadboard
        systems described elsewhere, the use of the range information is an
        option. In the following discussion it will be assumed that range
        information is not available.

Figure 16. Comparison of AUTO-Q Performance to Human Observer

35

PROBABILITY PERCENT

100

99

95
90

50

10
5

1

0

P_D

P_{F_A}

6   9   16

a) THRESHOLD OF "SIMILARITY
   MEASURE"

99

90

50

10

1

P_D

PRECOG

P_{F_A}

H   M   L

b) "SENSITIVITY"

79-0345-V-46

Figure 17. Comparison of AUTO-Q Performance on Synthetic Imagery
and Real FLIR Imagery

b. __Target Detection__

Detection of targets with the AUTO-Q system has consistently exceeded 90 percent. Third generation improvements in our preprocessor (in gradient tracking and the addition of level slicing) will improve this figure. We have dealt with a wide variety of vehicular targets, including Russian and Chinese tanks and APC's. Our videotape data base exceeds 70 hours of recording on tactical scenes.

c. __Target Classification__

Westinghouse feels that the prospects for meeting the 80 percent design goal are good, based upon earlier performance and with the addition of the improvements to be discussed below. We note that for the statistical performance tests for the Army correct classification was in the range of 50 to 65 percent, with four target classes, and 40 to 70 percent, for three classes, respectively.

How will we make an improvement from the 60 percent range with four target classes to the 80 percent range with 8 classes? The answer lies with improved FLIR imagery, with improved processing techniques, and with improved decision logic. Imagery used for the Frankford Arsenal tests was obtained by making 16-mm films of the AN/AAQ-5 display. The resulting imagery was heavily degraded in both resolution and available gray scale range. Imagery used for the NVL tests was affected enough by processing artifacts (noise and ripple) to reduce the corresponding human performance to about 50 percent. In this test it was found that machine performance slightly exceeded the human performance for the same data set. Therefore, if the data set permits 80 percent human response, we expect AUTO-Q to exceed this value.

Recent hardware developments provide an all-digital system, replacing an earlier analog scan converter in our original AUTO-Q breadboard. In addition, preprocessing operations have been improved at every stage.

Finally, we expect performance improvement associated with the classification logic. This will be obtained by an increased reliance on syntactical target descriptions. The AUTO-Q system is inherently syntactical in nature, but in earlier tests with low-quality imagery, application of this feature was limited.

For the larger targets, such as SAM sites, syntactical recognition techniques are particularly appropriate, as well as the use of context and textural clues.

d. <u>Misclassification and Nonclassification</u>
The specified misclassification design goal is 10 percent. Since the specified correct classification design goal is 80 percent, the permissible rate of nonclassification is 10 percent.

Nonclassification occurs when a defected target cannot be placed in any of the available target type classification categories; such targets must be classified by the human operator.

e. <u>Classification and Feature Measurement Modules for NRTEM</u> (SOW Paragraph 4.1.1.4.8)
AUTO-Q can provide the required feature measurements for such modules as an output from the RPTM if desired. Measurements such as shape, area, size, texture radiance, and reflectance are routinely obtained in vector form by AUTO-Q for use in classification of targets, or for discrimination between man-made and natural features.

<u>Computationally Intensive DHRS Functions</u>

Two of the required DHRS functions, rectification and target coordinate calculation, are computationally intensive and are therefore briefly discussed here.

1. LORAN (D) Navigation System
The LORAN (D) Navigation System is a highly accurate pulsed hyperbolic navigation system similar to and compatible with LORAN (C). It is designed for military tactical use. This discussion will explain the considerations of using LORAN with image systems where the LORAN data is imposed upon the frames of image data. First, a short discussion of conventional LORAN systems and receivers is presented. The LORAN System consists of master and slave transmitting stations each separated geographically. All of the stations transmit on precisely the same frequency (100 kHz) but they are skewed in time; i.e., the master transmits a burst, then Slave 1 transmit a burst, then Slave 2, etc. The user knows the exact location of the master and slaves. He also knows the exact time delay between the

master transmit time and each slave transmit time. The receiver measures the receive time difference between the master and each slave. This time difference remains constant as long as the receiver is not moving. The locus of points in which the difference is constant from 2 points (master and 1 slave) describes a hyperbola. To find the user location, the equipment measures 2 time differences thereby describing 2 hyperbolas and then intersects the curves. In the general case, there could be many intersections of two curves (each hyperbola has 2 distinct sections) but the geographic location of the master and slaves allows only 1 intersection over coastal waters.

The tasks that must be performed to derive position are listed below:

1. Determine which station is master (done by group repetition rate)
2. Determine which slaves are being received
3. Measure 2 time differences
4. Intersect hyperbolas
5. Translate time location to desired coordinates (UTM; lat/long; etc.)

One of the main problems arises with the measurement of the time differences. Noise corrupts the measurement of time in both the start and stop directions. To eliminate erroneous readings, conventional receivers use Kalman filters to average the time differences, eliminating the noise. A number of points taken in the average depend on the quality of the rejection of the 100 kHz receivers; the number and types of noise sources, the distance from the receivers, and other factors. The Coast Guard has put an upper limit of 20 minutes for lockout. This corresponds to approximately 12,000 sample time differences at worst case.

The image segment in the DHRS can vary from 30 seconds to 2 minutes; therefore, the number of samples ranges from 300 to 1200. If the samples are raw; i.e., not averaged, then just these samples alone would generally not be sufficient to eliminate the noise factor via Kalman filtering. If the receiver was the averaging type (i.e., ARN-101) and assuming it had been on for considerable length of time (5 min) then use of the last 300-1200 samples could be used to calculate position. The master and each slave would have to be identified with each time difference. Usually this is the case because the

interpreter knows what section of the world the image was taken in. To complicate matters, the image in question would be taken from a high speed aircraft. This means that not only time differences would have to be averaged but also bearing, velocity and altitude. The total number of sample points given with the image frames are not sufficient to average out the noise. These points must be averaged onboard the aircraft.

Calculating the intersection of the two hyperbolas and translating to correct coordinates is straightforward and should take about 20 milliseconds of CPU time (100K instructions at 250K instructions/sec) in the SCP.

Assuming that an onboard navigation system Kalman filters the required parameters, the CPU time to calculate the image position should be about 20 milliseconds. If the parameters are not filtered, then the data available (on the video tape) to the ground processing system is insufficient to calculate the position within any reasonable accuracy. This constraint should be included with any accuracy requirements in target location.

To improve location accuracy, eliminate the noise problem, and reduce calculation processing time, the DHRS could utilize the Global Positioning System (GPS) currently being implemented. The GPS will provide positional data by the time field deployable DHRS installations are a reality. Harris GCSD is actively involved in the GPS network development. The DHRS can be easily modified to accept and utilize GPS data as opposed to the less accurate LORAN (D) data.

2. Image Rectification

In this section image rectification is defined and the purpose of performing image rectification is discussed. The DLIR and FLIR image rectification geometry is described and the corresponding rectification algorithms are briefly discussed. A considerably more detailed treatment of the DLIR and FLIR rectification techniques is contained in Appendix 6.1.1 of the Technical Proposal.

40

When the image pixels from the Pave Tack FLIR or AN/AAD-5 DLIR sensors are displayed on a CRT without processing the displayed image does not exhibit uniform scale throughput the image. This is a result of the fact that sensor output samples that are uniformly spaced in time correspond to earth plane samples that are nonuniformly distributed in space. After rectification the displayed image exhibits uniform scale in both dimensions throughout the image.

In normal DHRS operation, FLIR rectification will not be employed; however, at the DHRS operator's option, image rectification can be performed on a FLIR image. DLIR imagery, on the other hand, is normally rectified in the SIM prior to storage, screening, or display. At the DHRS operator's option, DLIR imagery can be stored, screened, and stored in unrectified form.

2a. DLIR Image Rectification

The AN/AAD-5 DLIR sensor is a line-at-a-time, spinning mirror type, downward-looking sensor. Since the aircraft carrying the sensor is moving, the DLIR scan lines are not orthogonal to the ground track flight path. Moreover, since the sensor sampling is equiangular in nature over a flat earth, the pixel path in the earth plane is not a straight line but has a slight curvature. Figure 18 shows that the amount of curvature is so slight as to be completely negligible. Furthermore, the deviation from orthogonality between the flight path and the earth plane scan line pixel path is extremely small, viz.,
$\tan^{-1} \frac{0.835}{3461} = 0.138^{o}$ and may be neglected. Thus, along-track correction or rectification is not required at all.

