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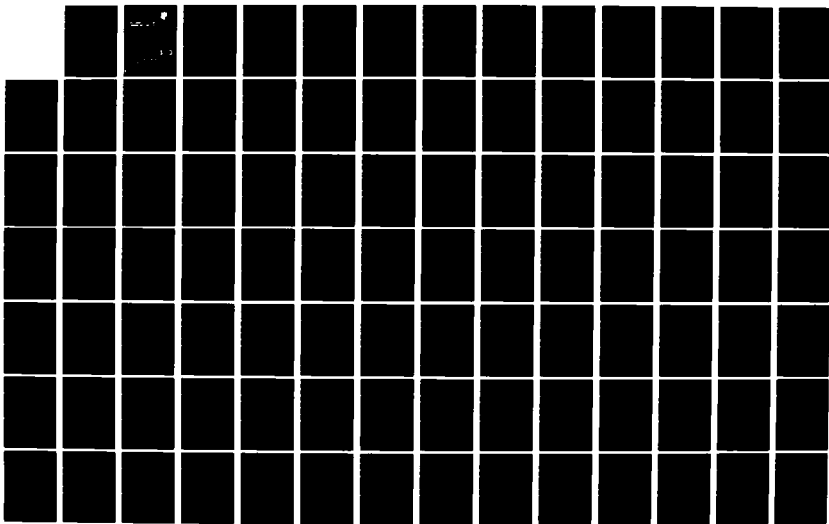
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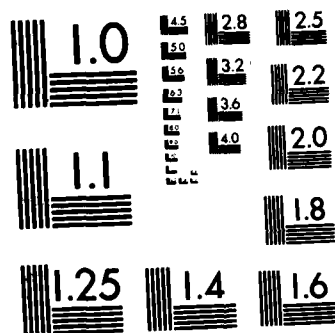
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AD A124887

ADC-TR-82-303
Final Technical Report
November 1982



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MULTI-IMAGERY EXPLOITATION CONFIGURATION DESIGN STUDY

Harris Corporation

Thomas E. Timothy
J. B. Slayton
Wilson E. Taylor

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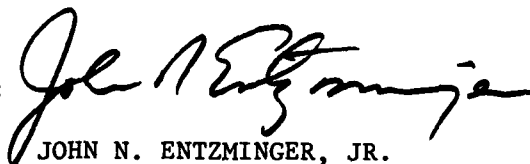
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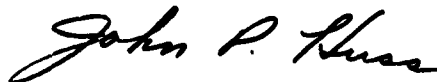
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-82-303	2. GOVT ACCESSION NO. AD-A124 887	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MULTI-IMAGERY EXPLOITATION CONFIGURATION DESIGN STUDY		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report
		6. PERFORMING ORG. REPORT NUMBER N/A
7. AUTHOR(s) Thomas E. Timothy I. B. Slayton Wilson E. Taylor		8. CONTRACT OR GRANT NUMBER(s) F30602-81-C-0095
9. PERFORMING ORGANIZATION NAME AND ADDRESS Harris Corporation Government Communications Systems Division Melbourne FL 32901		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 45941731
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (IRRE) Griffiss AFB NY 13441		12. REPORT DATE November 1982
		13. NUMBER OF PAGES 156
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same		15. SECURITY CLASS. (of this report) 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: Stephen J. Anthony (IRRE)		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Digital Imagery Electro-Optical Imagery Image Exploitation Forward Looking Infrared Imagery Reconnaissance Synthetic Aperture Radar Tactical Intelligence		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Multi-Imagery Exploitation System (MIES) is a program to develop technology for automating image exploitation for imagery received simultaneously from multiple sensors. The program goal is to be able to transmit exploitation reports within five minutes of receipt of the imagery for time sensitive targets. The interpreter will remain an important part of the cycle to perform a verification function. The primary technologies to be investigated include: automatic target detection and identification.		

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automatic target location, mass digital storage and retrieval, and the man-machine interface. ✓

This report is organized into six major sections. Section one is the introduction. The functional requirements definition including system level trade-offs is described in Section 2.0. This section elaborates on the required functions. All description of the requirements is in terms of these functions. An analysis of the system operation is covered in Section 3.0. Three candidate architectures are proposed in Section 4 to meet these requirements. Section 5.0 describes in greater detail the selected architecture, including candidate implementations. This section defines subsystems and describes the allocation of the functions of Section 2.0 to these subsystems. Finally Section 6.0 provides further analysis of the selected architecture, including aspects of reliability, maintainability, and human factors. An annex to the report includes human factors considerations applicable to such a system.

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 Scope

This report, together with the Interim Technical Report, documents the results of the Multi-Imagery Exploitation System (MIES) study performed by Harris Government Communications Systems Division under contract number F30602-81-C-0095. The study encompassed two main thrusts. The first analyzed requirements for a successful softcopy exploitation system and defined experiments to prove new concepts. The second examined candidate architectures and recommended a system configuration. The Interim Technical Report provides the results of the first 10 months of study and concentrates on experiment definition. This report continues the requirement analysis and examines candidate architectures. The experiment definitions from the Interim Technical Report will not be repeated here.

1.2 The Problem

Reconnaissance and surveillance systems with increasing image exploitation speed are being transitioned into the operational Air Force inventory. In the currently fielded systems, exploitation is extremely slow and lags behind collection rates. For example, radar systems can collect over 4000 square miles of ground coverage in an hour while an interpreter averages 200 square nautical miles/hour. Currently there is an advanced development program addressing the concept of developing a softcopy Data Handling and Recording System utilizing infrared sensors. Other programs each handle one or two sensors. The MIES program provides a common set of assets which support numerous sensors providing rapid exploitation for each.

1.3

Approach

The requirements for a softcopy exploitation system were analyzed using the MIES "strawman" architecture from the annexes of the statement of work for this contract as a starting point. Several candidate architectures were proposed and analyzed in the light of the derived requirements. An architecture was selected from the candidate architectures as the best approach. This architecture was further studied.

1.4

Results

A combination of magnetic tape recording of all input data with short term storage in random access memory is the basis of the selected architecture. Wide band magnetic tape provides the most cost effective solution to the massive storage requirements of the MIES input. The disadvantages of serial access to this data are overcome by providing buffers of random access memory capable of storing the sensor data only long enough for the images of interest to be extracted. The quantity of extracted data is sufficiently less than the total input data to make random access memory feasible for storage.

Analysis of the selected architecture indicates that the approach is feasible in current technology. A number of candidate implementations are suggested.

Areas for further study were indicated. These include mission scenarios, automatic target detection and classification, and target location.

1.5

Organization of the report

The final report is organized into five major

sections. The functional requirements definition including system level trade-offs is described in Section 2.0. This section elaborates the required functions. All description of the requirements is in terms of these functions. An analysis of the system operation is covered in Section 3.0. Three candidate architectures are proposed in Section 4.0 to meet these requirements. Section 5.0 describes in greater detail the selected architecture, including candidate implementations. This section defines subsystems and describes the allocation of the functions of Section 2.0 to these subsystems. Finally, Section 6.0 provides further analysis of the selected architecture, including aspects of reliability, maintainability, and human factors.

2.0 REQUIREMENTS ANALYSIS

2.0

REQUIREMENTS ANALYSIS

This section provides the results of the analysis of the functional requirements of the MIES ADM. Starting with a "strawman" set of requirements a more detailed set of requirements was generated on the basis of this study. These requirements are described below and are organized by major function. These functions are as follows.

- a. Sensor Input.
- b. Storage and Retrieval.
- c. Selection and Retention.
- d. Situation Display.
- e. Image Exploitation.
- f. Target Location.
- g. Communication.
- h. Systems Management.

The relationship of these functions is shown in Figure 2.0.

The basis of evaluation of these functions is how well they operate together to accomplish the MIES mission. The MIES mission is to provide rapid extraction of the intelligence information contained in data from a variety of reconnaissance sensors and to provide this information in a standard format to the Enemy Situation Correlation Element (ENSCE) via the Command, Control, Communication, and Intelligence (C3I) Network. On the basis of tasking and cueing commands received from the ENSCE, the MIES provides the capability to detect, classify, identify, locate, and analyze targets within the sensor data.

2.1

Sensor Input

This section describes the sensors with which the MIES ADM must interface and the number and combinations of sensors which

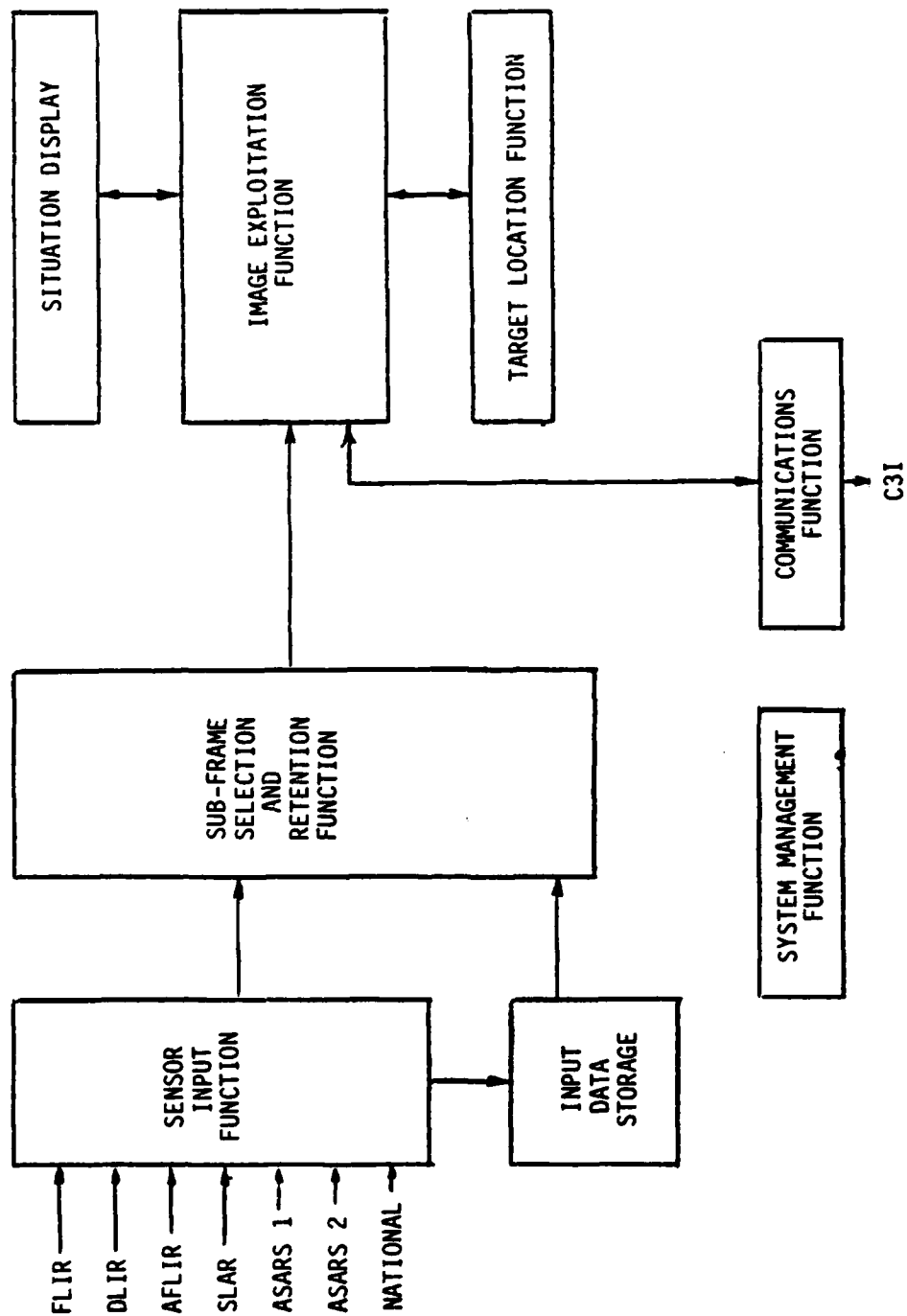


Figure 2.0. MIES Functional Block Diagram.

can be supported simultaneously. An aggregate sensor input rate of 144 Mbits/second was specified. This rate supports a large number of sensor combinations without incurring the system size and complexity penalties of worst case sizing.

2.1.1 Supported Sensors

Important characteristics of MIES, distinguishing it from current reconnaissance imagery exploitation systems both in production and under development, are: it supports a large number of sensor types, it can handle multiple sensors simultaneously, and it provides an automatic target cueing capability to aid the analysts. Electro-optic (EO), Infrared (IR), and Synthetic Aperture Radar (SAR) type sensors in both pushbroom and raster scan formats are supported. MIES will handle the following sensors which are described individually below.

- a. Forward Looking Infrared (FLIR).
 - 525 line format.
 - 875 line format.
 - EMUX format.
- b. Down Looking Infrared (DLIR).
- c. Advanced FLIR (AFLIR).
- d. Side Looking Airbourne Radar (SLAR).
- e. Advanced Synthetic Aperture Radar Sensor.
 - (ASARS1 and ASARS2).
- f. National Sensor.

All sensors are assumed to be received by MIES as baseband signals. Sensor data may be transmitted to MIES in one of the following ways:

- a. Radio links.
- b. Wide Band Tape.

c. Computer Compatible Tape.

d. Video Tape.

The transmission of sensor data to MIES is outside the scope of this study but this transmission may have an impact on the sensor interface. All four transmission methods listed above will probably provide different interfaces to MIES. This interface must be defined to complete the system design. In several cases the interfaces are well defined. These cases are discussed. In other cases the interface is not clearly defined. Further efforts are required to provide this definition.

All sensor data must be converted to MIES digital formats. Any ancillary data (sensor position and attitude along with other information depending on the sensor) must be saved and passed along with the associated imagery. This ancillary data is used within the system to determine the geographic position of points within the sensor data. In order to provide the analysts with the capability of remapping displays using the original input pixels, the digitized pixels must be maintained at the full pixel width as entered into the system.

2.1.1.1

Forward Looking Infrared (FLIR) Sensor

The FLIR sensor (AN/AAQ-9) is a passive infrared sensor operating within the 8 to 14 micron spectral band. The output of this sensor is available in the form of conventional analog TV signals in two formats. One format conforms to EIA RS170 and provides 525 lines in each frame. Frames occur at a 30 Hz rate. This format is compatible with commercially available video tape recorders. Another format provides for 875 lines in each frame. These frames also occur at a 30 Hz rate. This format is defined by EIA RS343. These standards define the electrical characteristics of the signals as well as the formats and

tolerances of the synchronization pulses. The standards, however, do not specify the digitization of the received signals.

After synchronizing to the input signal, the FLIR sensor interface must convert the received analog signals to digital samples. Each line of analog data must be uniformly quantized using at least 6 bits for each pixel. Sampling rates of 512 pixels/line for the 525 line format and 862 pixels/line for the 875 line format are regularly used for sampling analog video and are sufficient for MIES. The standards specify the number of active lines for each format at 480 lines for the 525 line format and 809 lines for the 875 line format.

Both formats are differently scanned versions of the same sensor data. This data may be available in a digital format, directly from the sensor or via a high bit rate recorder. Several formats of this data may be available. Line lengths of 960, 853, 720, and 640 pixels are available with frames of 320 and 360 lines. These digital formats are the preferred form for receiving the FLIR data since no intermediate sampling is required.

The FLIR digital data interface with MIES must be compatible with the AMPEX HBR 3000 series high bit rate recorder. Currently the AMPEX 1728 recorder is used on board the craft flying the sensor. This recorder produces a 28 channel tape which is compatible with the HBR 3000. The HBR 3000 is used by ground units to read the tapes produced by the mission. Ten channels of the recorders are used for sensor data. Each pixel of this data is recorded with ten bits, one bit on each channel. Two channels provide clock and sync signals while another channel provides ground truth data. This ground truth data must be accepted by MIES and treated in the same way as other ancillary data within the system. The complete interface description for the HBR 3000

used in this mode is available in Harris GCSD ESD 13964.

All FLIR data rates discussed here can be reduced on input by eliminating redundant data and reducing the width of the sync intervals. The method of scanning utilized by the FLIR sensor allows for the use of every other frame. This accomplishes a significant data reduction without reducing the information content. The rate of 30 frames/second utilized by all three formats is dictated by the television type formats. Television systems use the 30 frame/second rate to reduce flicker and to produce a good illusion of motion neither of which are problems for MIES. Figure 2.1.1.1-1 shows the geometries involved in determination of the amount of redundant information in the sensor data. It can be seen that this redundancy is a function of V/H , the depression angle of the sensor, and the vertical field of view. Even at MACH 2.5, a sensor will only move 94 feet in a thirtieth of a second. At slower velocities, higher altitudes, and smaller depression angles the redundancy increases.

The data rate can be decreased to half of the sensor input rate by using double frame buffers in the sensor input function and only retaining every other frame. This allows more sensor combinations to be supported simultaneously with the FLIR sensors. This reduction of redundant information also saves storage space on the input data storage and in the selection and retention function.