The across-track or along-scan distortions are due to equiangular sampling of the DLIR sensor output and are not negligible. The size, shape, and along scan spacing of the DLIR earth plane pixels changes as a function of distance along scan. The nature and extent of these changes are summarized in Figure 19 for the particular case of H = 200', V/H = 5 and FOV = 120 . The 4:1 growth of pixel spacing from nadir to end-of-scan requires along scan rectification or remapping in order to maintain uniform scale in the displayed image. This rectification process is performed in the SIM in real-time prior to placing the DLIR data on the image ingest bus. Since the image ingest bus feeds both the RTPM and the S/RM, the DLIR images are stored in rectified form in the S/RM.
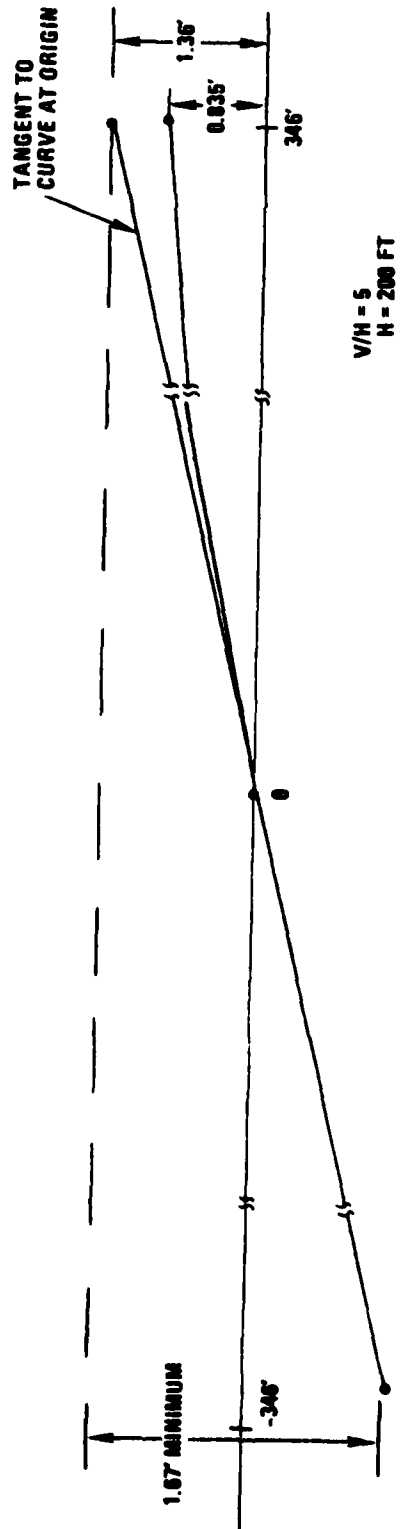
Figure 18. DLIR Along-Track Distortions

42
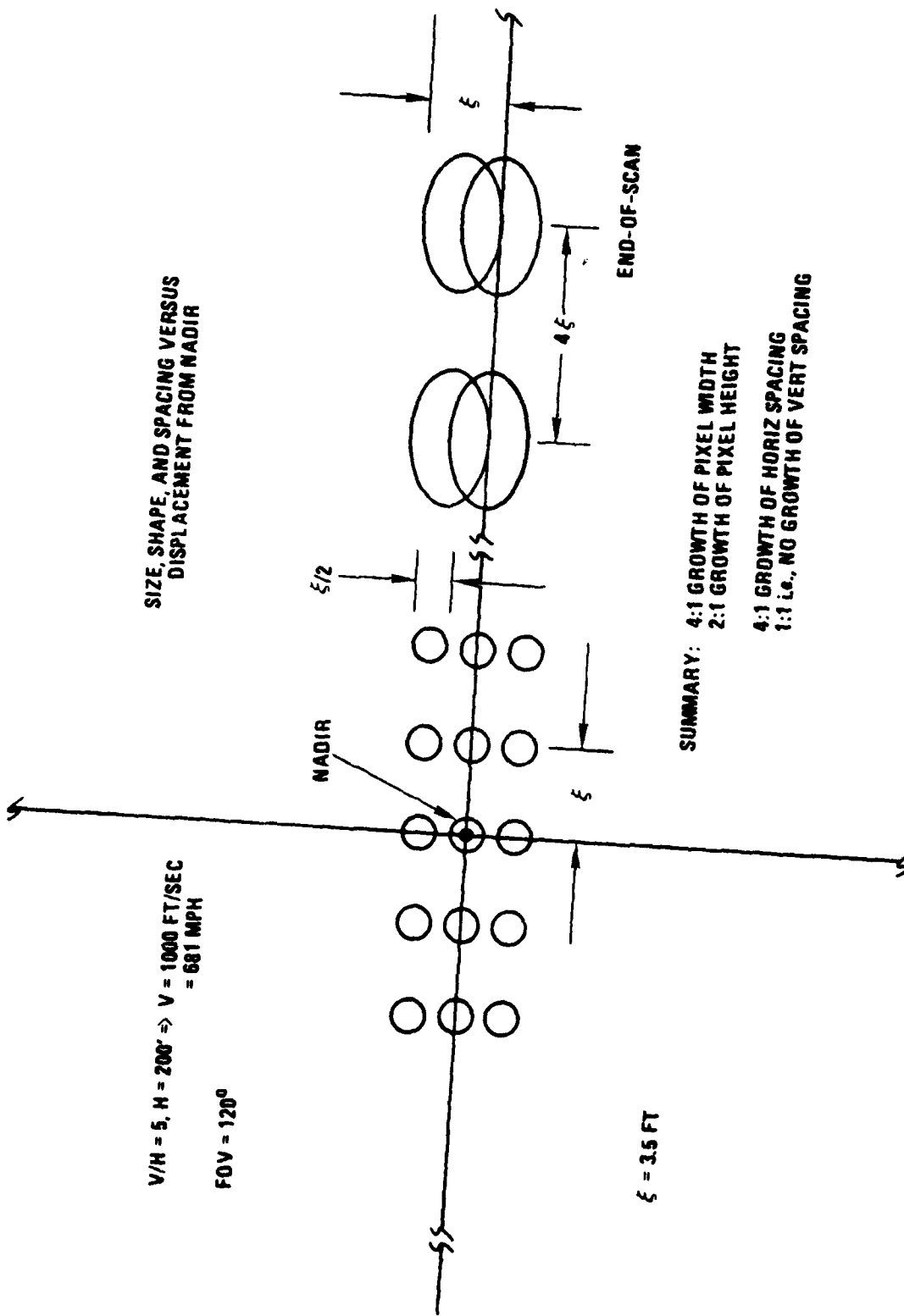
Figure 19. DLIR Ground Plane Pixel Growth

This rectification process is implemented by simply repeating pixel values as required along scan. Since no resolution reduction is permitted, pixel deletion in the DLIR rectification process is not normally allowed. The SIM determines the number of times each pixel should be repeated by consulting a look-up table. The raw DLIR pixels may be repeated 0, 1, 2, or 3 times depending upon the raw pixel position along the sensor scan. Since pixels can be repeated only an integer number of times there will be some local distortions in the rectified DLIR lines, but these will not exceed one display pixel spacing. The nature of the pixel-repetition table is shown in Figure 20.

The DLIR pixels corresponding to a single DLIR scan will be mapped into $6 \times 1024 = 6144$ pixels after rectification with the result that the resulting pushbroom-style rectified DLIR imagery that is stored in the S/RM will be six display widths wide.

The user may decide to rectify or not to rectify the incoming data. The result is that the Full-Frame Image Bus transfer rate will allow for higher bandwidth or wider dynamic range if rectification is not done on-the-fly. Another means of controlling data rate "expansion" is to use pixel deletion in the high resolution area near nadir. Either method can be accommodated by the look-up table method of rectification utilized in the AN/AAD-5 input submodule.

2b. FLIR Image Rectification

The FLIR image differs from the line-at-a-time image in that FLIR frames may be regarded as snapshots of what the FLIR sensor sees; in other words, the FLIR sensor images in a frame-at-a-time fashion rather than in a line-at-a-time fashion. The geometrical distortions are much more pronounced than in the case of DLIR imagery since FLIR sensor earth pixel ray paths are more nearly parallel to the earth's surface.

As in the DLIR case, uniformly spaced time samples yield earth plane pixels that are not uniformly distributed on the earth's surface. A top view of the resulting geometric distortion is shown in Figure 21 for both $\theta_{roll} = 0$ and $\theta_{roll} = 0$.
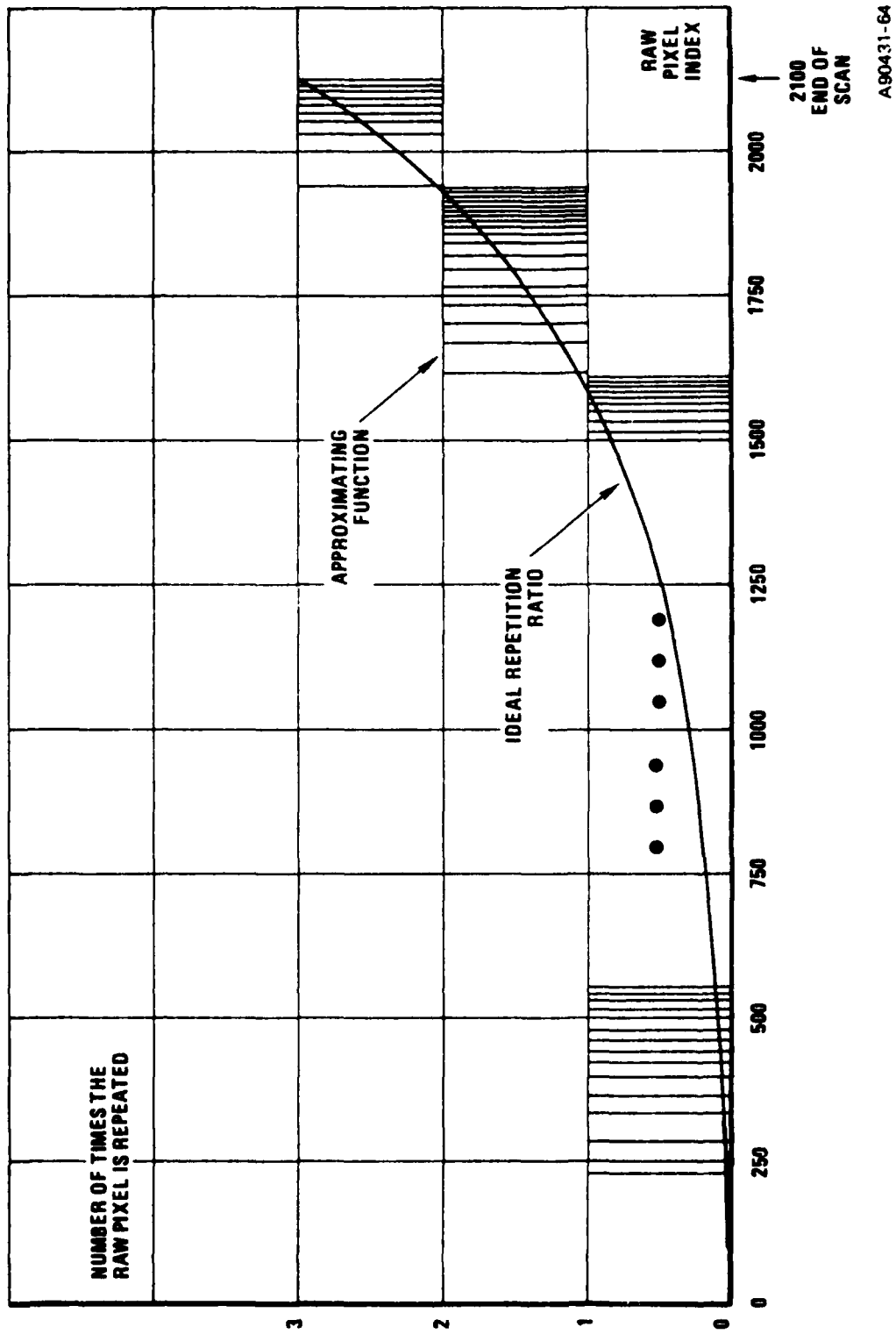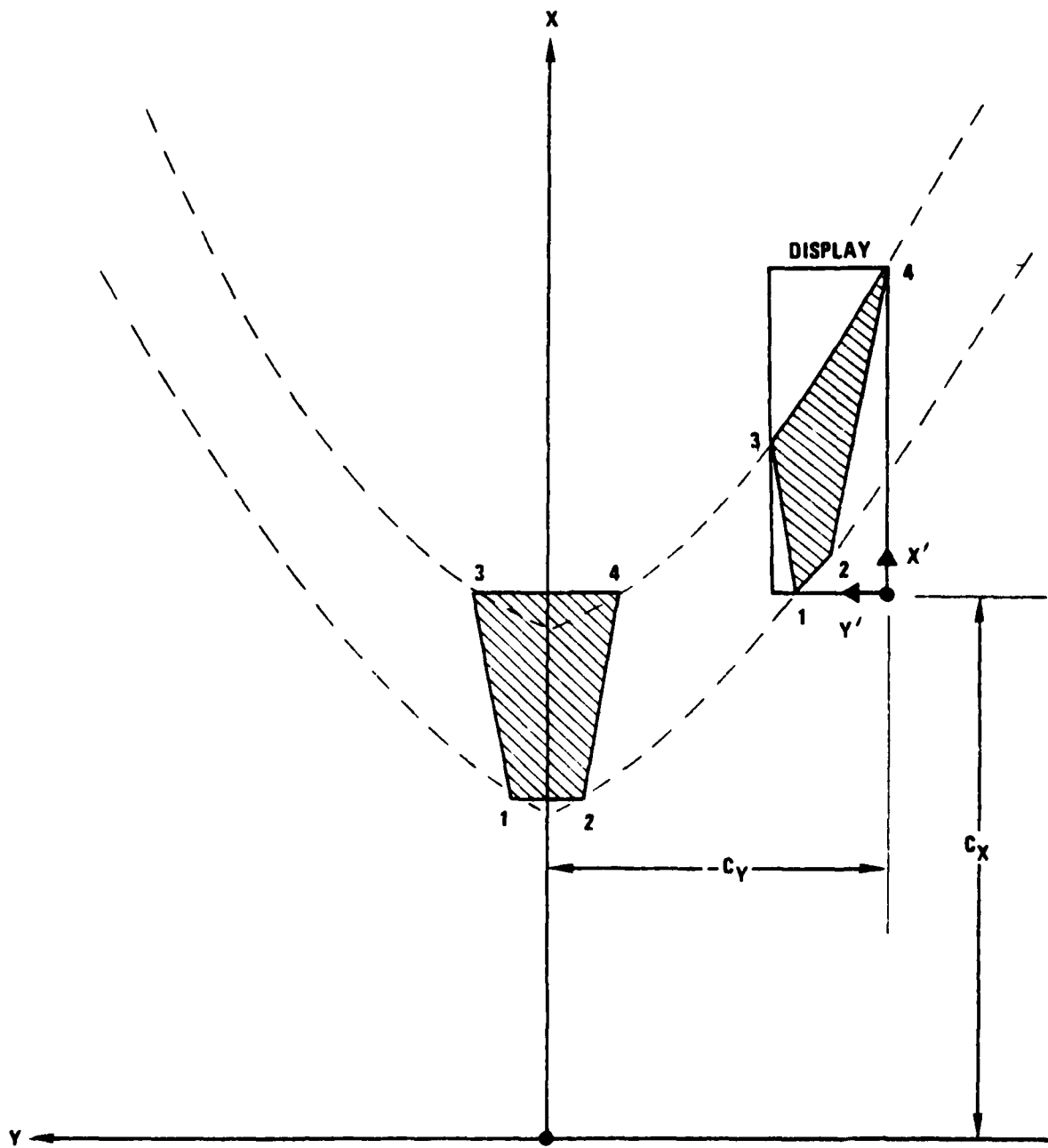
Figure 20. The Pixel Repetition Function for DLIR
Along-Scan Rectification

45

Figure 21. The Effect of Sensor Roll Upon FLIR Image Shape
and Position the Earth Plane

46

Analytical expressions for the inverse transformation equations for $\theta_{roll} = 0$ and the equations governing FLIR rectification for $\theta_{roll} = 0$ are available. The solutions to these equations for $\theta_{roll} = 0$ must be obtained using iterative techniques. Once this is done for a sparse set of display image control points a third order, two variable approximation to the required inverse transformation can be obtained for selected values of roll.