A potential problem with the FLIR sensors involves the interlace of the two fields of a frame. At high V/H ratios and large depression angles the possibility exists for registration problems with the interlaced fields. Figure 2.1.1.1-2 illustrates the problem. Since the sensor is moving during the scanning the first field scans one area while the second field scans a slightly different area, shifted

H = HEIGHT

Vt = VELOCITY X TIME

TIME = 1/30 SECOND

THETA = DEPRESSION ANGLE

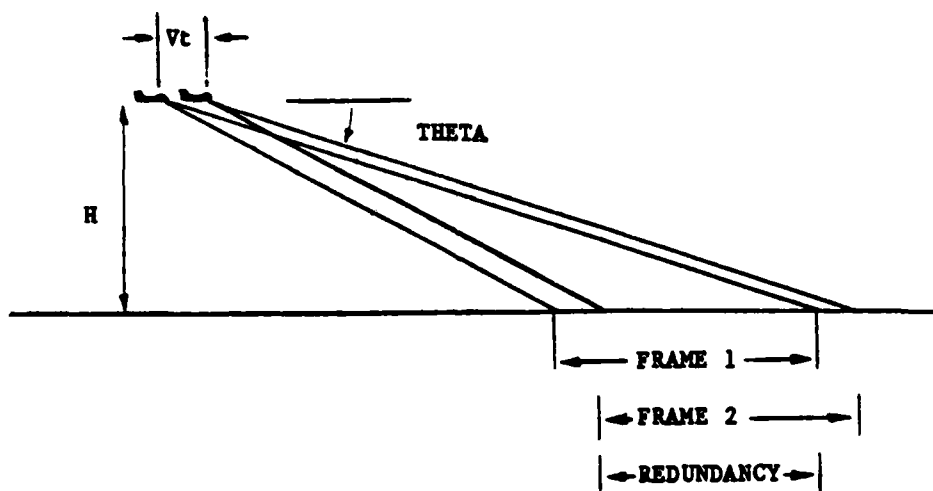


Figure 2.1.1.1-1. Redundant Data From FLIR Sensors.

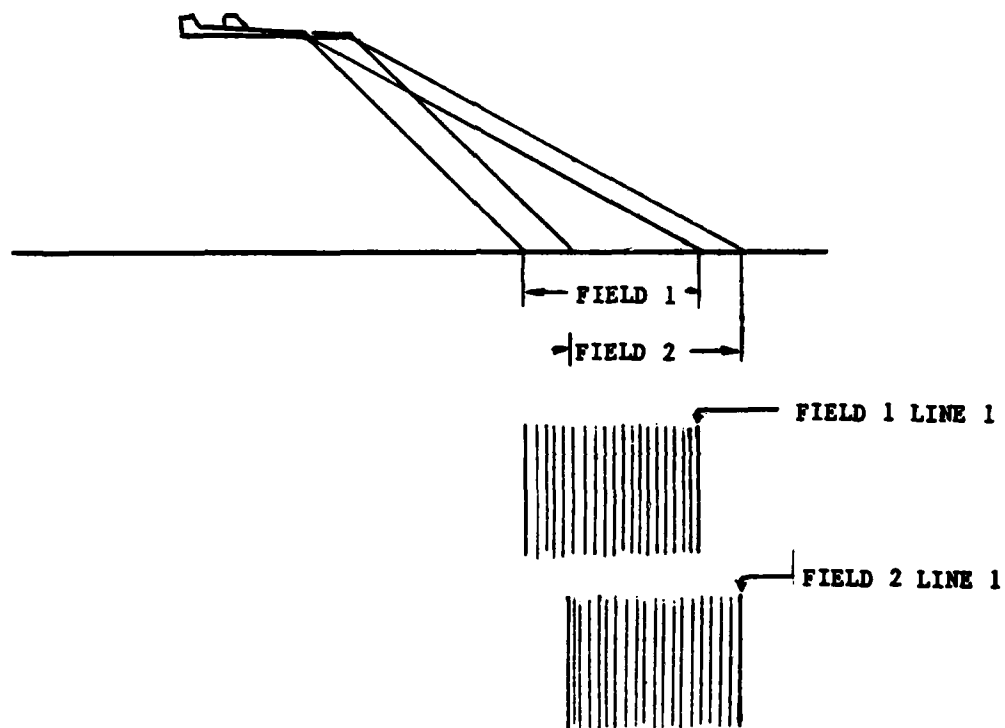


Figure 2.1.1.1-2. Interlace Misregistration.

forward of the first area. Interlace of the fields assumes no appreciable shift between these two areas. In an extreme case the interlaced image would appear as two identical ghost images offset from each other by the amount of the misregistration. The factors determining whether this is a problem are the V/H and depression angle.

If this interlace is a problem then rather than using every other frame of the FLIR data, every other field could be used. Unfortunately, taking every other field has the effect of taking every other line which reduces the resolution in the vertical dimension. This distorts the image. Either the lines could be repeated such that every line appears twice in succession or every other pixel could be deleted. Both operations return the image to its original aspect ratio.

Additional data rate reduction can be achieved by shortening the synchronization intervals. The standard formats used for FLIR data provide synchronization pulses which are designed for use in television systems. These pulses are of sufficient width to allow retrace of the scanning beam via magnetic deflection yokes. There is no requirement to provide for this time in MIES. The display systems automatically regenerate this synchronization time before display. Since these pulses account for approximately 20 percent of the total frame, a significant data rate reduction can be accomplished by shortening this time.

Table 2.1.1.1 shows the data rate characteristics of the AN/AAQ-9 FLIR sensor.

2.1.1.2

Down Looking Infrared (DLIR) Sensor

The DLIR sensor (AN/AAD-5) is a high resolution down looking infrared sensor of the pushbroom type. The sensor consists of

	FORMAT		
	525 LINE ANALOG	875 LINE ANALOG	EMUX DIGITAL (TYPICAL)
Pixel/line	512	862	720
Lines/frame			
Active	480	809	360
Total	525	875	393
Line Scan (microseconds)			
Active	53	31	79
Total	64	39	85
Input pixel sample rate (Mp/s)	9.66	28.82	9.07
Bits/pixel	6	6	8-10
Bit Rate (Mb/s)			
Within a line	58	166	73-91
Line average	55	138	68-85
Frame average	50	128	62-78
Every other frame	25	64	31-39

Table 2.1.1.1. AN/AAQ-9 Data Rate Characteristics.

12 paralleled, overlapping channels which are utilized in such a way that as the V/H ratio increases more channels are engaged. Each channel scans a line perpendicular to the path of the sensor and depends on the motion of the sensor to provide new ground coverage on each scan. If the sensor is moving very fast or is close to the ground, paralleled overlapping sensors are engaged to maintain ground coverage.

Currently the AN/AAD-5 DLIR sensor is recorded on tape using the RCA Advisor 62A recorder. Only six channels are recorded on the RCA Advisor 62A. It is recommended that the MIES interface for the DLIR sensor be compatible with this recorder. The parameters for this interface are described in Harris GCSO ESD 13969. Data rate considerations are discussed in the Westinghouse Final Report, a study of sensor characteristics and automatic target detectors performed as part of the MIES Configuration Design Study.

DLIR sensor data is analog while between scans is binary ancillary data. The sensor data must be converted from analog to digital using uniform quantization of 8 bits/pixel. The ancillary data must be decommutated and converted to a MIES internal format.

Three types of image correction should be performed on the sensor data. First, the adjacent channels of the AN/AAD-5 sensor are offset and must be realigned with the other channels. Second, the V/H overlap should be corrected. This can be performed simply by monitoring the V/H parameter, included in the received ancillary data, and when it indicates overlapping data the alternate lines of the sensor data are deleted. Thirdly, the data should be corrected for cross track geometric warp. This geometric distortion is introduced due to the method of scanning in conjunction with the perspective of the sensor relative to the ground. It manifests itself as sensor data which is

more highly resolved at the center of the scan and less at the ends. Rectification of this distortion may be accomplished by repeating pixels as a function of the position of the pixel in the scan line.

2.1.1.3 Advanced Forward Looking Infrared (AFLIR) Sensor

The Advanced Forward Looking Infrared sensor is a higher resolution sensor similar to the older FLIR sensors. Since the method of scanning is the same 30 Hz interlaced technique, the same data reductions are possible. The data rate may be halved by using every other frame. The same interlace issues may apply as discussed with the FLIR sensors.

The AFLIR sensor resolution and data rates are discussed in the Westinghouse Final Report.

2.1.1.4 Side Looking Airbourne Radar (SLAR) Sensor

The SLAR sensor (UPD-4) consists of the AN/APD-10 radar mapper and the ES 83A correlator-processor. The output data for this sensor is rectified providing uniform ground distance scales on both axes.

The resolution and data rates for the SLAR sensor are discussed in the Westinghouse Final Report.

2.1.1.5 Advanced Synthetic Aperture Radar Sensors (ASARS)

Two types of Advanced Synthetic Aperture Radar Sensors, ASARS 1 and ASARS 2, are supported by MIES. These sensors are based on the UPD-X radar.

The resolution and rates for these sensors are discussed in the Westinghouse Final Report.

2.1.1.6

National Sensor

A National Sensor is to be supported. The specific characteristics of this sensor are not clearly determined at this time.

2.1.1.7

CCT Sensor Input

Much of the currently available library of sensor data is in the form of computer compatible tapes in a standard NATO format. This data is recorded on 1/2 inch wide magnetic tape with either 7 or 9 tracks at either 800 or 1600 bits per inch. MIES should be capable of both receiving and creating tapes compatible with this format. Capability to support the 9 track format at 1600 BPI is recommended. Each tape provides one or more images with each image preceded by two header records describing the image data. The first header is well defined and described by the NATO standard. The second header is specified by the NATO standard as free format. Several formats are currently used. The first header gives source and date of the tape and describes how the tape is structured. The second header describes the sensor type, orientation, conditions under which the image was recorded, and ground truth within the image frame.

This capability, to be useful, must be connected into the rest of the system. Images received from tape must be displayable by the exploitation function. Any displayable image should be capable of being recorded by this function to create a NATO compatible tape.

2.1.1.8

Other Sensors

The requirements of the MIES sensor interface are

sufficiently diverse that the common format used between the sensor interfaces and the input data storage and the selection and retention function should be able to accommodate most new sensors. New sensors probably can be accommodated if they meet the following conditions:

- a. Number of pixels/line is constant within an image.
- b. Maximum sensor input rate is less than 144 Mbits/second.
- c. Pixels are quantized with 24 or less bits.
- d. Maximum line length is less than 20 K pixels/line.

In order to take advantage of this flexibility a requirement is placed on the sensor interface function to allow for expansion. This includes the capability to interface the electronics required to provide translation between the unique interface of the new sensor and the common MIES format.

2.1.2 Sensor Combinations

An important requirement of MIES is that it supports multiple sorties simultaneously. A sortie of one sensor type requires a different input data rate than a sortie of another data type, as was just discussed. Different sensor combinations also require different input data rates. A very important parameter with system wide impact is the maximum total input data rate. This parameter not only affects the sensor input function but also the input data storage function size and rate, the selection and retention function size and rate, and the image exploitation function size and rate. In short, the higher the system input rate the higher the rate of data transfer and the larger the sys-

tem storage throughout the path of the sensor data. Thus this parameter must be considered carefully.

Three approaches to sizing the input data rate are:

- a. Worst case sizing.
- b. Sizing based on sensor utilization statistics.
- c. Sizing based on currently implementable technologies with considerations of complexity.

Worst case sizing involves requiring the system to handle all possible combinations of any three sensors. Thus the input rate is simply three times the rate of the highest rate sensor. If the highest rate sensor required 110 Mbits/second, then three times this rate gives a system input rate of 330 Mbits/second. Eight minutes of three missions at this rate would require 20 Gbytes of input data storage, a large amount of storage in any technology. Reliable transmission of this data rate on twisted pair wires between racks of a shelter would require over 40 bit wide busses. Additional circuitry would be required to multiplex and demultiplex the data into and out of its original format. Using coax would reduce the width of the bus required. Yet, even a 16 bit wide bus would require transmitting each bit at a rate of 20 MHz. The input data storage function and the image selection and retention function both would have to be capable of inputting the entire 330 Mbit/second rate. The selection and retention function would have to store the targets from this data. Presumably the targets would also occur more frequently due to the high input rate. This would impact the remainder of the system. The transmission and storage of data at this rate can be accommodated with current technology with only an increase in complexity and cost. The question is whether

this increase in complexity and cost is justified. How often will all this bandwidth be utilized? This question leads us to the second approach, sizing based on sensor utilization.

This approach involves sizing the input data rate by analyzing statistics on the utilization of the various sensors and providing sufficient input bandwidth to assure that the sum of the probabilities of occurrence of each unsupportable sensor combination is less than a specified value. In other words, the system could be sized to assure that unsupported sensor combinations were relatively unlikely. Unfortunately, the required sensor utilization statistics were not available for this study.

The final approach involves making reasonable assumptions about the input data and considering implementations in cost effective technologies. Clearly, the input data rate must be sufficient to support the highest rate sensor. This is accomplished by a rate of 144 Mbits/second. This rate also supports the sensor combinations shown in Table 2.1.2. This table takes into account both the rate and the line lengths of the sensors listed. The system will also support subsets of the sensors shown. For instance sensor combination 1 shows that three FLIR 525 sensors can be supported. MIES will also support 2 FLIR 525 sensors or a single FLIR 525 sensor. These combinations which are subsets of the listed combinations are not shown in the table.

A rate of 144 Mbits/second also divides nicely into three eight bit groups each bit of which operates at 6 MHz. RS 422 differential drivers and receivers can transmit each bit at this rate for up to fifty feet over twisted shielded pair cable.

Thus 144 Mbits/second is an implementable rate which supports a variety of sensor combinations. This rate is selected for

SENSOR	COMBINATION																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
FLIR 525	3	2	2	2	2	2																1	
FLIR 875		1					1	1	1	1													
FLIR EMUX			1				1				3	2	2									1	
AFLIR														1	1								
DLIR 6 CHANNELS				1				1								2							
DLIR 12 CHANNELS																	1						
SLAR					1				2			1		2				3	2		1		
ASARS 1/2						1				2			1		2				1	3	2	2	
NATIONAL																							1

Table 2.1.2. Sensor Combination.

the maximum input rate and the remainder of the system is sized in accordance with it.

2.2 Input Data Storage

The input data storage function provides for the storage of all sensor input data and for the output of previously stored data to the image selection and retention function. This function is required so that raw sensor data may be retrieved after exploitation of the mission has been completed. The capability to store input data at the same time that different data is being retrieved increases system throughput. Input and output rates should sum to no more than 144 Mbits/second. Eight minutes of input at this rate must be stored.

The input data storage supports all non-real-time operations. This includes continuous sensor data output in support of manual verification. Portions of the sensor data may also be retrieved by geographic location for further analysis.

The input data storage must support the maximum sensor input rate of 144 Mbits/second. In the case of maximum input there is no requirement for simultaneous retrieval of data. Since the maximum sensor input rate requires the full resources of the sensor interface, the selection and retention function, and the image exploitation function, there are no resources available to receive retrieved data. The same is true for the case where the input data storage function is outputting previously stored data at the maximum rate of 144 Mbits/second. No input can be received while outputting data at this rate. However, when a low rate sensor is being input and stored, the output of another relatively low rate sensor is supported. In this case resources throughout the system are available to handle both. The determination

of whether resources are available to handle both input and output simultaneously should be based on the sensor combination table discussed in 2.1.2.

A directory on the location of stored data must be created and maintained in order to speed access of the stored data.

2.3 Sub-frame Selection and Retention

This function provides for the automatic selection of displayable sub-frames from sensor data received either from the sensor interface or the input data storage. A sub-frame is a displayable 1024 pixel/line by 1024 line image. Selection of sub-frames will be based on one of three criteria.

- a. Geographic location.
- b. Automatically detected targets.
- c. Decimated major frames associated with
selected sub-frames.

These selected sub-frames are stored until requested by the analyst.

2.3.1 Location Dependent Selection

In this mode displayable sub-frames are extracted from input data on the basis of geographical location. This mode may be used with or without decimation and with or without storage. By specifying all areas, this mode provides an analyst with all the received sensor data. Location dependent selection may be performed on real-time sensor data from the sensor interface or on recorded data from the input data storage.

In the modes where all locations have been specified, certain combinations of these options must be restricted. In

this mode, data input must be from the input data storage. This is due to the high rate of the data from the sensor input and the fact that all frames are selected. Data from the input data storage can be slowed to the rate at which it can be used, while input sensor data cannot. This all location mode is required in order to support manual verification and can support variable decimation ratios. Data received from the input data storage is passed (possibly decimated) to the image exploitation function for display. Coordination between the image exploitation and the input data storage is required to maintain the correct data rate. This rate must be controllable by the analyst since different tasks will be scanned at different rates.

The location dependent selection may also provide a single displayable sub-frame with selectable decimation to the analyst from the input data storage.