V   SUMMARY OF RESULTS

The functional description and the described user scenario were used to define the detailed DHRS.

The DHRS consists of several vendor supplied items integrated with special purpose hardware to provide an efficient implementation of the target detection/classification/verification function. These vendor supplied items include the high density magnetic tape recorder, the image display console, the voice recognition module, and the system control processor. The RTPM will consist of a combination of Harris and Westinghouse technologies providing a real-time target detection/classification capability. All other functions will be implemented in dedicated hardware/software modules utilizing existing Harris technologies.

Each individual subsystem is discussed in detail in the following paragraphs.

The techniques utilized in the hardware developed by Harris have been demonstrated on many previous programs requiring data management, variable data rates, synchronization and A/D conversion, intelligent retrieval techniques and image enhancement/display.

DHRS will consist of four interconnected subsystems. The data flow among these subsystems and the inputs, outputs, and functions of each of these subsystems will be briefly described below. Following this overview of DHRS, the interfaces and functions of the subsystems will be described in more detail in subsequent paragraphs. The following acronyms for the four subsystems will be used:

SIM = Sensor Input Module
S/RM = Storage and Retrieval Module
RTPM = Real-Time Processing Module
NRTEM = Near Real-Time Exploitation Module

48

Figure 22 is a top-level block diagram of the DHRS system which shows how the various subsystems are interconnected. Figure 23 is a more detailed block diagram of the DHRS system that shows the constituent parts of each of the subsystems. There are four well-defined functions performed within the DHRS. The Ingest function is performed by the SIM module, the Storage and Retrieval function is performed by the S/RM module, the Target Screening and Target Classification function is performed by the RTPM module and the interactive verification function is performed within the NRTEM module by the human operator. These four modules are interconnected using a low-risk bus architecture approach in order to accommodate the extremely high data rates involved. The input to the DHRS system consists of infrared imagery which is stored on analog video tape using an RCA Advisor 62 video tape recorder. There are presently three input data types of interest: 525 line FLIR, 875 line FLIR and AN/AAD-5 DLIR.

The data flow in the DHRS is best understood by referring to Figure 23. The SIM subsystem converts the analog input data into digital form and routes it to the Storage and Retrieval Module and also to the Real-Time Processing Module.

The Storage and Retrieval Module performs two functions. It provides an archival long-term storage capability and also permits the interpreter to recall selected frames for display. The Real-Time Processing Module performs the automatic screening operation. The screening operation consists of automatically examining input image frames, detecting any targets that exist within the frame, and classifying the targets that ʻre detected according to type, such as tank, aircraft, etc. The frame numbers of those frames containing targets are passed from the RTPM to the NRTEM or verification subsystem. This information is then used to retrieve the targeted frames from the Storage and Retrieval Module. The retrieved image frames are then queued up in a first-in/first-out image frame buffer that resides in the NRTEM subsystem. Using the image display capabilities of the NRTEM subsystem, the image interpreter then visually inspects the classification results obtained by the RTPM screening subsystem. For each of the targets identified within the displayed image frame, the image interpreter either concurs with the automatic classification of each target or corrects the classification, if he determines that it is incorrect. This verification operation is facilitated by the use of an interactive voice input, man/machine interface. The output of the DHRS system is a printed target report. This target report identifies all targets and gives information regarding the location and target type of each target.
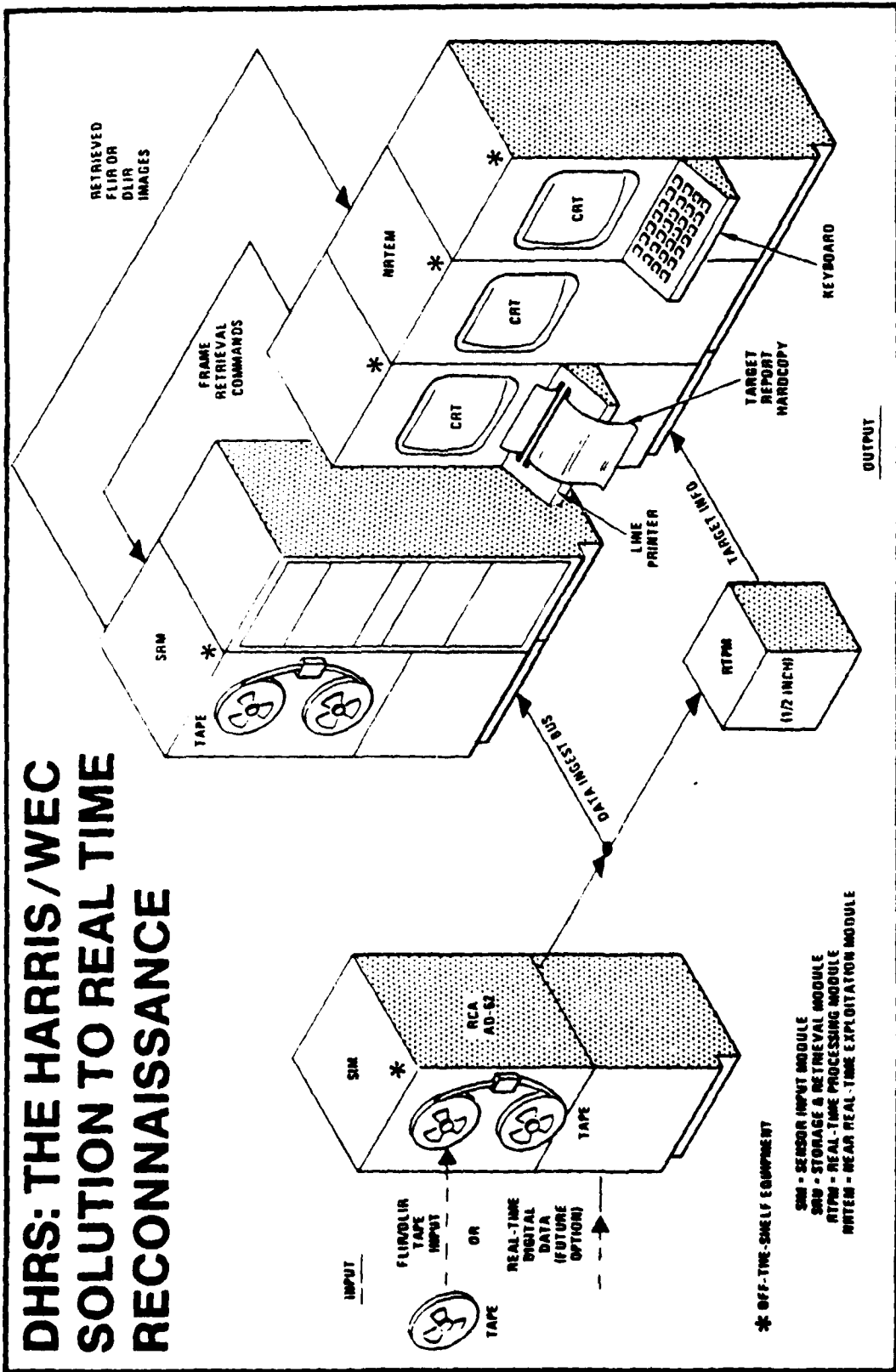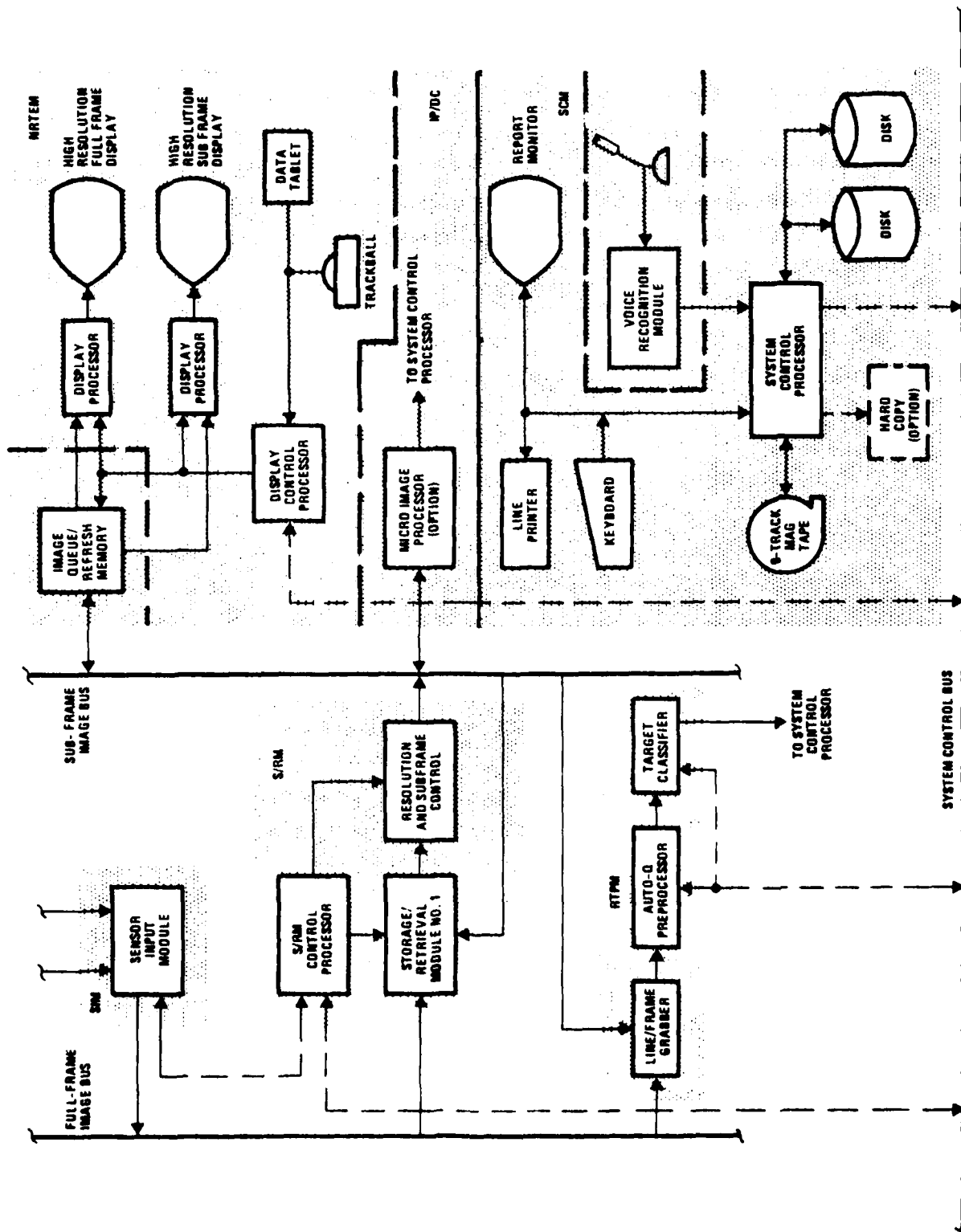
Figure 22. DHRS Block Diagram