2.3.2 Target Dependent Selection

Target dependent selection is the primary mode of sub-frame selection. In this mode Automatic Target Classifiers (ATC's) detect and classify targets in the sensor data. Displayable sub-frames containing the detected targets are extracted from the sensor data and stored for display to the analyst. This section describes the requirements for this function and identifies some problem areas requiring further study.

The specification of the ATC is a very important system parameter. If the ATC misses a large number of targets then an analyst must regularly screen the entire high resolution sensor input data. Only with a reliable ATC does MIES provide enhanced speed of exploitation over softcopy systems which require analysts to review all

the input data. On the other hand if the ATC detects all the targets but also outputs a large number of false alarms then the analysts will be slowed by the task of sorting the false alarms from the actual targets. The latter is preferable as long as the number of false alarm frames plus actual target frames is less than the total input data.

Thus an important parameter of the ATC is the probability of not detecting a target at a given false alarm rate. Unfortunately this specification is not so simple. Clearly, an ATC will exhibit variations of this parameter with different sensors, with different targets, with different views of the same target, and with different noise levels in the input signal. Also the different types of sensors provide different performance levels depending on the "quality" of its energy source. For instance, the ATC for an electro-optic sensor will provide dramatic differences of performance based on sun angle. Obviously, the ATC for an EO sensor does not operate well at night. So, too, with the ATC for an IR sensor when the engine of the tank is the same temperature as the background.

The complete description of an ATC may be thought of as existing in an N dimensional space where a particular test image defines a point in that space. With a large number of carefully thought out test images this space can be sampled. Determining the false alarm rate by using test images without targets might be more difficult. A tally could be kept of the correctly detected targets and the false alarms to determine the ATC performance. The specification of the ATC is a difficult area where much additional study is required.

To support such testing the MIES ADM has included an entry in the target data base which records the detection method (by ATC, by analyst, or by other means). Entries detected by the ATC are

correct detections by the ATC while entries by the analyst indicate an ATC missed target. A separate tally is kept on the false alarms.

Another feature included in this function is the capability of thresholding sub-frame extraction based on target type or confidence parameters. The ATC outputs target location, target class, target size, and confidence of classification parameters. In the thresholding mode, sub-frame selection is based on the values of target class and confidence parameters. The threshold values of these parameters may be set by the analyst. In this way the analyst can reduce the false alarm rate by increasing the threshold on the confidence parameter so that only those detected sub-frames exceeding the specified confidence threshold will be extracted and stored for analyst verification.

After the ATC has identified the targets, the sub-frames containing them must be extracted and stored. This extraction involves identifying the boundaries of the sub-frame. Since multiple targets may be included in a sub-frame the efficiency of the boundary definition algorithm will be in terms of the number of sub-frames extracted for a given set of targets. Optimization of the boundary definition is desirable since fewer sub-frames would require storage, reducing the input bandwidth and total storage requirements of the retention function. Also fewer images would have to be viewed by the analysts. The time available to the algorithm will constrain the degree of efficiency possible.

2.3.3 Major Frame Selection

In order to provide a context for the selected full resolution sub-frames, decimated images of the entire sensor swath are

provided for display to the analyst. This function need only operate on major frames of sensors whose line length is greater than the display size. If the sensor's full resolution line length is less than the display size then the selected full resolution sub-frames contain all the context information available. If the sensor's full resolution line length is much greater than the display size then decimation of the major frame provides a view of the area around the selected sub-frame. The decimation ratio is such that the resultant image is displayable in a 1024 pixels/line by 1024 line display. The decimation ratio of the major frames should be selectable by the analysts with a set of default values available. Thus the analysts will not be required to calculate the decimation ratio for each sensor yet can alter this ratio if a different magnification is desired. Integer decimation is sufficient to cause any decimated image to fall between a 1024 x 1024 and a 512 x 512 display window.

2.3.4 Sub-frame Retention

Extracted sub-frames are stored until requested or deleted by an analyst. This section describes the considerations involving this storage including the size, storage priorities, and methods of access and release.

The requirement is to provide random access storage to all extracted sub-frames at least for a complete mission. Unfortunately, this does not clearly define a memory size since the number of extracted sub-frames for a mission may be any number between zero and all the sub-frames in the mission. If this memory is sized to hold every sub-frame in the mission it would store approximately 8 Gbytes or 8000 sub-frames. It is unlikely that all sub-frames will ever be

selected and the cost of providing storage for this case is quite significant. A more reasonable approach is to provide sufficient storage for the most likely cases and to provide controls to handle overflow cases through priority schemes. This is the recommended approach. The details on the size and rate characteristics of the sub-frame retention are given in 6.1.

The priority schemes define which sub-frames are retained in the case of overflow of the sub-frame retention function. Priorities may be assigned on the basis of location, target class, target confidence, and acquisition order. Two acquisition order priorities are defined as:

- a. Newest sub-frames have priority
- b. Oldest sub-frames have priority

The priority mode must be defined before the mission (possibly during the configuration of the equipment) so that it can automatically be entered on overflow. In the priority mode, sub-frames with priority overwrite sub-frames without priority. If storage becomes available due to the deletion of sub-frames by the analyst then the priority mode is automatically exited. In this case the new sub-frames are stored in the available space. If the available space is again exhausted, the priority mode is automatically reentered.

The record of targets contained in sub-frames which have been overwritten in a priority mode is kept in the target data base as described in 2.5.4. Sub-frames containing these targets may be retrieved from the input data storage function by using location dependent selection.

A method must be provided for the release of sub-frames from storage by the analysts. Two methods of release were

considered:

- a. Release on access.
- b. Separate delete.

The release on access method releases the sub-frame from storage on the first access of the sub-frame. In this case the operator accessing the sub-frame must retain it. The reason for retaining the sub-frame after access and display is to provide a source of full resolution data for remapping as described in 2.5.3.1. Because the operator must retain the sub-frame, the access then becomes a transfer from one storage media to another. The disadvantage of this method is that the transfer is slow. The advantage is that storage space in the retention function is freed as soon as possible.

In the second method, sub-frames are released only by a separate delete function. They may be accessed multiple times before deletion. Because the sub-frames are not deleted on access, they need not be stored elsewhere. This speeds the transfer and simplifies the handling of the sub-frames. A separate delete function would be required, even if the release on access were implemented, to delete those sub-frames which were not accessed. The only disadvantage of this technique is that the retention function storage must be larger.

While the release on access method is assumed throughout this report, the decision on which method to use should be reserved until the implementation of MIES is more clearly defined.

2.4

Situation Display

The situation display provides the analysts with a graphical picture of the geopolitical data and previously detected targets of interest associated with a mission area. The analyst can

initialize the display so that the cartographic and prime target data for the area that is to be covered by the mission is presented on the situation CRT. During the processing of the mission the analyst can refer to this display in order to orient his viewing to the general geographical area and to targets of interest that have been previously detected.

When the analyst is processing mission data from the SRS, non-real time processing, the situation display can be used to display all the targets that were detected during that mission. In this mode the analyst has the capability of interacting with the targets. By locating a cursor on a displayed target the analyst can request more data on that target or request that the subframe which contains that target be displayed on the subframe display.

The situation display is constructed from two graphic overlays, a cartographic overlay and a prime target overlay. If the display is to be used in the non-real time processing of data then a mission overlay which includes the sensor swath and detected targets is also displayed.

The cartographic overlay provides geopolitical data for the area of interest. This data is pulled from the cartographic data base, described in 5.6.5, and is scaled and clipped to the area of interest.

The prime target overlay displays the symbols representing targets which have been designated prime targets within the target data base and which are located within the displayed area of interest. Prime targets are previously acquired targets which have been so designated by the analyst. In the A-level specification, prime targets were called key targets. Due to a confusion with target keys,

described in 2.5.5, it was decided to rename key targets, prime targets. These targets may be non-moving targets previously validated which form a reference for the analyst or they may be used to flag the movement of a target when a subsequent mission does not show a target in the same location. The prime targets may be chosen for any number of reasons which may be defined in the operational procedures.

If the display is to be used non-real time then a mission overlay is displayed over the cartographic overlay. The mission overlay includes a graphical representation of the ground coverage of the sensor and symbols representing targets or accumulations of targets. The targets are obtained from the target data base and are displayed at the appropriate location on the display.

2.5 Image Exploitation

The image exploitation function provides the capability for manual target detection and classification, verification of automatically detected and classified targets, and further target analysis. This function maintains and updates a target data base. The man machine interface is discussed in this section.

2.5.1 Manual Screening

Manual screening provides a mode in which an analyst may review all or portions of the high resolution sensor data on the display from the input data storage function. In this mode the analyst must be capable of controlling the rate of display speed, of stopping and starting the display, and of moving forward or backward.

This mode implies control between the exploitation function and the input data storage to control the rate of data flow

from the input data storage.

Manual screening is required to support searches for targets for which the ATC's have not been trained. The different rates are required because different sized targets, numbers of targets, types of terrain, and resolutions of sensor data all can be screened at different rates. Once a target is detected the analyst must classify it. This certainly requires stopping the data during the classification. Also, the target must be logged into the target data base.

Different types of sensors may require different displays for screening. For instance, pushbroom type sensors may be most effectively displayed in a waterfall type display where a new line is added to the top of the display and each currently displayed line is pushed down by one line. Scanned sensors such as FLIR may be best displayed frame by frame. An investigation should be made into which type of displays best present the data to the operator. Speed of manual screening and operator fatigue should also be considered.

The Data Handling and Recording System (DHRS) is using a frame by frame approach where the operator provides speed control by requesting each frame by voice commands. Results on the effectiveness of this technique will be available soon.

2.5.2 Target Verification

Target verification allows the analyst to review the selected sub-frames from the selection and retention function. In this mode the analyst must be able to verify that the location and classification decisions of the ATC are correct and must be able to update the target data base in the case where errors have been made.

This function supports various methods of access of

selected sub-frames of a particular sensor. The desired access method is specified by the operator by one or more of the following parameters:

- a. Mission.
- b. Target class.
- c. Location.

Also the order of presentation is controllable by the operator. A first-in-first-out capability presents the first available sub-frame meeting the access parameters above, followed by the second and so on. In another mode the presentation of frames is controlled by the operator requests for particular targets. These requests are effectively implemented through interaction with the situation display.

Consideration must be given in this mode to the controls required to allow analysts to verify sub-frames from the same mission. Some method is required to prevent the same sub-frames from being verified multiple times.

As sub-frames are presented to the analyst they are removed from the selection and retention function to make room for new sub-frames. Any sub-frame pulled from the retention function becomes the responsibility of the operator who pulled it. If further analysis is required it should be stored locally.

2.5.3 Target Analysis

In this mode softcopy image manipulation and enhancement techniques are brought to bear on the problems of target classification and identification, and target velocity and direction. The following capabilities are available to the analysts and are described separately below.

- a. Grey scale remapping.
- b. Convolutional filtering.
- c. Magnification.
- d. Decimation.
- e. Roam.
- f. Rotation.
- g. Rectification.
- h. Animation.
- i. Pixel mensuration.
- j. Addition and Subtraction.
- k. Inversion.

2.5.3.1 Grey Scale Remapping

Sub-frames are stored in the selection and retention function and in the image exploitation function with the same number of bits/pixel as received from the sensor input function. Yet all sub-frames are displayed with 8 bit pixels. A lookup table function provides translation of the input pixels to the display pixels. This lookup table must provide for at least 10 bits to handle the required sensors. A 16 bit capability could provide expansion capability for future sensors at only a small cost. The contents of the table will be interactively manipulated by the analysts to perform enhancements through grey scale distribution remapping. Nonlinear tables, thresholding, and pseudocoloring should be included. To aid in the table definition the operator may request a histogram display of the grey scale distribution within a certain area.

This function supports expansion of grey scale differences which are very small. For instance, a tank under a tree in the

shade may be represented by pixels whose values are only a few grey levels different from the pixels in the background. At eight bit quantization these differences may not be detectable by the human eye. By histogramming the area the center value can be determined about which the differences in the pixel values are expanded, magnifying the difference between the tank and the background. Thus the tank becomes visible.

2.5.3.2 Convolutional Filtering

Additional image enhancement is available through two dimensional filtering. A single process can provide high and low pass filters and edge enhancement by using different coefficients. Provisions are included to store coefficient matrices for each of these operations.

The size of the coefficient matrix must be determined. Three by three matrices give reasonable results and are available in hardware on some video processors. If this operation is done in software it could take a significant amount of time due to the computational load. An N by N matrix operating on a X by Y image requires $N \times N \times X \times Y$ multiplications and additions. The amount of time in processing is incentive enough to keep the coefficient matrix dimensions to a reasonable size.

2.5.3.3 Magnification

The analyst must be able to magnify a display in order to see more clearly the individual pixels. This may be accomplished by pixel replication. Factors of 2, 3, 4, 5, 6, 7, and 8 are adequate. Non-integer magnifications using resampling can be achieved

at the cost of increased time and processing power. For this application non-integer magnifications are not recommended.

2.5.3.4 Decimation

The capability to reduce an image by the same factors as the magnification is included. This decimation should involve filtering before sampling. Simple down-sampling without filtering gives acceptable results for decimations factors of 2 or 3 but with factors of 8 the results are unacceptable.

2.5.3.5 Roam

The capability to roam through a 2048 x 2048 image with a 1024 x 1024 window is included. This gives the analyst the capability to search through an area at full resolution. Location dependent selection could provide the four adjacent 1024 x 1024 images necessary to put together the 2048 x 2048 image. The magnification function can work in this mode to effect small window sizes, thus allowing a magnified roam.

2.5.3.6 Rotation

A rotation function allows the analyst to rotate an image up to 360 degrees in one degree increments. Interpolation is required to avoid distortions caused by nearest neighbor resampling. This function allows the analyst to change the orientation of the image to more closely match another image or a map.

2.5.3.7 Rectification

This function provides correction for distortions in

the imagery due to the position and attitude of the sensor. The corrected image appears as it would if viewed from above. This function should be capable of operating with as few as four points in the image being earth located. The located points are used to determine a third order polynomial to be used for the coordinate transformation. The algorithm for determining the polynomial should be capable of operating with 4 or more earth located points. A polynomial is required for the approximation of the coordinate transformation because of its speed of solution. This polynomial outputs the coordinate in the input image for each coordinate in the output image. To determine each pixel in the output or resultant image, the input image coordinate is determined and the input image may be resampled by either nearest neighbor, bi-linear interpolation, or cubic convolution.

This technique of rectification will work very well with down looking sensors. Forward looking sensors present problems to this technique due to the height variations of objects within the images. For instance, a FLIR image taken from low altitude might contain a tree seen from the side. No third order polynomial can provide a coordinate transformation that will correctly transform the pixels of the tree as well as the rest of the image.

Solutions to this problem such as orthorectification techniques require considerably more processing. As the amount of processing involved in rectification is already large this additional load could be too much for a tactical system.

The rectification problem is discussed in detail in the appendices of the Interim Technical Report.

2.5.3.8

Animation

An animation function is included to aid the analysts in determination of target speed and direction and to provide support for the manual screening function. This function will animate image or graphic frames in a specifiable sequence of between 30 and 0.1 frames/second.

2.5.3.9 Pixel Mensuration Function

The pixel mensuration function provides the ground distance between two displayed pixels. The pixels may be identified by cursor positioning on the image CRT's. The calculation will be accomplished by using the applicable sensor model and performing sensor model location on each of the identified points as described in 2.6. From the two locations the distance between them is readily calculated.

2.5.3.10 Addition and Subtraction

The analyst has the capability to add or subtract two images to produce a third image.

2.5.3.11 Inversion

An inversion function is available to the analyst. This function compliments the grey scale values such that white becomes black and black becomes white. This function is used to make certain infrared images look more like visual images.

2.5.4 Target Data Base

Once a target has been detected, a record must be kept of its existence. The target data base was designed for that purpose. Throughout the image exploitation function, additions and up-

dates to this data base will be made in order to maintain all of the essential data about the targets. The exact time or reason for deleting a target has not yet been determined, with several possibilities under consideration.

The target data base will maintain target information taken from the selected sub-frames as a result of automatic target screening, manual screening, manual verification of automatically detected and classified targets, and target analysis. The image exploitation function will be responsible for data access, update and maintenance of this data base.

2.5.5

Target Keys

In order to help the analysts verify the detected targets, a set of target keys will be provided for comparison purposes. These target keys should provide the analysts with enough content that the target can be identified. The problem with implementing and maintaining this set of target keys is two-fold: the amount of detail required to accurately identify a target is needed to determine how it will be displayed; and the quantity of data to maintain could become quite large because of the number of views needed, in addition to the different types of sensors available.

There are currently three methods seen as possible solutions to this problem: the first is to have a file cabinet that is readily available to the analysts that contains hardcopy images of all the different targets from the various angles as seen through the different sensor types. The second solution would be to store a softcopy image of all those same images. The final possible solution would be to maintain a 3-dimensional vector model of the various targets from which

the different views can be synthesized. Each of these implementations has at least one disadvantage. The file cabinet is not easily accessible by its nature. Maintaining all of the softcopy images will require storage at least in the range of 20 Gbytes (assumptions: three sensor types--EO, IR, SAR, 26 viewing positions, 200 target types, and up to 1024 x 1024 bytes per image totals 16.4 Gbytes). In the final option using vector models, it is not clear whether enough detail for target identification would be presented or not. It becomes obvious that additional study is needed in this area. One possibility would be to examine in more detail (i.e., processor type, storage size, computation speed and cost) a computer image generator that was developed in France by Pascal Leray.

2.5.6 Hardcopy Output

A hardcopy output function is required. This function must be capable of providing for the output of any displayable sub-frame. The resolution should be sufficient to support a 1024 x 1024 display. Ease of film development is an important consideration.

2.5.7 Reference Image Data Base

When processing images, an analyst may decide to store an image for later reference. The reference image data base was designed to fulfill that purpose with at least two variations: to retain images that contain unique objects or targets for later reference or processing; and to keep a reference source of target keys with which analysts compare current images, if the chosen method of maintaining those keys is softcopy images of all possible views. The reference image data base will maintain these designated displayable sub-frames

and their associated ancillary data. Reference images can also come from sources other than mission sensor data. The image exploitation function will be responsible for data access, update, and maintenance of this data base.

2.5.8 Man Machine Interface

Human factors research has typically emphasized the physical design of the hardware equipment. It is only recently with the proliferation of the use of microcomputers by people with little knowledge of computers that serious design consideration has been given to interactive operator-computer interface.

This has led to the development of human-factors guidelines that can be used for the design of human-computer interface. The design principles to be used for the MIES ADM are: define the system users, know their skills and limitations, and find the simplest interface.

The general requirement for human-factors system design, whether it is hardware or software is to recognize the needs of the users. The factors which must be considered in the MIES ADM design are given in the paragraphs that follow.

2.5.8.1 Menu-Driven Operator Interface

The most important criteria for a man-machine interface is that it must be user-friendly, yet at the same time service a variety of users who range from the naive to the sophisticated. A good approach is to use a menu-driven interface which can support the requirements listed above. The following modes of user interaction are presently in use throughout the industry:

- a. Low - provides naive users with detailed menus, prompts and helps.
- b. Mid - provides moderately sophisticated users with more rapid interaction.
- c. High - experienced users control the system with modified dialogs - no prompts.
- d. Combination - a combination of these three modes which supports a range of different users.

Trade considerations include:

- a. Examine important characteristics of user-system interface.
- b. Skill level of system users.
- c. Maintain a high degree of efficiency.
- d. Maintain user-friendly interface.
- e. Consider community of users.
- f. Cost impact of various modes.

An approach which uses a combination of the modes listed is recommended. A hierarchical-menu system should be designed which will guide the new user through a set of menus where each menu is tailored for a specific function and provides a set of prompts to tell the operator what action is required, what the system default values are, and provides a set of help messages to explain each operation upon request. At the same time, the capability to provide the experienced user a method of suppressing these detailed menus and allow data entry via a system of modified dialogs with no prompts should be supported. This dual-menu approach is feasible if enough consideration is given the input data requirements and the range of system users can be well

defined.

2.5.8.1.1 Interactive Display Guidelines

As a result of Human Engineering studies in the area of man-machine interface a set of well defined guidelines for designing terminal interactions have been developed. These guidelines are listed in Appendix A paragraphs 1.0 and 2.0.

2.5.8.2 Hardware Input Devices

The input devices which must be considered for MIES ADM include an alphanumeric keyboard, graphical input devices.

2.5.8.2.1 Keyboard Input Device

The alphanumeric keyboard is a universal input device used to type in commands and enter data for programs. Design of keyboards which maximize ease of user entry include such features as: a numeric keypad, programmable function keys, a detachable keyboard which allows the positioning of the keyboard to the users preference, adjustable tilt, and sculptured keys for easier, faster use.

2.5.8.2.2 Graphical Input Devices

For interactive graphical applications, the keyboard is inconvenient or inadequate. If, for example the user wishes to indicate one of several symbols which appear on the screen it would be a difficult procedure using the keyboard unless the symbol had a label. It would be more natural for the user to point to the symbol.

Graphical input devices which support this type of interaction and are applicable for the type of uses that MIES requires

include the data tablet and stylus, the joystick, and the trackball. The choice of graphical input device for the MIES ADM is application dependent.

2.5.8.3 CRT Criteria

Monitor evaluation and selection must take into account both the environment in which the system will operate and the limitations and requirements of the users who will be operating the system on a daily basis.

There is almost an infinite range of monitor sizes, types, and display capabilities on the market. The monitor selection process for MIES must be based on finding the closest fit which meets the requirements of MIES, is compatible with existing commercial equipment, and has a good price/performance tradeoff. Wherever possible the equipment selected should be off-the-shelf commercial equipment, however because the MIES ADM has some special requirements it might be necessary to purchase custom hardware.

CRT features which should be considered from the human factors relationship as well as the hardware characteristics are discussed in the following paragraphs.

2.5.8.3.1 Monitor Screen Size

CRT monitors are available with nominal screen diagonals of up to 25 inches. A screen size of 19 inch diagonal has been selected for the MIES ADM. This selection is based on both the human factors evaluation and economy.

2.5.8.3.2 CRT Resolution

A resolution capable of displaying a 1024 x 1024 image has been selected for the video processor monitors. At the present time, this is considered to be a high resolution image and this size is supported by many commercial-type displays. This resolution presents a 1:1 aspect ratio which give a "square" image presentation and is readily available from many commercial sources.

Consideration must be given to the resolution of the display monitor. The video processor monitor will be used to display images (i.e. a picture which has gray scale values) whereas the situation display monitor will be used to display data which is more graphical in nature (i.e. cartographic information, symbols which denote the location of targets, etc.).

Therefore, this display should have the capability to perform high speed vector generation, and also , construct rectangles, arcs and markers at high speed. A trade-off study should be made regarding the resolution for the situation display device.

2.6 Target Location

Two types of target location are performed by MIES. The first type uses ancillary data and a sensor model to perform a rapid and relatively rough calculation of location. This calculation is performed often by the system since targets and images are often referenced by location. The second type uses the first type to access a Point Position Data Base and a Digital Terrain Elevation Data Base. Point transfer techniques are used to perform very accurate target location. Each analyst interacts directly with the target location function.

2.6.1 Sensor Model Location

The parameters required by the sensor model location algorithm include an image coordinate to be located, a sensor model for the applicable sensor, ancillary data giving the sensor location and attitude, and possibly a Digital Terrain Elevation Data Base (DTEDB). The result of the algorithm is the earth location of the image coordinate in a prespecified geographical projection. The sensor model together with the ancillary data and the image coordinate define a ray from the sensor to the ground assuming flat earth. Using the DTEDB it can be determined where this ray intersects the ground in the non-flat earth case. A flat earth may be assumed if a rapid calculation is required. With down looking sensors the error incurred by skipping the non-flat earth correction is smaller than in the forward looking cases.

An error sensitivity study was performed to determine the effects of errors in the values of roll, pitch, yaw, height, FOV, and depression angle. The method of analysis and the results of this study were presented in the Interim Technical Report.

Some analog FLIR formats do not provide ancillary data. For these formats location by this technique is infeasible. These image frames may be located by the PPDB technique if the general area of the mission is known.

2.6.2 PPDB Location

The sensor model technique of target location described above is not expected to provide location accuracies within the desired 50 feet unless the Global Positioning System (GPS) is used as the navigation source. In the case where GPS is not used the desired accuracy can be obtained by using the Point Position Data Base techniques described here.

The technique of location determination by PPDB has been proven through fielded systems. These systems use hardcopy film as the data base format. The time required to obtain a target location with these systems is excessive, on the order of 20 minutes. To attain the 2 minute time line, and for many other reasons, it is desirable to implement an all digital form of this technique.

The problems that must be addressed are the data base design and the point transfer procedures to be utilized. The current concept involves using the sensor model coarse location to access mono-perspective imagery from the PPDB. Sufficient imagery is pulled to cover potential errors in the sensor model location. The target point is then transferred into the PPDB image. The precise target location can then be calculated from the geodetically controlled reference image using well known photogrammetric procedures.

This is an important area for further study, particularly in the area of point transfer techniques.

2.7

Communications

The MIES ADM communicates with a correlation center via the C3I Network. The physical interface, message transfer, and message format levels of this communications are discussed.

2.7.1

Physical Interface

The MIES physical interface with the C3I Network is defined as an RS 232C interface with selectable, synchronous bit rates of 300, 600, 1200, 2400, 4800, or 9600 baud. This is a standard interface utilizing standard bit rates. Provision is included for utilizing an internal or an external clock. This is provided to aid in network

timing synchronization.

2.7.2 Message Transfer

The MIES link procedures are specified to be compatible with AUTODIN I, Mode I. This provides for full duplex operation with automatic error and channel controls, allowing independent and simultaneous two-way operations. This is the most efficient AUTODIN I mode of transmission. In this mode all transferred data is formatted in fixed length frames with error codes. Each correctly received frame is acknowledged by the receiver. Frames received in error are negatively acknowledged. Negatively acknowledged frames are retransmitted.

Messages are defined as consisting of multiple frames beginning with a header and ending with a trailer. Formats for the headers and trailers are defined in JANAP 128(H). Routing and message level error controls are also defined in this document. JANAP 128(H) is a very general specification defining many formats for different applications. Appendix I of the A level specification defines a sub-set of JANAP 128(H) for MIES.

Between the header and trailer records is the message content. This is discussed in the next section. For the purposes of JANAP 128(H) the message is a DATA PATTERN message, the format of which is not specified at this level.

2.7.3 Message Formats

The message formats specified in DIAM 57-5 FORMAT will be used within the MIES ADM to transfer imagery intelligence to the correlation center. The information provided in the Initial Photo Interpretation Report (IPIR), Supplemental Photo Interpretation Report

(SUPIR), Multi-mission Imagery Photographic Interpretation Report (MIPIR) and Reconnaissance Exploitation Report (RECCEXP) will be adapted for use in the MIES ADM.

The IPIR/SUPIR/MIPIR formats have provisions for containing sufficient information to satisfy current intelligence requirements, support subsequent detailed interpretation and to be entered into the DIA Automated Intelligence Data Base. The RECCEXP format provided for reporting on Essential Elements of Information (EEI). Together these formats provide for mission reporting and individual target reporting.

The mission report format will provide mission identification information and textual messages containing mission objectives, highlights and significant results. Additionally, the report will contain information on individual items of interest that were included in the mission, the geographical and geopolitical location of the items, as well as any interpretation data pertaining to the items. Also included in the mission report will be imagery reference data (source and quality of the imagery data) and any obstructions or weather conditions that may effect the interpretation of the imagery. A detailed description of the mission format can be found in the DO Operation Instructions 200-4, 16 November 1977, titled Intelligence - Initial and Supplemental Photo Interpretation Reporting - DIAM 57-5A FORMAT.

The individual target report format will be used to respond to specific target requests and EEI requests. The target category along with the information about the target will be reported to the requesting center. The standards outlined in STANAG No. 3596 (Edition No. 4) promulgated on 21 April 1980 will be used when reporting

on EEI and targets. The individual target format will also have provisions for recording explanatory remarks for unanswered EEI or undetected targets. The DO Operating Instructions 200-2, 7 September 1979, titled Intelligence - Reconnaissance Exploitation Report (RECCEXP) explains in detail this reporting format.

2.7.4 Report Generation

Reports must be generated and transmitted via the C3I in response to the detection of new targets, for position updates to existing targets, and also in response to requests for information concerning specific targets. The data necessary for the report is collected and formatted. The supervisor is notified before the report is transmitted via the C3I link.

There are two general types of target reports sent by the MIES ADM. The first contains information concerning a group of targets acquired as a result of the processing of a mission. When a mission is received, sub-frames of imagery are removed from the frame queue buffer in real-time for examination by a target analyst. The analyst validates each target and upon completion of the analysis the sub-frame is removed from the queue. Any remaining targets within the image are not validated individually but are group validated. As analysts verify, classify, analyze, and locate targets, this information is stored in a MIES target data base. The analyst also interacts with the data base to correlate new targets with previously classified targets to determine speed and direction of travel. The message generation function gathers the information necessary to generate reports from the analyst's activities while validating targets. A mission report containing parameters for each target is automatically generated when all

targets for a single mission have been individually or group validated. The IPIR/SUPIR/MIPIR as specified in DIAM 57-5 contain the necessary information needed for mission reporting.

A second type of report transmitted via the C3I is generated in response to a request for information concerning specific targets. The request may be for an EEI, it may be a frag order or a RECCE task. A RECCEXP provides for reporting on individual targets and EEI.

A request may create the possibility of an inquiry about a target not found within the target data base. This may be because the request is received before the mission has been completed, because the target detection system could not identify the target in question, or because the target does not exist. In such cases, the analyst must respond to the request and ascertain the reason for no target found. The RECCEXP contains provisions for including reasons for unanswered EEI or targets that could not be acquired.

The supervisor is notified as the reports are generated, and the reports are then stored until authorized for transmission. The supervisor has the option of reviewing the reports before authorizing them.

2.7.5 Communication Security

The information passed between MIES and the Enemy Situation Correlation Element (ENSCE) would be quite valuable to the enemy. This information must be protected. The most common method of protection in this case is by encryption. Encryption of the data typically involves encrypting every bit output to the link including framing characters, headers, and trailers. All incoming data is decrypted.

This is the simplest means of encryption for MIES. On the other end of a dedicated link is a complimentary encryption/decryption device(s). If any further routing is required these links are also encrypted.

2.8 System Management

2.8.1 Definition

The purpose of System Management is to provide a centralized control point for all ingest, processing, communication display and man-machine interface operations of the MIES ADM. The local supervisor must be provided with the capability for mission control, configuration control, and status monitoring and reporting.

2.8.2 Mission Control

Local resources are allocated to support a mission on a priority basis. A real-time scheduler will operate to organize the system workload to ensure the most effective use of all resources and satisfy the key objective of maximizing system throughput. It will automatically couple the steps required to process a mission to resources available. The scheduler provides access to limited resources by allocating one or more of three input sensor channels available to support the required bandwidths, tape drives required for data storage, memory, DFQ space, and bus space. Also selected is one of three possible sub-frame selection and retention functions and a processing route for incoming data. In addition to assigning and initializing resources, the real-time scheduler will select the required ATC processing algorithm based upon the sensor type.

Under normal operations the scheduler will incorporate information concerning incoming missions: their duration, sensor types, priority and the type of processing to be performed, and will

then select optimum configurations for highest priority missions. If the workload requested cannot be handled by the system or cannot be scheduled, then the supervisor is notified and advised as to possible system configurations and the consequences of alternate selections. This allows the supervisor to make informed decisions regarding resource allocation for mission support. Workload problems may occur when the system is required to support high priority missions on short notice.

The real-time scheduler will be designed around a set of tables which may be easily modified as the system is expanded with new or additional sensors or other resources. These tables will correlate sensors to resources and determine the effect of different combinations of sensors.

The supervisor or target analyst has the capability to terminate image production or initiate image retrieval. These operators are also provided the capability for audit trail processing and reporting.

The system management function is the interface control point for error message handling. The supervisor has responsibility for data access, update and maintenance of the help and error message data base.

2.8.3 Configuration Control

The supervisor has the capability to configure the image exploitation system by assigning the available consoles to the necessary operators. Upon command from the supervisor, the software necessary for the selected configurations will be downloaded to the consoles. The current configuration status will be made available to the supervisor and/or other software.

The supervisor also initiates the startup procedure, which activates the software components and assigns logical devices to physical devices. In this way the supervisor can bring up the system after initialization, or restart it in the case of a shutdown. All programs can be deactivated by the supervisor.

2.8.4 Status Monitoring and Reporting

The status monitoring and reporting function regularly receives and compiles system status information and makes this data available to the supervisor upon request.

At the system level, status is reported by exception, so that a resource is reported as inoperative when an attempt to access it has been unsuccessful, or self-diagnostics indicate a malfunction. Such failures, along with indications of healthy conditions, are reported to the system status monitoring and reporting function where they are collected and used to determine overall system status.

Also available to the supervisor is a GO-NO GO readiness test which is a tool for determining the system's capacity to handle a given mission. This test effectively determines the accessibility of the required resources. The results of the test signify the general system status.

MIES ADM system status may be reported upon request to the ENSCE. This will allow ENSCE to plan and coordinate missions based upon available ground support.

2.9 System Timelines

System timelines should not be levied on the MIES

ADM in order to allow cost effective implementations in commercially available equipment. The specification of timelines must be considered carefully since unreasonably short timelines can have dramatic effects on the cost of the system.

2.10 Security

An enemy could gain considerable advantage from the acquisition and use of the information within the MIES ADM. Therefore, measures must be taken to safeguard that information. A complete threat analysis should be performed and a set of safeguards constructed to protect against these threats. This section outlines some of these considerations.