Figure 23. DHRS Baseline Architecture: Detailed Block Diagram

51

In summarizing, the overall operation of DHRS, we may say that a very large number of input image frames are ingested into DHRS and that these frames are automatically screened without human intervention by the screening subsystem. The RTPM produces the target frame numbers and passes them on to the NRTEM. These frame numbers are then used to recall these image frames from the Storage and Retrieval Module for display to the I/I. The I/I either concurs with or corrects the classification decisions made by the automatic screener. The net result of this sequence of events is that the I/I need only examine those frames that are known to contain targets. The I/I does not waste time looking at the frames that do not contain targets. The result is that a single Image Interpreter can perform the image interpretation function for a mission in a much more timely fashion with an accuracy comparable to that obtained if manual image interpretation is used.

The following paragraphs will describe the subsystem functions of the DHRS.

SIM Subsystem (Input Function)

The purpose of the SIM is to condition and format the image data from the various input sensors so that it can be processed by the remainder of the DHRS. The Harris design of the SIM is modular and flexible so that it may be tailored to available sensors and easily expanded to accommodate future sensors. The SIM will consist of three submodules designed to accommodate the three types of sensor input data: 525 FLIR, 875 FLIR, and DLIR. A four bit control message from the system controller is received by the SIM that specifies which of the three sensors will be in use for a particular mission. Figure 24 shows how the submodules are connected to a common formatter. Also shown are the data flow and control signals within the SIM. Sync signals and digital documentation data signals are stripped off of the input data signal in each of the SIM submodules. Thus, the signal formatter within the SIM receives three types of signals from whichever submodule is in use: Sync Signal, Digital Documentation Data Signal (Navigation Data), and IR Imagery Data. The output of the SIM consists of IR Imagery data and Digital Documentation data which is put onto a high-speed parallel bus. This imagery data and documentation data is then simultaneously transmitted to both the Storage and Retrieval Module (S/RM) and the Real-Time Processing Module (RTPM).
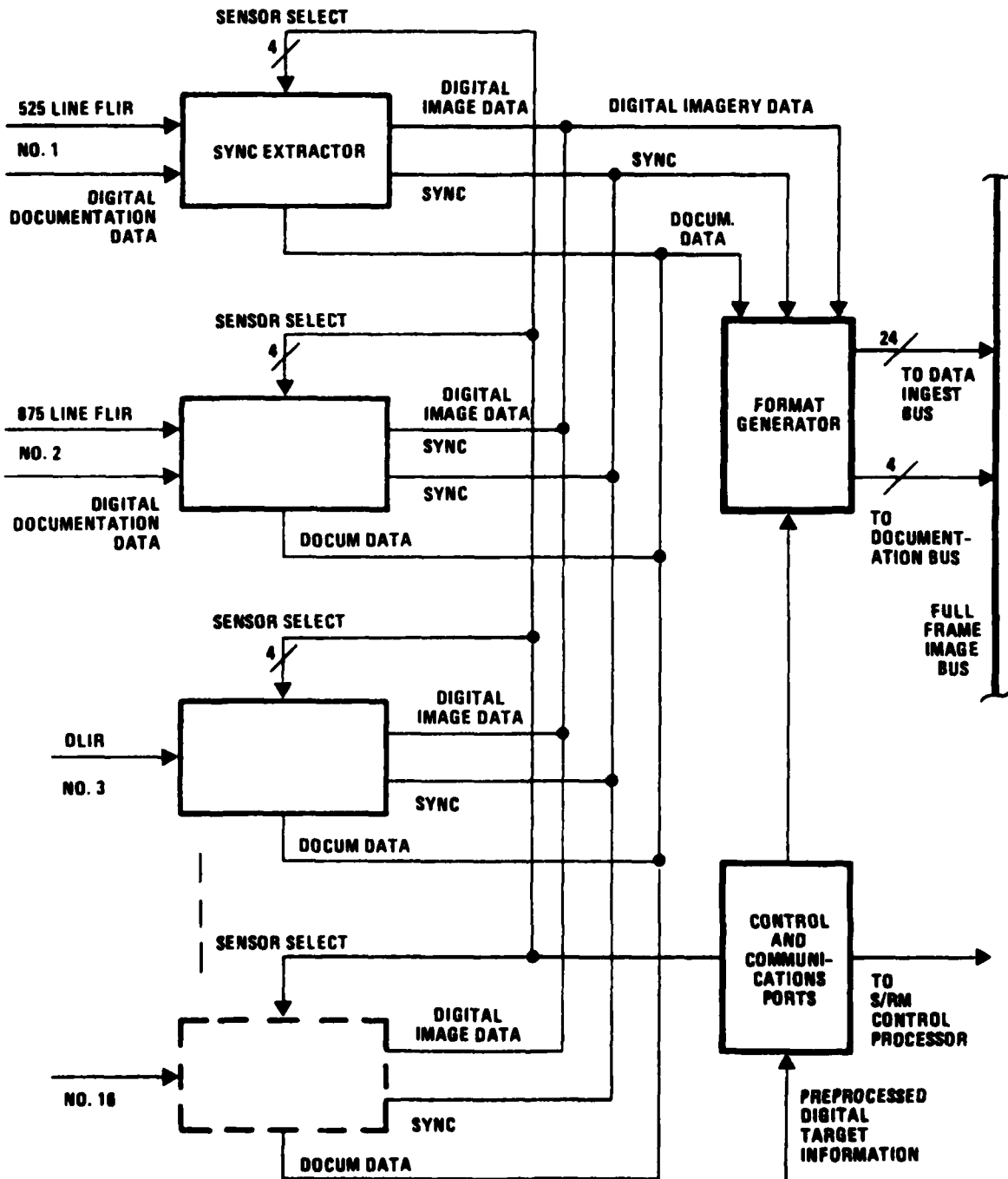
Figure 24. Expandable SIM Configuration

53

S/RM Subsystem (Storage and Retrieval Function)

The S/RM will provide two functions for the DHRS. It will provide a long-term archival storage function whose capacity will virtually be unlimited (10^{11} bits/reel) and it will also provide a fast short-term retrieval capability which will be used by the NRTEM to retrieve and display frames with targets. The heart of the S/RM will feature a modular design so that an expansion to twice the existing capacity of 10^{11} bits on-line can easily be accommodated with no impact to the rest of the system. The bus control, search control, bus select and Storage and Retrieval Module will have the following components as shown in Figure 25: Its own dedicated storage and retrieval control processor, input processor, subframe extractors, decimator, and bus interface. The S/RM control processor will maintain the SIM Format Generator, search control, subframe extraction, decimator, and bus interface functions of the S/RM.

The image pixels will be represented by either 6-bits or 8-bits and these pixels will be packed into 24-bit words for storage on and retrieval from the tape recorder. The 1.2 Megaword/record format means that five 875-line FLIR frames, fifteen 525-line FLIR frames, or 512 - 6000 pixel DLIR imagery lines will be stored in one record. Auxiliary tracks of the recorder contain record numbers, header data, and sync information in order to facilitate the retrieval process. Recall that the S/RM control processor, upon command from the System Control Processor, will control all the details of the data recording, retrieval, subframe extraction, and bus interfacing processes and thus offload the system control process.

The input processor will unpack the video data words from the 24-bit bus, extract record sync, frame sync, field sync, and line sync, and generate a pixel count within each line of imagery. The output of the input processor will drive a video and sync bus and pixel count bus interfaced to each of the six subframe extractors. The subframe extractors will select a subframe from the DLIR data (or a full FLIR frame) and output the desired subframe (or frame) to the subframe display bus via the corresponding bus interfaces. The decimator will perform line and pixel averaging on the DLIR subframes and will output a display size DLIR image to the subframe display bus.
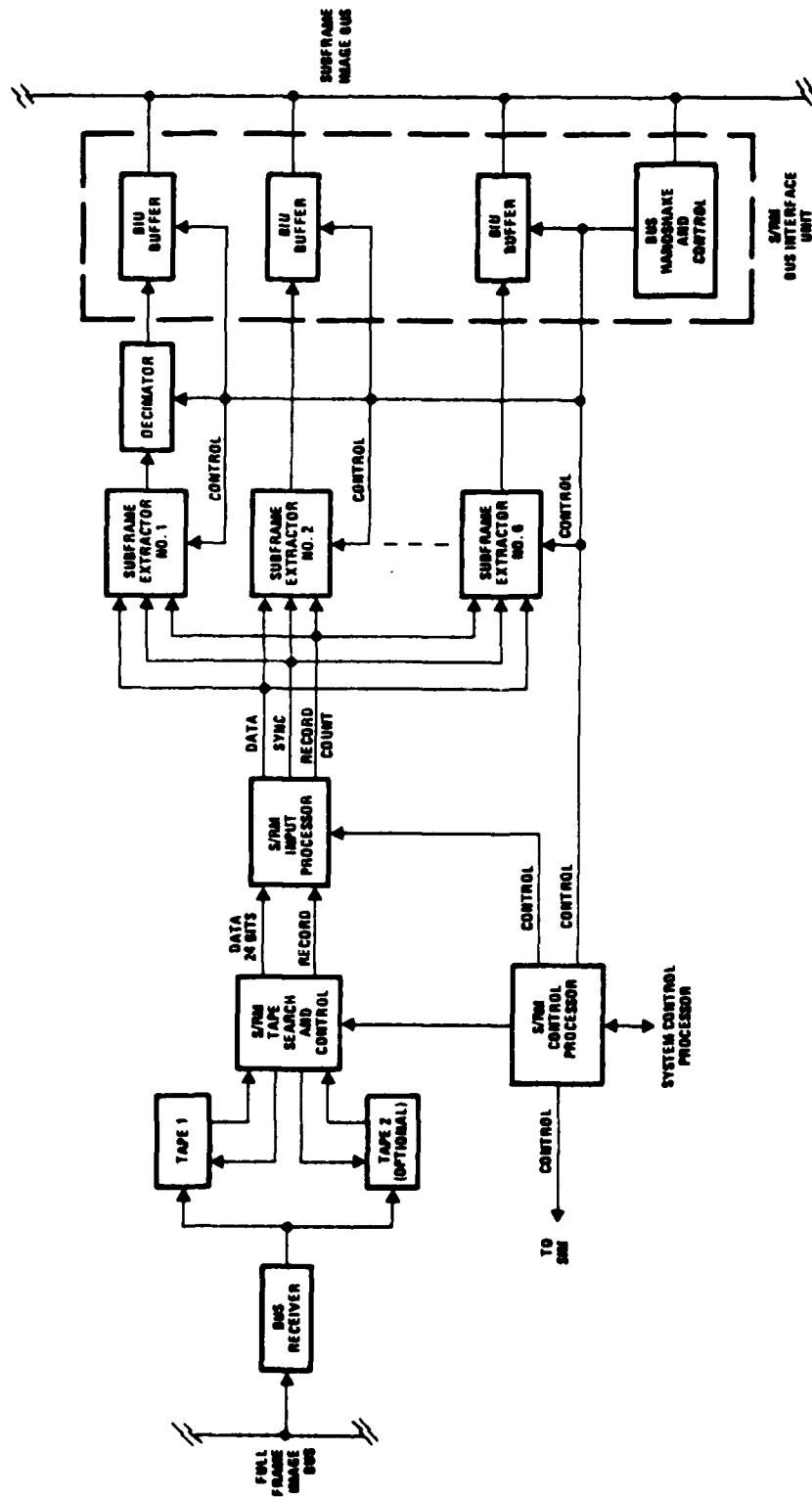
Figure 25. Storage and Retrieval Module Configuration

RTPM Subsystem (Automatic Screening Function)