The ADM could be operated at a system high security classification in a shielded and physically secure lab. In this mode the complete ADM is operated at the security level of the part of the system requiring the highest security. All operators would be cleared to this level. Physical security could prevent access of personnel not cleared to this level. TEMPEST shielding of the equipment area as a whole prevents compromising emanations without having to repackage commercial equipment into TEMPEST enclosures. The ADM can be completely enclosed with only AC power requiring Red/Black isolation. Equipment for simulating the C3I interface and for providing the sensor input could be included in the same enclosure. Consideration should be given to the problems of bringing magnetic media in and out of the secure area. A clean/clear function should be provided to sanitize storage media.

3.0 OPERATIONS ANALYSIS

3.0

OPERATIONS ANALYSIS

This section describes the operation of MIES from the point of view of the operator and the considerations which lead to this implementation. The analysis is broken down into four major areas--Real-Time and Non-Real-Time Analyst Operations, Supervisor Operations and Utility Operations. A diagram depicting this breakdown is illustrated in Figure 3.0.

3.1

Real-Time Analyst Operations

Within the real-time analyst operations, there exist three possible process routes for the data. The first process route serves the primary purpose of the MIES ADM--the high speed processing of reconnaissance sensor data. The analyst enters this mode in order to ingest reconnaissance imagery, select sub-frames, validate targets detected and generate reports. The first step in this sequence is the ingesting, formatting and storage of the imagery and ancillary data. Simultaneous with storing the data, sub-frames are selected based on targets detected and/or geographic location of the sub-frame. The analyst then examines and validates those chosen sub-frames. Accumulating data on the targets for the entire mission and generating a report is the final step.

The second process route that is available in real-time is to ingest the data, store it, and select sub-frames for later validation. The purpose of this option is to handle the situation where all of the analysts are occupied working on missions with a higher priority. In this way, the data is preprocessed to the maximum extent and is ready for validation by the next available analyst.

The final real-time process route is composed of two

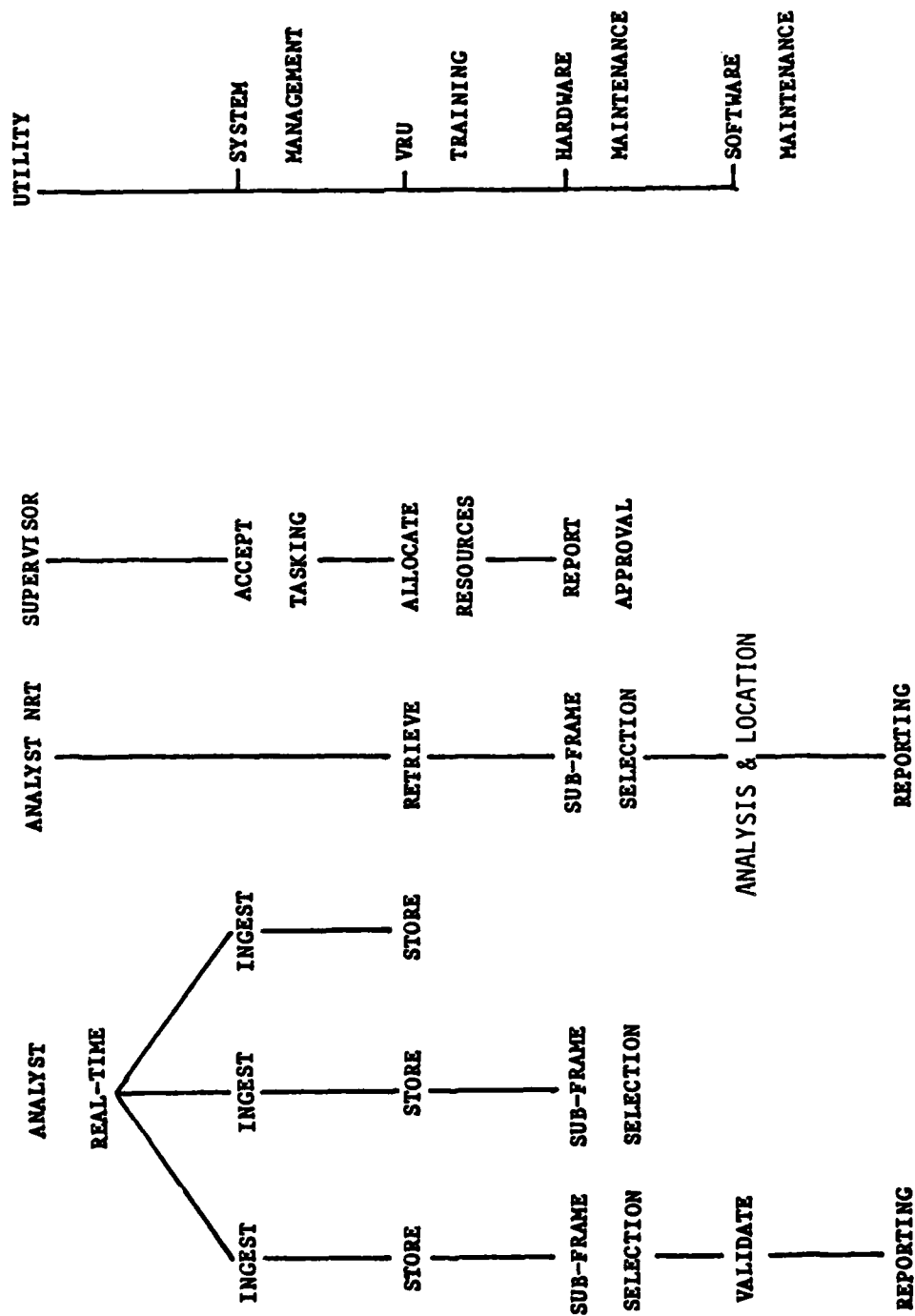


Figure 3.0. Operational Breakdown.

basic steps: ingest and store the data. This route was devised to handle the case where all of the ATCs are currently occupied working on higher priority data. As in the second route, the data is being preprocessed to the maximum and is waiting for the next operation, namely sub-frame selection.

3.2 Non-Real-Time Analyst Operations

In non-real-time the analyst has extended analysis capabilities in addition to the capabilities of the real-time operations. In this case, the analyst retrieves previously stored data through the input data storage function. Sub-frames are then selected out of the major frames by one of three methods: target detection, target detection and location, or location. The data can now be processed by an extensive list of image manipulation functions, including image enhancements. Other options available to the analyst are: target location, determining direction and speed of travel of targets, utilizing the situation display and comparison of target images with reference images and target keys. The analyst would also follow-up on outside cueing orders, searching for specific targets or trying to obtain more information on known targets.

3.3 Supervisor Operations

The Supervisor performs the system management functions required to initialize and configure the MIES ADM, including system startup, shutdown, and initialization.

The Supervisor accepts mission tasking via the C3I and allocates resources and personnel to the missions on a priority basis. The System Management function is informed of expected missions,

their sensor types and priority, and the type of processing to be performed, and will then provide the Supervisor with information, including optimum resource assignments to assist in configuring the MIES ADM to support the missions. The Supervisor must allocate input sensors to channels, tape drives, memory, DFQ space, bus space, and choose a sub-frame selection and retention algorithm and a processing route.

The Supervisor also has the capabilities of image production termination and audit trail tracking. Equipment malfunctions are reported to the Supervisor, who must also respond to system help and error messages. The Supervisor is notified of all reports that have been generated and has the option to authorize them before being transmitted via the C3I. Intelligence data base queries will also be performed by the Supervisor.

3.4 Utility Operations

The utility operations mode is entered to perform Voice Recognition Unit (VRU) training, or software and hardware maintenance. Voice training consists of displaying vocabulary words to the analyst and receiving and saving resulting voice reference patterns generated by the voice recognition unit. The software maintenance operation consists of software updates (compilation, task building, etc.) and operating system updates. The hardware maintenance operation performs hardware diagnostics and built-in tests for all subsystems. The supervisor initiates diagnostics of built-in tests to a particular subsystem and the result of the test is displayed on the analyst's alphanumeric terminal.

4.0 DESIGN ALTERNATIVES

4.0

DESIGN ALTERNATIVES

This section presents three candidate architectures and presents the advantages and disadvantages of each. A system with tape storage only is compared with a system with random access memory only. A hybrid, with both tape storage and random access memory is shown to be the best approach for current technology.

4.1

Low Cost Architecture

The low cost architecture provides mass storage via a serial access storage device such as Wide Band Tape (WBT). This architecture is shown in Figure 4.1 and is described below.

The sensor input function receives the sensor data, performs format conversion, and passes the data to tape storage and to the ATC's. The ATC's detect and classify targets. The location and classification data is stored in the target data base. After the mission is completed the tape is rewound and the previously stored data is output to the frame selection function. Using the target location data stored in the target data base, the frame selection function pulls the targeted frames from the sensor data and passes them to the exploitation function for verification and analysis by the operators.

The advantage of this architecture is the cost effectiveness of the mass memory. Up to 80 Gbytes may be stored on a single reel. Reels may be readily changed so that data can be archived. The cost per Mbyte is on the order of tens of dollars. Considering the changing of reels as additional storage capacity makes this media even more attractive. Also an advantage is the simplicity of the architecture.

Serial access storage presents several

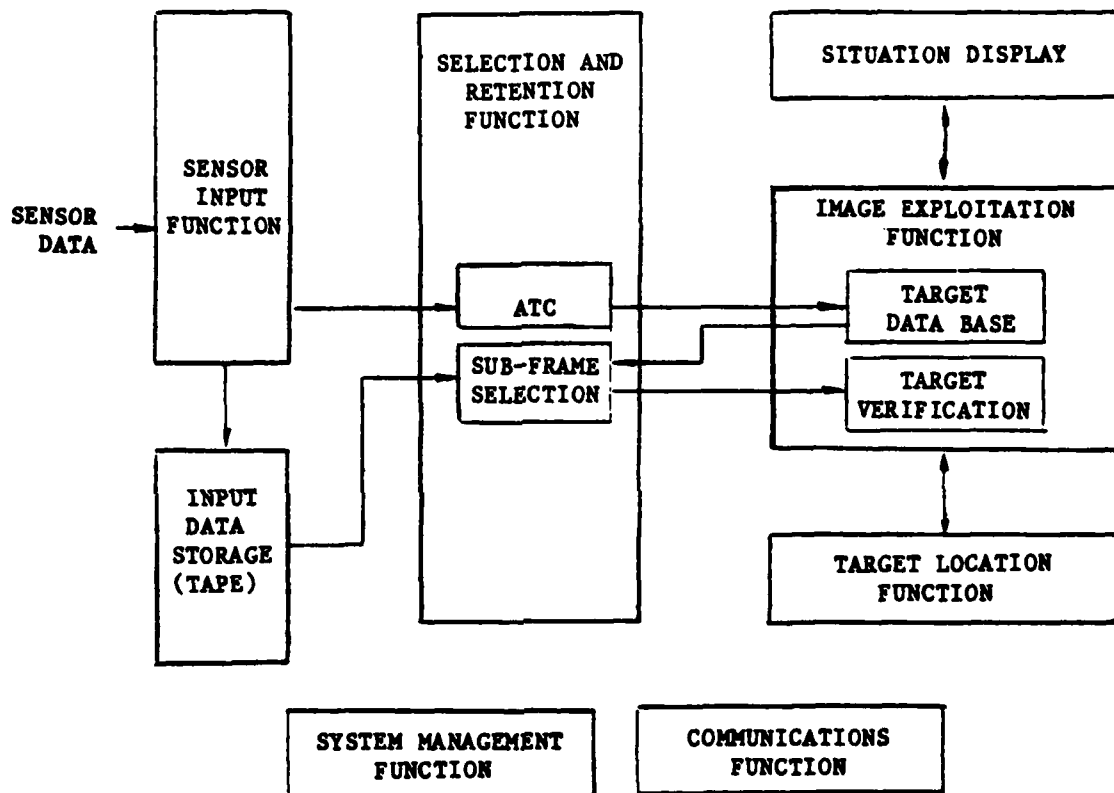


Figure 4.1. Low Cost Architecture.

disadvantages. The operator must wait for the entire mission to be completed and the tape to be rewound and restarted before the first frame can be verified. For an eight minute mission with 6 minute rewind time, it could be almost 15 minutes after the mission began before the first frame could be displayed. Two tape units could increase the efficiency of the system by overlapping sensor input with frame selection. An access method to the targets other than first-in-first-out would incur a time penalty as the tape would have to be rewound or fast forwarded to access the requested data. On most wide band tapes the time to stop or start the tape is on the order of seconds.

Unfortunately, the disadvantage of the time penalties of the serial access are increased dramatically when three sensors are operated simultaneously. Since operators will perform at different rates more starting and stopping of the tape is required. Response time to a request for a targeted frame would be on the order of minutes in this case. Since a primary goal of MIES is to increase the speed of exploitation while supporting multiple sensors this response time is unacceptably slow.

4.2

High Performance Architecture

A high performance architecture using all random access bulk storage was considered. This architecture is shown in Figure 4.2. In this system all data from the sensor input is passed to an ATC and is simultaneously stored in a large random access memory. The frame selection function extracts sub-frames from this memory and passes them to the exploitation function. Sufficient random access memory must be included to support the full input rate for eight minutes.

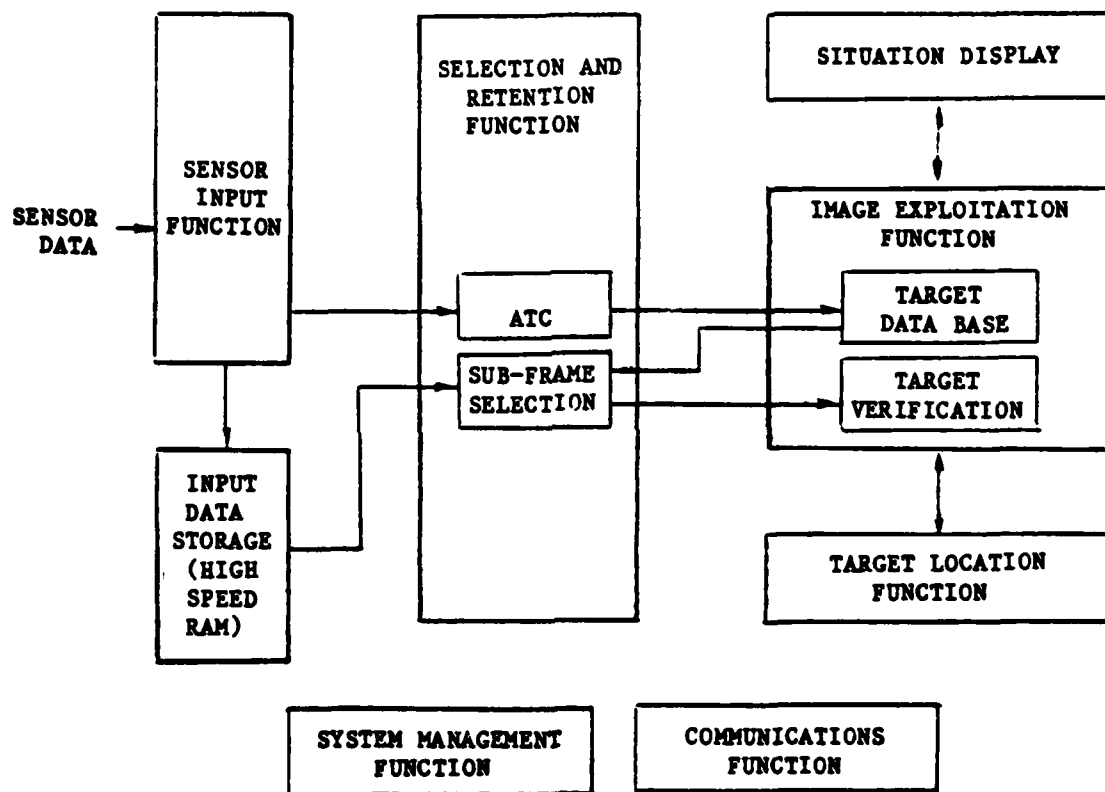


Figure 4.2. High Performance Architecture.

This architecture has the advantage of being very fast. The random access memory reduces access time penalty to less than the data transfer time. The first target is available to the analyst within seconds of its detection. The large memory enhances the system flexibility. The operator can validate targets in any order. After the mission is over sensor data can be rapidly extracted for any location or for any target. Three operators could perform manual verification simultaneously up to the bandwidth of the memory without impacting each other. In short every operation involving sensor data access would be dramatically faster than the tape storage architecture.

The drawback with this implementation is its cost and size. A memory system capable of storing an 8 minute mission at 144 Mbits/second would require 8.6 Gigabytes. If the memory were implemented with 300 Mbyte disks, 29 drives would be required to support the storage. But 29 drives are insufficient to support the bandwidth requirements. If each disk provides 450 Kbytes/second after taking into account head moves and rotational latency, then 40 drives will support the input rate. The output bandwidth requires still more.

The picture is even bleaker when solid state memories are considered. Dynamic 64K RAM's are currently being packaged with as much as 64 Mbytes per 15.75 inch chassis. At this density 135 chassis would be required. While optical disks may be a reasonable solution to this problem, the devices meeting this requirement are still under development.

Clearly the high performance architecture is not currently a reasonable solution to the MIES problem.

4.3

Hybrid Architecture

This architecture combines the high density memory of tape storage with the speed of random access memory to obtain most of the advantages of each while avoiding most of the disadvantages. This architecture is shown in Figure 4.3.

In this system all data from the sensor input is stored on Wide Band Tape at the same time as it is being stored in a relatively small high speed random access memory. The ATC also receives the sensor data and detects and classifies targets. Full resolution data containing the targets is pulled from the high speed memory by the frame selection function based on inputs from the ATC. The targeted data is stored in a larger random access memory where it is available to the exploitation function.

This system provides the high density storage advantages of Wide Band Tape. All sensor input data is recorded so it is available after the mission. Thus the bulk of the data storage is handled by the most efficient storage media. The high speed RAM provides short term storage to hold the raw sensor data only long enough for the ATC or the location dependent selection algorithm to provide the location of the required sub-frames and for these sub-frames to be pulled. Only the requested sub-frames (those containing targets, those for a requested location, and those of decimated major frames) are stored in the next random access memory. Thus the size of the random access memories is greatly reduced from the high performance architecture. The high speed RAM might be implemented with as few as 4 chassis. The larger memory might be implemented with three 300 Mbyte disks. Yet random access of requested targets is still retained. The two stages of random access memory add a small time penalty over the high performance architecture. Still the first selected sub-frame is

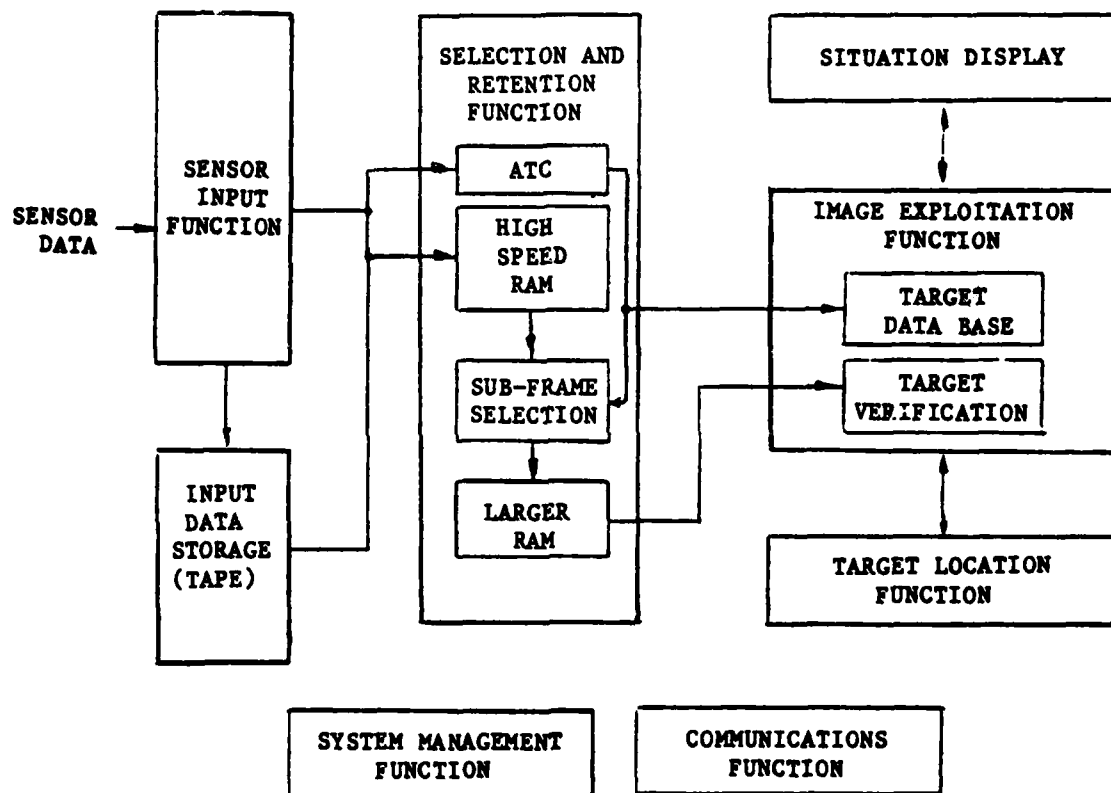


Figure 4.3. Hybrid Architecture.

available to the operator for validation in a matter of seconds. The access penalties of the tape storage are reduced because the tape is not accessed as frequently as in the tape based system. Since the requested sub-frames are available in random access memory, the tape need be accessed only for manual screening and for retrieving requested sub-frames after the mission.

This architecture was selected to meet the MIES mission. Details of the architecture are discussed next.

5.0 SELECTED ARCHITECTURE

5.0

SELECTED ARCHITECTURE

This section describes the architecture selected for the MIES ADM. The description begins at the system level with the definition of the subsystems and the associated data flow. The subsequent subparagraphs detail the operation of the subsystems with a discussion of candidate implementations where applicable.

The MIES ADM will be divided into the following subsystems:

- a. Sensor Input Subsystem (SIS).
- b. Storage and Retrieval Subsystem (SRS).
- c. Image Staging Subsystem (ISS).
- d. Target Detection and Identification Subsystem (TDIS).
- e. Display Control Subsystem (DCS).
- f. Control Processor Subsystem (CPS).
- g. Point Position Data Base (PPDB).
- h. Internal Distribution Subsystem (IDS).

A subsystem block diagram of the MIES ADM is shown in Figure 5.0. Imagery and ancillary data from the sensors is received by the Sensor Input Subsystem (SIS). The SIS formats the data into a common digital format which can be processed by the system. All received data is stored in the Storage and Retrieval Subsystem (SRS) for later non-real-time exploitation of the sensor data. Data retrieved from the SRS is passed back to the SIS for further processing. The SIS passes either real-time sensor data or non-real-time data retrieved from the SRS to the Target Detection and Identification Subsystem (TDIS) and the Image Staging Subsystem (ISS). The TDIS detects and classifies targets located in the input imagery and passes this information to the ISS. The

ISS selects displayable subframes from the input imagery based on geographic location as determined by the ancillary data and/or targets found by the TDIS. The selected subframes are stored by the ISS until they are released by the Display Control Subsystem (DCS). The DCS provides a complete image processing man machine interface. Each DCS is provided with a personality module which allows it to support image analysts or the MIES ADM supervisor. The image analysts have access to the Point Position Data Base (PPDB) which allows the accurate location of designated targets. The Control Processor Subsystem (CPS) provides general system configuration support, a C3I communications interface, and common data bases required by the DCS's.

5.1 Sensor Input Subsystem

A block diagram of the Sensor Input Subsystem (SIS) is shown in Figure 5.1. The SIS provides a Source Interface Module (SIM) for each required sensor interface. Each SIM provides synchronization with the incoming data stream and analog to digital conversion on analog sensor inputs. Any ancillary data is decommutated from the imagery data if required. The digital imagery and ancillary data is passed to the Data Formatter (DF). The DF formats the incoming data into records with header data which indicates the mission and record number. The header data is used throughout the system to uniquely identify a subframe of sensor data. The DF passes the formatted data to the SRS for storage and distributes real-time sensor data and/or data retrieved from the SRS to the ISS and the TDIS. The Input Control Processor (ICP) provides SIM selection and format selection for the DF under the control of the CPS.

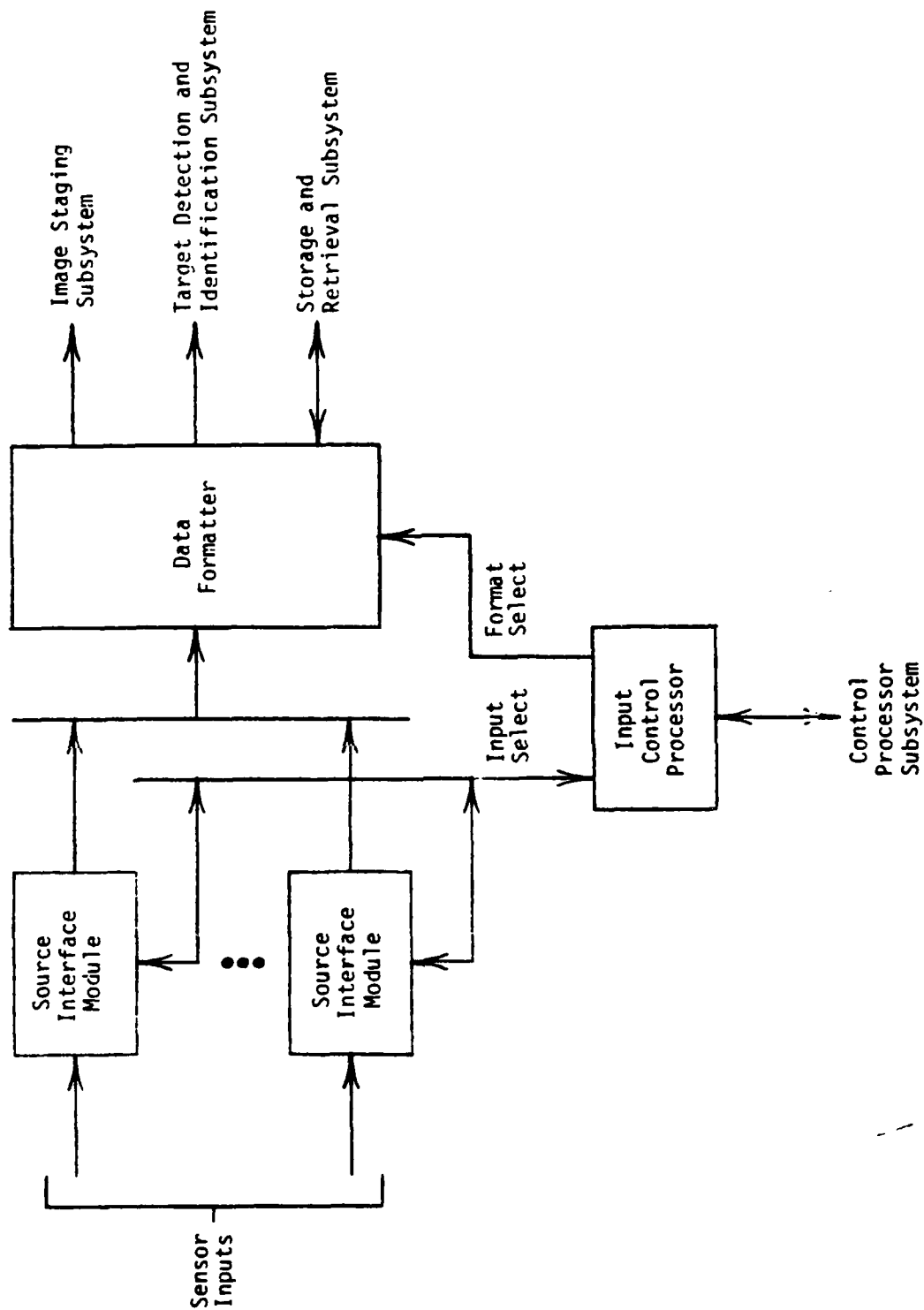


Figure 5.1. Sensor Input Subsystem Block Diagram.

5.1.1 Sensor Input Module (SIM)

The SIM's should be designed to provide a common digital interface with the Data Formatter (DF). This will allow the SIS to be configured to support different existing or future missions.

5.1.2 Data Formatter (DF)

The DF formatting function must be capable of receiving data from up to three SIM's simultaneously. This data must then be formatted in a manner which will allow any subframe of imagery to be uniquely identified over a reasonable time frame. To accomplish this, each mission is assigned a unique number and the incoming data is broken into numbered records of equal length. An individual subframe is then identified by mission, record and the pixel and line within the record of its upper left corner. The data format must also provide for the recognition of the beginning of a line, field, or frame. The format should also minimize the differences between the sensor types within the system.

The DF distribution function performs the switching between the real-time and non-real-time modes within the system. All formatted sensor data received by the system must be passed to the SRS for storage. The data distributed to the TDIS and ISS is selectable between real-time sensor data and non-real-time data retrieved from the SRS. Up to three independent missions must be supported by this function with any combination of real-time and non-real-time data.

5.1.3 Input Control Processor (ICP)

The ICP interfaces with the CPS to provide system control of the SIS. The ICP enables CPS selected SIM's to the DF and

instructs the DF of the data types being formatted. Any SIS error checking will be performed by the ICP and reported to the CPS.

5.1.4 SIS Implementation

All of the functions performed by the SIS are unique to the requirements of the MIES ADM. Custom designed hardware and software will be necessary to meet the requirements.

5.2 Storage and Retrieval Subsystem

A block diagram of the Storage and Retrieval Subsystem (SRS) is shown in Figure 5.2. The Data Mux/Demux (DMD) receives imagery and ancillary data from the SIS and distributes it to the appropriate Storage Media. The ancillary data is also passed to the SRS Control Processor (SCP). The SCP formats the ancillary data and the storage location of the data and sends it to the CPS. On data retrieval, the DMD searches the retrieved data for the correct record and transfers this data to the SIS for non real-time processing.

The required data storage for the SRS is 20 Gbytes at an input rate of 144 Mbits/second. With current and near-term projected technology, Wide Band Tape (WBT) is the only cost effective medium capable of supporting these requirements. With WBT as the storage medium, the requirement to be able to store and retrieve data simultaneously means that at least two WBT drives must be available in the system since WBT drives do not support random access during simultaneous record/playback.

5.2.1 Data Storage

For data storage, the DMD is responsible for switch-

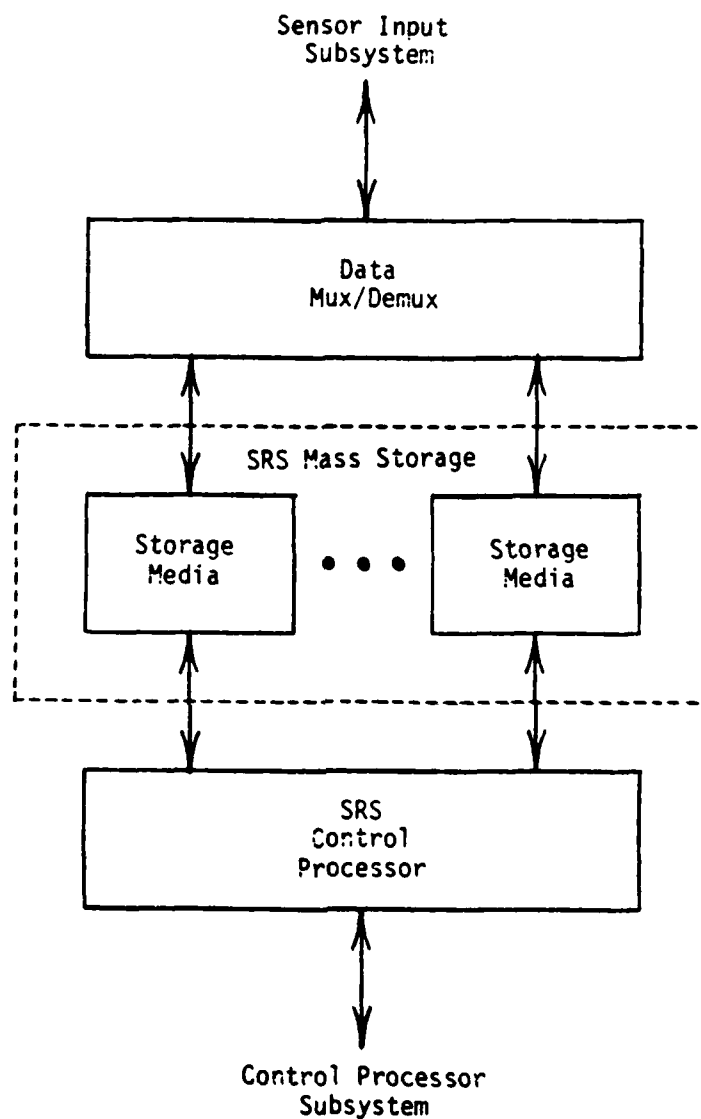


Figure 5.2. Storage and Retrieval Subsystem Block Diagram.

ing the incoming data to the correct tape drive. The ancillary data is also passed to the SCP. The SCP combines the ancillary data with a tape location value from the WBT drive and the tape reel identifier and transmits this data to the CPS to allow the generation of an SRS tape directory.

5.2.2 Data Retrieval

For data retrieval, the CPS checks to see if the required tape reel is mounted and issues a tape mount message if necessary. When the proper reel is on line, the SCP is notified by the CPS. The SCP winds the tape to the approximate location determined by the CPS and the DMD searches the playback data for the specified mission/record. When the record is located, the data is passed to the SIS for exploitation. The speed of playback is controlled by the ISS via the SIS.

5.2.3 SRS Implementation

The functions performed by the DMD and the SCP are unique to the requirements of the MIES ADM. Custom designed hardware and software will be necessary to meet the requirements. The Honeywell HD-96 is a candidate for the WBT drives. The HD-96 meets all of the requirements of the SRS Mass Storage.