The function of the RTPM will be to automatically screen the input imagery data. Specifically, frames containing targets will be identified. These targets within the frame will be classified and located. The RTPM will consist of the three subfunctions of Figure 26. Frame Grabber, Target Detector, Target Classifier. In normal operation, frames of real-time FLIR or lines of real-time DLIR imagery data will be loaded via the full-frame message bus to the frame grabber. The frame grabber will deliver one line at a time of the frame to the target detection function. The target detection function will detect the targets and transfer feature information to the target classifier submodule. The target classifier will classify each of the detected targets as one of a preselected number of target types. The target detection submodule and target classifier submodule of Figure 27 will be subcontracted to Westinghouse Electric Corp. The algorithms for target detection and target classification are fully developed and tested and the deliverable hardware will consist of a modification of existing hardware developed at Westinghouse. The Westinghouse target detection and target classification submodules will operate at real-time imagery rates.
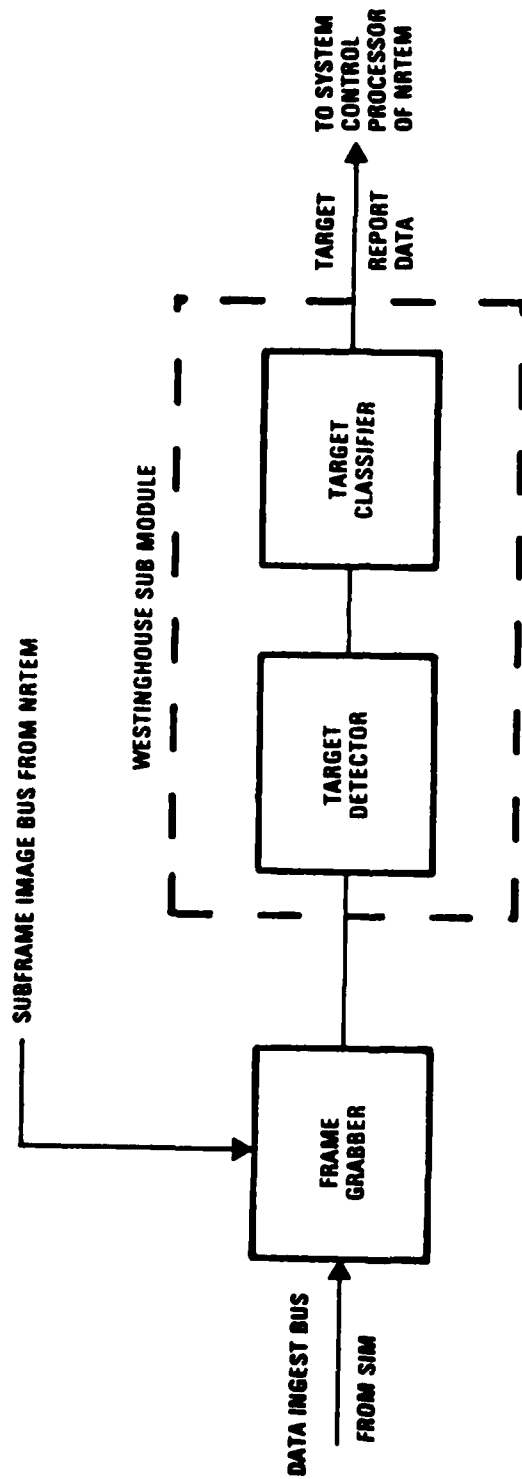
NRTEM Subsystem

The NRTEM subfunctions will allow the operator to verify the RTPM decisions. The two subfunctions within the NRTEM will be:

a. Image Processing and Display Control (IP/DC)
b. System Control for the Overall DHRS

The hardware that performs these two subfunctions will be off-the-shelf and vendor supplied, with the exception of some custom interfaces that will be required for communications with other modules.

The IP/DC will contain the following components: a display processor for real-time image enhancement, image display, image queue/refresh memory and a display control processor to provide ancillary device control. The architecture for the IP/DC is shown in Figure 28.

56

SUBFRAME IMAGE BUS FROM NRTEM

WESTINGHOUSE SUB MODULE

TARGET DETECTOR

TARGET CLASSIFIER

TARGET REPORT DATA

TO SYSTEM CONTROL PROCESSOR OF NRTEM

FRAME GRABBER

DATA INGEST BUS FROM SIM

A90431-33

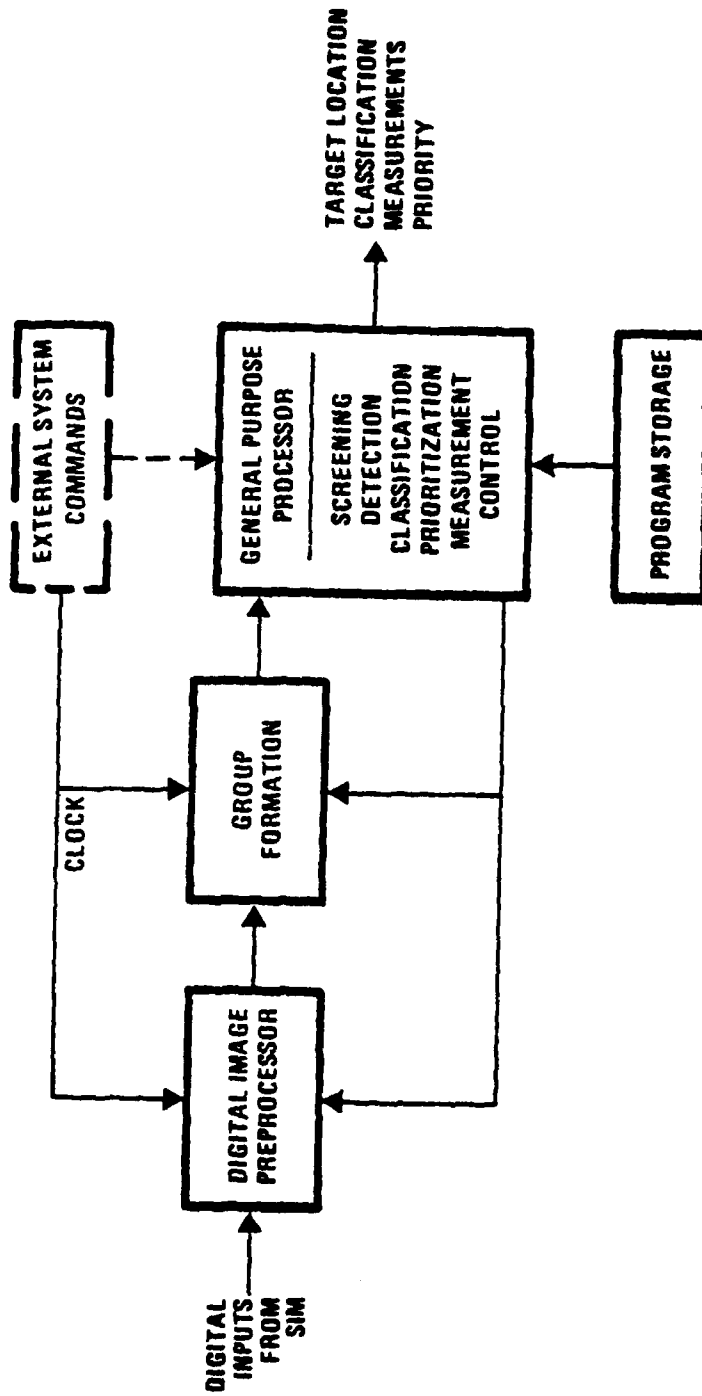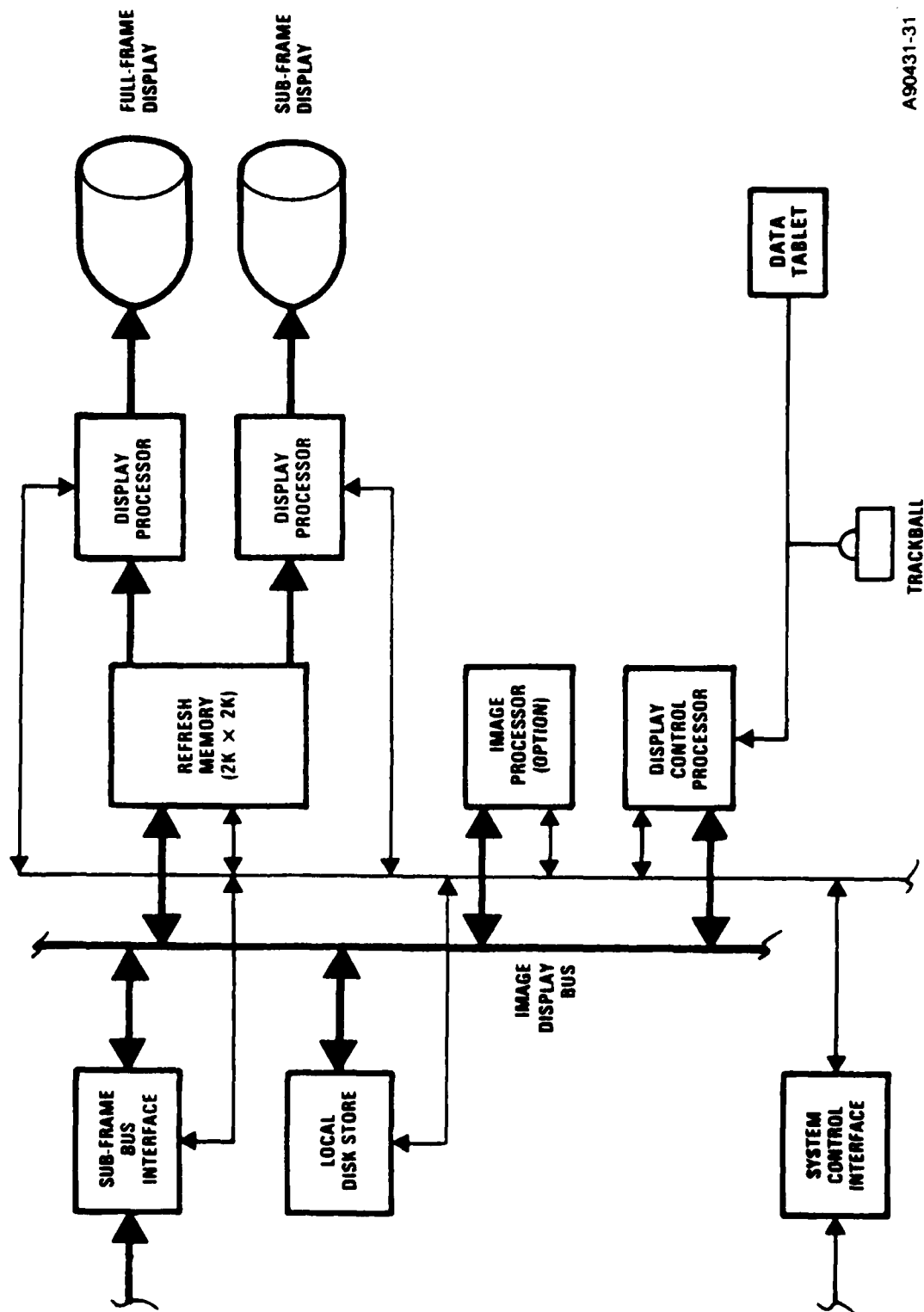Figure 26.   The Harris/WEC Real-Time Screener Configuration