5.3 Image Staging Subsystem

A block diagram of the Image Staging Subsystem (ISS) is shown in Figure 5.3. The Buffer Input Processor (BIP) receives data for up to three sorties from the SIS. The BIP maintains a rolling window of full resolution and full-frame decimated data from each of the

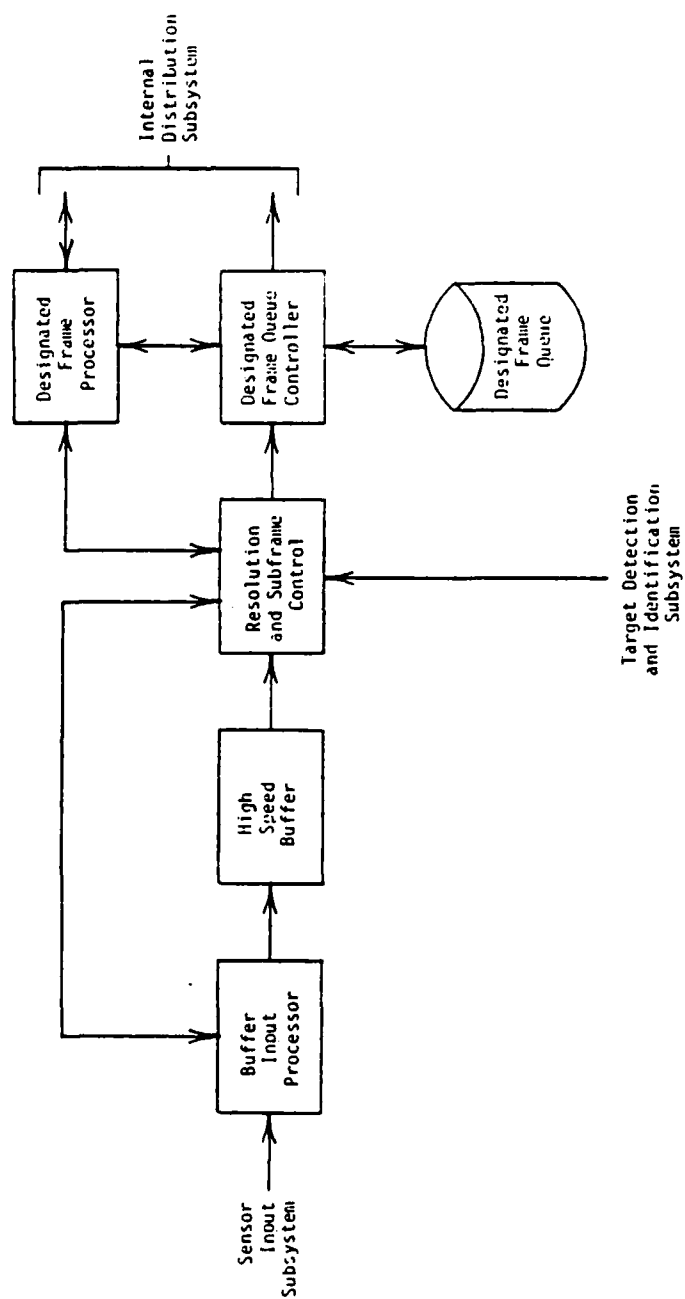


Figure 5.3. Image Staging Subsystem Block Diagram.

sensors in the High Speed Buffer (HSB). As the imagery is loaded into the HSB, the BIP updates the HSB directory maintained by the Resolution and Subframe Control (RSC). The RSC selects sub-frames from the HSB based on geographic location as determined by the ancillary data, targets located by the TDIS, or a combination of these two parameters. The selected sub-frames are stored on the Designated Frame Queue (DFQ) by the Designated Frame Queue Controller (DFQC). As the sub-frames are stored, the Designated Frame Processor's (DFP) queue directory is updated. The DFP maintains the queue directory and handles requests for sub-frames received via the IDS from the DCS consoles. When a sub-frame request is received, the DFP determines the location of the sub-frame on the queue and notifies the DFQC. The DFQC pulls the sub-frame from the queue and transmits it to the requesting DCS via the IDS. Sub-frames are automatically deleted from the queue as they are pulled by the DCS's.

5.3.1 Buffer Input Processor (BIP)

The BIP maintains a rolling window of high resolution data in the HSB for up to three simultaneous missions. A candidate approach to handling this requirement is to provide three independent memory controllers, one for each of the three simultaneous missions. Each of the memory controllers will have a portion of the HSB allocated to it for data storage. Each of the memory controllers will have to communicate with the RSC to identify potential data overwrite problems. For a single, high speed sensor data input, the three memory controllers could be synchronized to allow each controller to handle one third of the sensor data. Similarly, an intermediate speed sensor could be handled by synchronizing two of the controllers, leaving the third con-

troller available for a low rate sensor.

The BIP must also perform the pre-staging decimation of the input imagery for up to three simultaneous missions and maintain a rolling buffer of each in the HSB. This decimated data is used to provide the analysts with a positional reference for sensors with more than 1K pixels per line. The candidate approach here is similar to the high resolution storage approach discussed above. Three decimators are provided which can be operated independently or in synchronization depending on the sensor input data rate. The decimators also have to communicate with the RSC to identify data storage locations.

All of the functions performed by the BIP are unique to the requirements of the MIES ADM. Custom designed hardware and software will be necessary to meet the requirements.

5.3.2 High Speed Buffer (HSB)

The HSB will require a minimum of 120 Mbytes of high speed random access memory. These requirements can be met with existing technology. Rapid advances are making this technology more cost effective. Two candidate architectures for the HSB have been considered and are discussed below.

The first candidate architecture for the HSB is to divide the buffer into n smaller, physically independent, byte-wide buffers where n is greater than or equal to 9. Each of the smaller buffers would be dynamically allocated to one of three input buses or three output buses. With this architecture, a larger number of buffers (n) provides easier control over the allocation of the buffers. The minimum requirement of 9 buffers is based on the three simultaneous missions case. This would allow three buffers to be assigned to each

mission, one input buffer, one output buffer, and one idle buffer for rate buffering. This architecture eliminates the I/O bandwidth problem of the HSB since each buffer is performing a single operation (i.e., either reading or writing) at a given point in time. Addressing of the memory by the BIP and RSC is not more complicated using this approach. The primary disadvantage of this approach is the requirement to design the smaller memory systems. The number of buffers necessary with this approach is a subject for further study.

The other candidate architecture for the HSB provides a single physically contiguous memory system with a word width of 64 bits or greater. Memory systems of this size typically use interleaving and wide words to provide a high I/O bandwidth. This will allow the memory to be dual ported with one input port and one output port. With this architecture, the BIP and the RSC will provide a first in first out buffer for each mission to allow data to be burst into the HSB at the maximum bandwidth of the memory system. This additional buffering is necessary to allow the memory interleaving process to function. Memory systems of the type described here are available as off-the-shelf systems from multiple vendors.

The storage of the full frame decimated images is probably best handled by a smaller, independent memory system. This allows the full bandwidth of the larger memory system to be dedicated to the full resolution data. The full frame storage requires 3 Mbytes of memory with a lower I/O bandwidth requirement due to the decimation process.

5.3.3

Resolution and Sub-Frame Control (RSC)

The RSC has to select and pull high resolution sub-

frames from the HSB. Sub-frames are selected based on location and/or targets detected by the TDIS. As the sub-frames are pulled from the HSB, this function also provides the capability to perform decimation at ratios determined a priori by the analysts.

Sub-frame selection by location is the least demanding of the two processes. This process must allow selection of a set of geographic points and/or a bounded geographic area which have been selected a priori. This allows time for preprocessing to determine the sub-frame geographic areas which must be pulled from the HSB. During the mission as the data is stored into the HSB, the RSC must calculate the geographic area covered by the incoming imagery using the ancillary data and sensor model. When a match is found the appropriate sub-frames are pulled from the HSB.

Sub-frame selection by target locations detected by the TDIS is a more demanding process with all calculations having to be performed in real-time as the data is ingested. This process is complicated because of the requirement to pull as few sub-frames as possible which completely contain all of the targets. It should be noted here that a target located on the boundary of a sub-frame is not very useful for validation and exploitation due to having insufficient background information for contextual reference. It is assumed in this discussion that targets contained by a selected sub-frame do not lie within a given distance (in pixels) of the edge of the sub-frame. The size of this boundary is a function of target size and sensor resolution. However, it is necessary to store as few sub-frames as possible to prevent unnecessary storage of redundant data on the DFQ, a limited resource. The TDIS must provide both a location and size in pixels for this function to operate effectively. After a sub-frame has been identified the RSC

must transfer the imagery data from the HSB to the DFQ for longer term storage. This requires that the RSC coordinate data transfers with DFQC. Ancillary data for the selected sub-frame must be transferred to the DFP for storage in the DFQ directory. Two candidate sub-frame selection algorithms are discussed in the following paragraphs.

The first selection algorithm defines a rectangle which just fits the first target detected. As new targets are detected, the algorithm determines if the current rectangle can be expanded to contain the new target and still be smaller than the displayable area of the sub-frame. If the new target fits within the expanded current rectangle then the current rectangle is updated and the next target is obtained. If the rectangle extends too far along a line then a second rectangle is begun to contain it. When the TDIS has processed all of the lines contained by a sub-frame identified by one of the test rectangles, then the sub-frame is pulled from the HSB for storage. There are several problems associated with this algorithm. Under certain target clusterings, the selected sub-frames are nearly 100 per cent redundant. It is also unclear how to determine when the TDIS has processed all of the lines contained in a particular sub-frame.

The second selection algorithm uses a similar technique to identify the first sub-frame. The difference is that in areas of target clustering, the first sub-frame defines a 1K by 1K grid which is used to pull completely non-overlapping contiguous sub-frames within the area of clustering. This algorithm provides stored sub-frames which are entirely non-overlapping. This technique will typically require that two or four sub-frames be displayed simultaneously at the DCS, scrolled to form one large image. This will be necessary to prevent targets from appearing only at the edge of a displayed image. This rep-

resents a new requirement on the DCS and will impact image display timelines. The advantage is better utilization of the DFQ resource.

More study will be required to determine the optimum algorithm for sub-frame selection and to select the hardware necessary to support the algorithm. All of the functions performed by the RSC are unique to the requirements of the MIES ADM. Custom designed hardware and software may be necessary to meet the requirements.

5.3.4 Designated Frame Queue Controller (DFQC)

The DFQC must support a multiple disk drive storage system with simultaneous input and output. The DFQC is responsible for performing the actual data transfers under the direction of the DFP. Data transfer rates for this function are discussed in section 6. Data storage and retrieval locations will be determined by the DFP. Retrieved sub-frames will be transferred to the appropriate DCS via the IDS. The functions performed by the DFQC will require a combination of custom hardware and software and off-the-shelf disk controllers.

5.3.5 Designated Frame Queue (DFQ)

The storage and data transfer rate requirements of the DFQ are most cost-effectively met by a multiple disk drive storage system. These requirements can be met by multiple Winchester technology or parallel transfer head drives. The number, throughput, and sizing requirements for the parallel transfer head drive approach is discussed in section 6. There are a large number of vendors who manufacture Winchester technology drives applicable for use in the MIES ADM. The candidate for the parallel transfer head drive is the Ampex PTD-9309.

5.3.6

Designated Frame Processor (DFP)

The DFP maintains a directory of the sub-frames stored on the DFQ and an associated data base containing the ancillary data for each of the sub-frames. The DFP is responsible for the allocation of the DFQ resource to the current missions and for accepting sub-frame image requests from the DCS's and initiating transfers of the imagery to the DCS. The DFP is a general purpose computing system operating a data base access system. The candidate for the DFP is a DEC PDP 11/44. The software required for this system will be a combination of off-the-shelf data base software and custom interface and control software.

5.4

Target Detection and Identification Subsystem

A block diagram of the Target Detection and Identification Subsystem is shown in Figure 5.4. The Automatic Target Classifiers (ATC) receive sensor imagery data from the SIS. The active ATC's process the sensor data to detect and classify targets and the resulting target list is transferred to the ISS. The ATC's interface with the IDS for control, selection, and potentially for algorithm downloading.

5.4.1

Automatic Target Classifier (ATC)

Automatic target classification is a relatively immature technology. Some limited success is being obtained for infrared sensors, but ATC's for electro-optical and radar sensors are just in the initial phases of study. With current technology the requirements for the ATC's can only be met with custom hardware for a real-time system. A considerable amount of additional study will be required to completely specify the requirements, hardware, and algorithms for this function. A

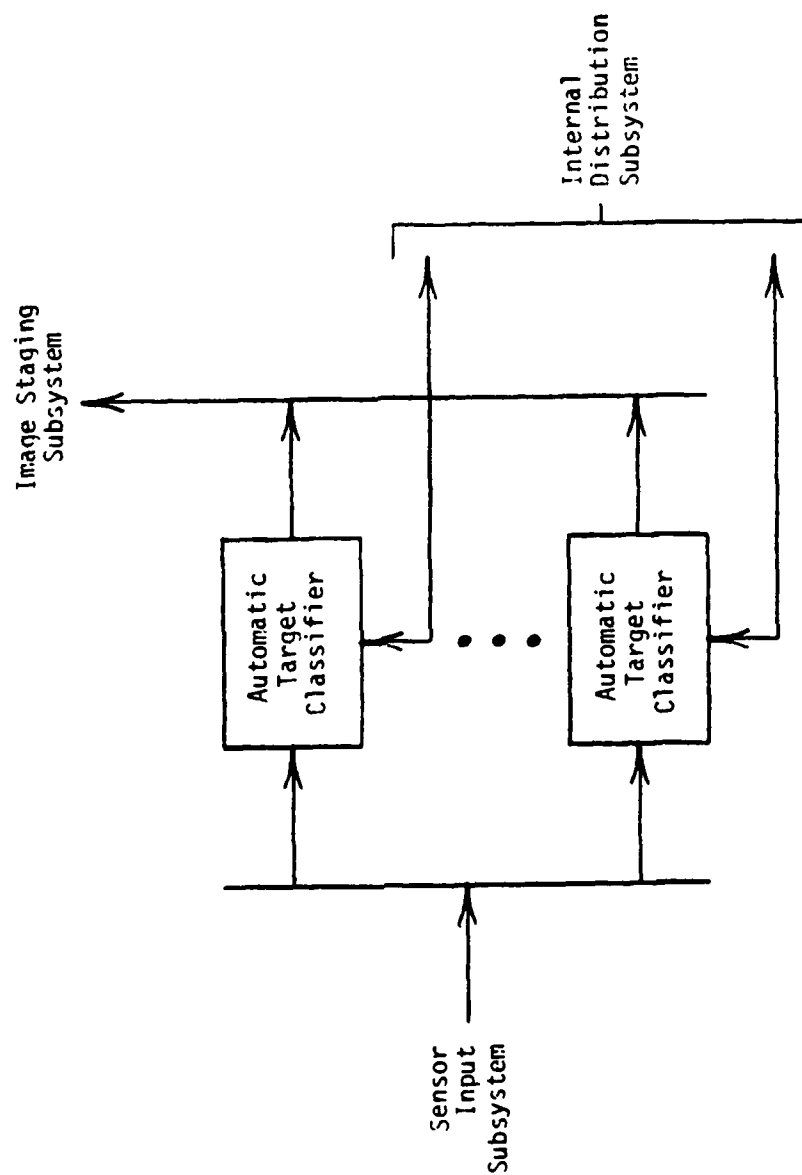


Figure 5.4. Target Detection and Identification Subsystem Block Diagram.

more complete discussion of the requirements for this area is found in the MIES ADM Interim Technical Report.

5.5 Display Control Subsystem

A block diagram of the Display Control Subsystem (DCS) is shown in Figure 5.5. The Display Control Processor (DCP) controls the operation of the DCS via operator interaction and inputs from the CPS via the IDS. The Video Processor (VP) generates two high resolution imagery displays with imagery received from the IDS. The VP also provides interfaces for the Ancillary Device Control and Image Hardcopy Device. The Situation Display Processor (SDP) provides a high resolution graphics display for the Situation Display. The Alphanumeric Terminal Controller and the Voice Input Processor (VIP) provide the operator with control of the system.

5.5.1 Display Control Processor (DCP)

The DCP controls the operation and data flow of the DCS. A candidate for the DCP hardware is a DEC PDP 11/44. The software resident on the DCP will consist of a collection of custom routines executing under a vendor supplied real-time operating system.

The DCP will control the operation of the VP and setup image transfers between the VP and the IDS. The DCP will have to perform image processing algorithms which are too complex to be handled by the VP. These include image decimation, rotation, rectification, and pixel mensuration.

The DCP will control the operation of the SDP. The DCP will receive the cartographic data for a specified geographic area from the CPS and download the vectors to the SDP for display.