57

Figure 27. AUTO-Q Digital Image Processor - Block Diagram

Figure 28. Target Frame Queue, Image Display Processing Portions of NRTEM

59

The System Control Module (SCM) will contain the following components: system control processor with necessary peripherals, voice recognition module, and system software. The SCM configuration is shown in Figure 29.

SYSTEM CONTROL PROCESSOR

**BASELINE ARCHITECTURE
HARDWARE CONFIGURATION**
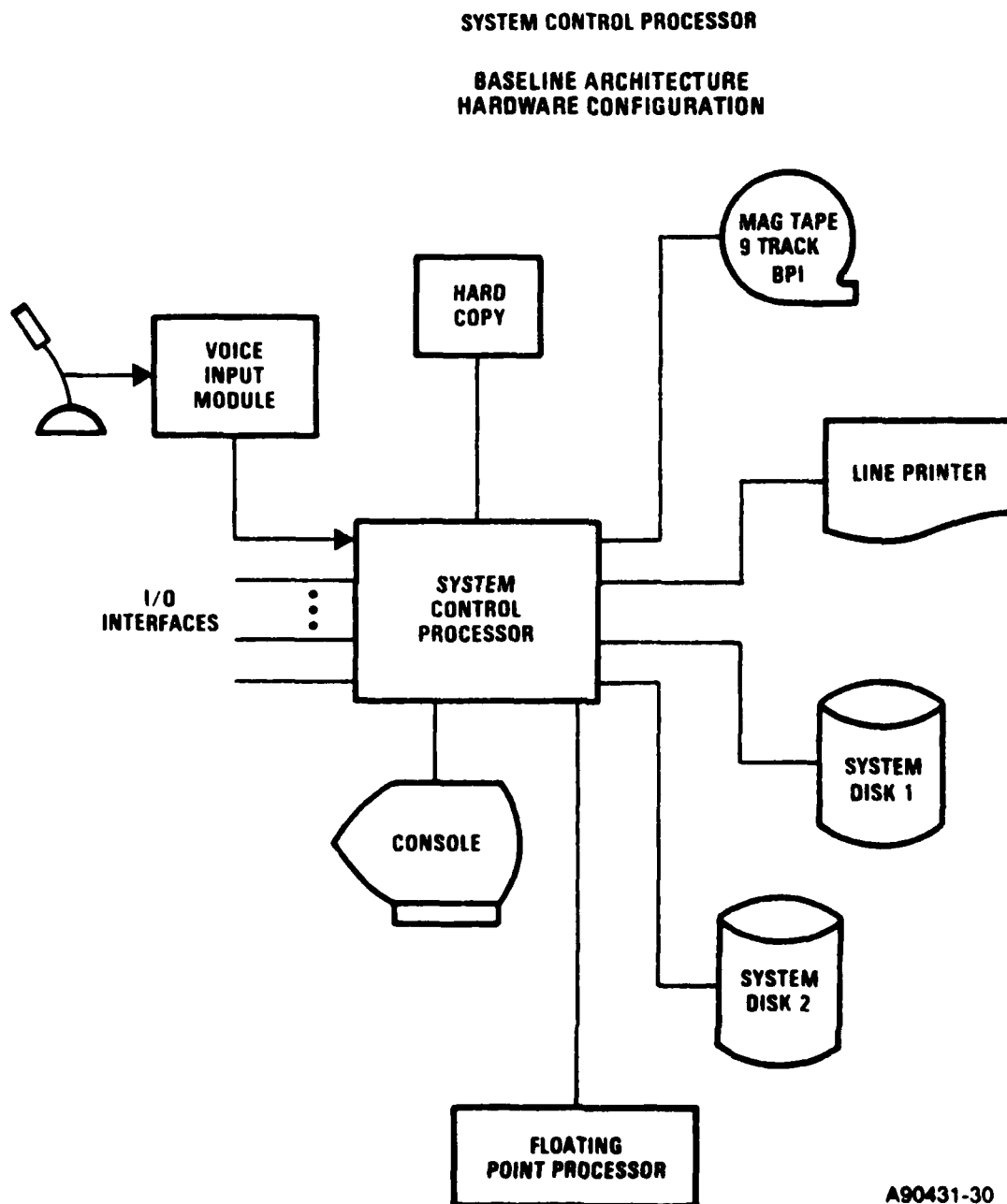
A90431-30

Figure 29. System Control and Voice Input Portions of NRTEM

60

VI   CONCLUSIONS

The Harris/WEC DHRS baseline has the following features:

1. Low Risk
    ● WEC target screener developed
    ● Harris and WEC are stable, large corporations with existing test facilities
    ● System baseline has survived close scrutiny over a period of several months
    ● Experienced personnel
    ● Significant amount of off-the-shelf vendor items
    ● Harris experience in high speed technology

2. Real-Time Reconnaissance Capability
    ● Utilizes real-time Westinghouse screener
    ● 140 Mb/s ingest bus exceeds SOW requirements and accommodates the maximum sensor bandwidths

3. Approved DHRS Baseline
    ● Our DHRS baseline has survived close internal scrutiny
    ● Our DHRS baseline has survived customer reviews intact

4. Flexibility
    ● Easily accommodates alternative or future sensors
    ● Additional on-line tape storage requires minimal software modification only; except for the added tape recorders, no additional hardware is required
    ● Clean interfaces permit modular upgrading of DHRS
    ● Selectable quantization precision to 12 bits/pixel
    ● Modular software permits easy addition/deletion of software functions

5. Superior Overall DHRS Harris/WEC Combinations
   * WEC screener is 4th generation equipment with proven performance
   * Harris has experienced personnel with expertise in image processing, high speed bus technology, and complex software and hardware architectures

The benefits of using the Harris/WEC DHRS are:

6. Efficient and Effective utilization of Air Force Equipment and Personnel
   * One Image Interpreter has a span of control that accommodates many more missions per unit time
   * More effective use of strike force since less time is spent in air waiting for instructions

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.