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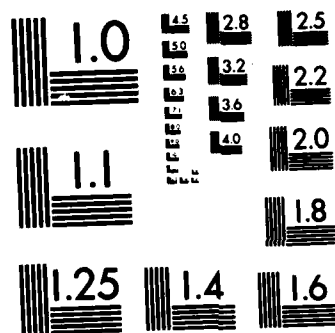
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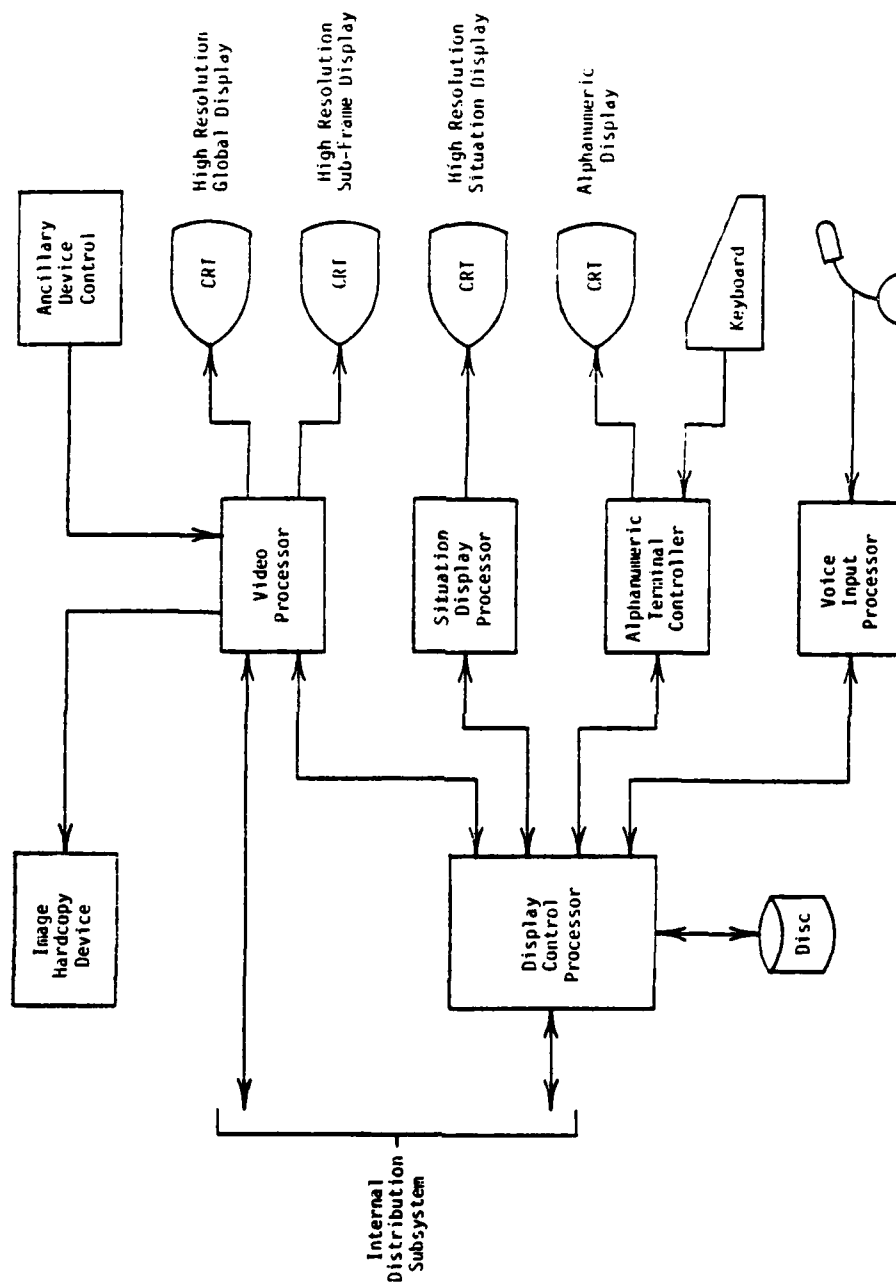


Figure 5.5. Display Control Subsystem Block Diagram.

The DCP will control the operation of the Alphanumeric Terminal Controller. This will include the capability to download character fonts, provide menu driven prompts to the operator, and do limited graphics.

The DCP will control the operation of the VIP. This will include the capability to upload or download voice pattern files for training and setup and to accept recognition codes from the VIP during normal operation.

5.5.2 Video Processor (VP)

The VP will provide two high resolution 1024 pixel by 724 line imagery displays. These displays will be on standard RGB raster scan driven monitors. The VP shall provide a standard RGB raster scan interface for the Image Hardcopy Device. The VP will also provide an interface for the Ancillary Device Control. There are multiple vendors which sell off-the-shelf video processing systems which will meet the requirements of the VP. A candidate for the Ancillary Device Control is a trackball.

5.5.3 Situation Display Processor (SDP)

The SDP is a graphics vector list display processor. There are two major types of processors which can perform these requirements. The first is a solid state refresh memory raster scan processor. The second is a vector stroke processor which directly scans the vectors on the CRT. The raster scan processor is more cost effective and provides better color displays. The vector stroke processor provides smoother vectors and has better resolution. Further study will be required to select the best technology for this system. Hardware for

both technologies is available from multiple vendors.

5.5.4 Alphanumeric Terminal Controller

The Alphanumeric Terminal Controller will provide an 80 character per line by 24 line alphanumeric display from a palette of 8 colors. The Controller will also provide a keyboard interface for operator input. The Controller will provide menu and forms management and the capability to do character oriented graphics. There are multiple vendors providing off-the-shelf systems which will meet the controller requirements.

5.5.5 Voice Input Processor (VIP)

The VIP will provide operator voice input to the system. These capabilities must also include vocabulary training and vocabulary upload and download. Several vendors make systems which will meet the requirements of the MIES ADM.

5.5.6 Image Hardcopy Device

A shared hardcopy output function is available to the operators on which any displayable sub-frame may be printed. Two different types of hardcopy output devices are compared and contrasted.

The first is a high resolution (25K pixels/line) roll feed film printer, the Fire 240 manufactured by MacDonald Dettwiler Associates. This printer produces 9 inch by 9 inch frames on 4 or 7 mil film. This is a black and white printer utilizing a laser for film exposure.

The second system is a color graphic camera system. Hardcopy output can be generated on an 8 inch by 10 inch film media that

includes Polaroid type 808 polacolor2, color transparency, and black and white transparency. This system photographs a color monitor display of the image. The photographed display has 1400 line resolution. Two vendors, Matrix Instruments and Dunn Instruments, manufacture systems of this type.

The color camera system is suggested since no requirement has been identified for display of full resolution major frames. The speed and ease of film processing are major advantages of the Polaroid film. If a requirement is identified for hardcopy output of major frames then the hardcopy function must move to the Input Staging Subsystem. No full major frame data is available in the DCS.

5.5.7 Operator Voice Pattern Files

In order for an operator's voice inputs to be recognized as the appropriate command, the operator's voice pattern file must first be downloaded to the voice input processor (see Section 5.6.6). When an audible command is entered, the voice input management will then match the operator's identifier and the command's reference pattern with an entry in the file, locating the associated command pattern number. From that number the alphanumeric command in the voice command file in the CPS can be found.

5.6 Control Processor Subsystem

A block diagram of the Control Processor Subsystem (CPS) is shown in Figure 5.6. The CPS performs system configuration, control, communication, and data base management services. Internal communications is provided by the IDS, SRS, and SIS links. External communications with the C3I Network is provided by the Communication I/O

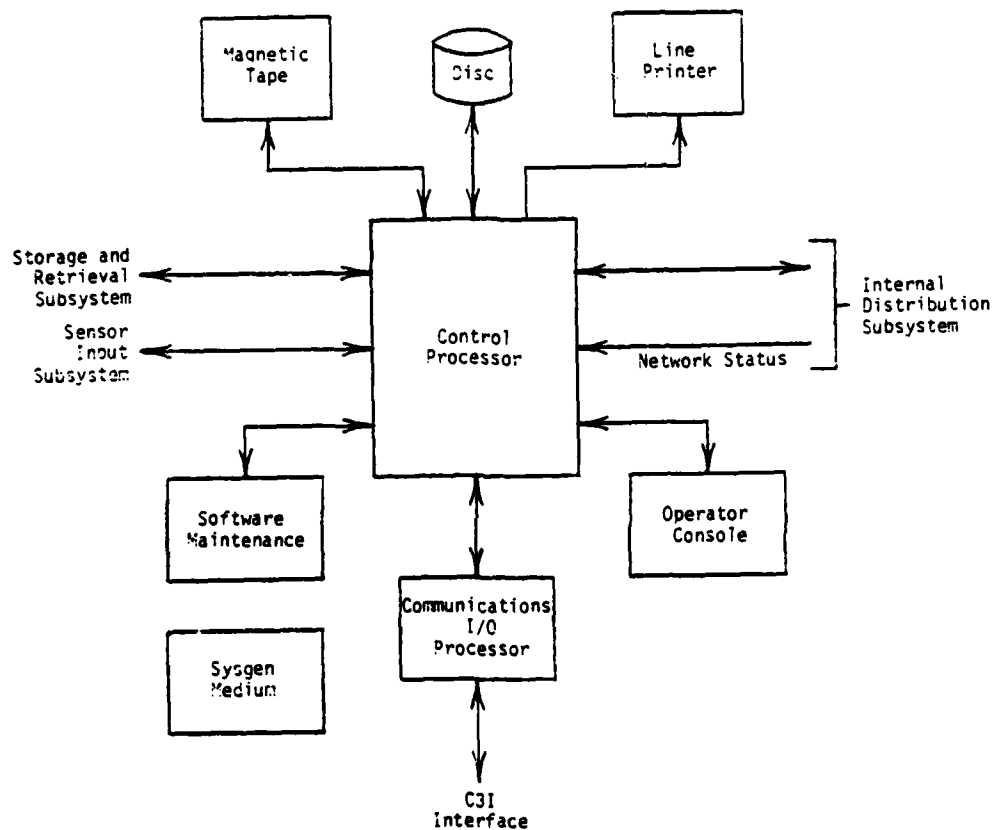


Figure 5.6. Control Processor Subsystem Block Diagram.

Processor.

5.6.1 CPS Architecture

The requirements of the CPS will be met with a general purpose programmable computer system. The magnetic tape drive is a 7/9 track 800/1600 BPI unit. It is used for software and imagery transportation. The line printer is a standard 600 line/minute unit with a 96 ASCII character set. The line printer is used for hardcopy reports, system status reports, and system maintenance. The system will require a minimum of 1800 Mbytes of disc storage to accommodate the data bases discussed in the following paragraphs. The Communication I/O Processor is an intelligent microprocessor controlled communication interface which performs all of the network link level protocol. The sysgen medium is a portable tape drive unit which can be used to regenerate an operating system on any general purpose computer in the system after a major system failure. The DEC VAX 11/780 processor system is a candidate for the CPS.

5.6.2 Target Data Base

For each target detected, it is recommended that at least the following information be included in the target data base:

- a. Unique target identifier.
- b. Target classification.
- c. Classification confidence.
- d. Verification flag.
- e. Detection method.
- f. Number of pixels in target.
- g. Previous target type.

- h. Target location (both latitude/longitude and an abbreviated name of the area).
- i. Precise location flag.
- j. Time and date of acquisition.
- k. Direction and speed of travel.
- l. Target characteristics.
- m. Object window (vertical and horizontal length in pixels).
- n. Prime target flag.
- o. Reference image data base flag.
- p. Target location in sub-frame (line and pixel).
- q. Location of imagery sub-frame in Storage and Retrieval Subsystem and Image Staging Subsystem (mission, record, line and pixel).

This format may include the capability to extract the portion of the imagery header records and object records used on the NATO format computer compatible tapes that is applicable to the MIES ADM.

In the target data base, the detection method element is needed to keep track of how well the MIES ADM and the ATCs are detecting targets (targets can be sighted by three methods: by the automatic target classifier, by the analyst, or from external information sources). Another means of monitoring the system's performance would be with the previous target type element. This data element may provide a pattern of the ATC detecting and misclassifying a certain type of target.

The target characteristics element is an alphanumeric field available to the analysts to maintain additional target

information (e.g., specific nomenclature, troop and operator occupancy, and any other attributes the analyst observes). The prime target flag indicates to the situation display whether or not a target is to be included in the prime target overlay. And finally, the reference image data base flag identifies a target for which the source sub-frame has been stored in the reference image data base for later examination. If an image is not stored in that data base at the time an analyst processes it and is subsequently needed again, it will have to be obtained from tape in the Storage and Retrieval Subsystem.

With the exception of data elements l, p and q (target characteristics, target location in sub-frame, and location of imagery sub-frame in SRS and ISS), these records should be accessible by any of the elements or any combination of elements. For instance, an analyst may request the location of all unverified tanks within specified boundaries that were acquired within the last 48 hours. In another case, it may be decided that all mobile targets that were detected more than say five days ago have probably moved and can be deleted from the data base.

Three operations are possible on the target data base--add records, update records, and delete records. The capability to delete records (targets) from the data base will again be based on any combination of the data elements (with the exception of the ones listed above). As previously mentioned, the deciding factor for deleting target records is as of yet undetermined. Obviously if a target has been destroyed, removed, or has otherwise disappeared, its corresponding record should be deleted. Or it may become a policy to automatically remove all information on targets detected more than a certain number of days previously. In another case, the users may decide to keep data on

as many targets as possible with the amount of storage facilities as the determining factor (when all of the storage is filled, delete the "oldest" target record in order to make room for a "new" one). Another option is to delete records of targets within a certain location, perhaps one that is no longer of immediate concern. If the confidence level of a target is too low or if a target detected by the ATC cannot be verified, the user may decide to delete those records. These are all examples of decisions concerning deletions that need to be made.

In order to determine if this implementation is achievable, a very rough estimate of the size of the target data base can be calculated as it could be implemented with Digital Equipment Corporation's Record Management System (RMS-11) on a PDP-11 minicomputer. Several major assumptions were necessary in order to reach this estimation, including the number of records in the data base (3,000) and the size of the data elements (creating a record length of 119 bytes). Using the unique target identifier as the primary key and 13 other alternate keys, in addition to assumptions on the number of records with duplicate access keys and the bucket size, the total initial allocation required was calculated to be 17 Mbytes. Note that this figure is over 47 times the product of the record size and the number of records (357,000) due to the many different access keys. If the various assumptions are correct, then this data base, although large, is implementable. The next question presented is the access time: is it within a reasonable time frame, or will it take hours to retrieve the data from a multiple access key inquiry? Are all of those alternate keys and their combinations essential? Does every alternate key require a separate index or can some be implemented by searching the records directly? These questions and others need more investigation in order

to put together the optimal data base configuration, including the trade-offs between speed, storage and access methods. The commercial data base management systems, both in software and specialized hardware, also need further study to find the most applicable for the MIES ADM. These considerations apply to all of the data bases within MIES.

5.6.3 Reference Image Data Base

It is recommended that at least the following information be included in the reference image data base:

- a. Reference image (1024 x 1024).
- b. Associated ancillary data.
- c. Geographic location (both latitude/longitude and an abbreviated name of the area).
- d. Mission, record, line and pixel.
- e. Sensor type.
- f. Time and date of acquisition.
- g. Number of objects in image.
- h. Object sizes (to accuracy of pixel mensuration computation).
- i. Alphanumeric descriptor.

In the reference image data base, the object size element was included for the case where the analyst wants to investigate targets of comparable sizes. Because an image can contain more than one target, each record (corresponding to one image) could have multiple size elements (corresponding to multiple targets). The alphanumeric descriptor is for the analysts' convenience in storing and retrieving images by an identifier--such as a target type, an analyst's name, a mission number, etc.

With the exception of the actual reference image data, these records should be accessible by any of the data elements or any combination of elements. For example, an analyst could request to see all targets within a size range of 15 to 18 feet as recorded on a down looking infrared sensor.

In this data base, records can be added, updated or deleted. However, it is recommended that all updates be done only by the supervisor for control purposes. As in the target data base, the capability to delete records from the data base will be based on any combination of the data elements. However, the only method by which an image can be deleted is for the operator to explicitly specify the image(s) to be removed--there should be no mechanism that comes through periodically and automatically deletes some.

5.6.4 SRS Directory Data Base

The SRS directory data base will provide the mechanism by which all data stored in the Storage and Retrieval Subsystem is accessible. This data base is an index of data in the SRS, both imagery and ancillary data. As data is entered into the MIES ADM and stored in the SRS, an index entry for a group of records of imagery data is created and added into this data base. When imagery records are removed from the SRS, for whatever reason, the corresponding index entry is to be eliminated. The SRS will be responsible for data access, update and maintenance of this data base.

Imagery data stored in the SRS is broken into units called records. Normally the ancillary data will correspond to more than one record at a time, depending on the type of sensor. For each group of records and its ancillary data header, there should be one

entry in the SRS directory. It is recommended that at least the following information be included in each entry of this directory:

- a. Each record's number and storage location.
- b. Geographic location.
- c. Mission id.
- d. Sensor type.
- e. Time of acquisition.

With the exception of the record's physical storage location, these records should be accessible by any of the data elements or any combination of elements. An example might be an analyst requesting to see all the records from a certain mission taken within a specified time frame or perhaps within a certain geographical region. The normal procedure, however, would be for all of the data, as it is being stored in the SRS (and its directory in the SRS directory data base) to be also going through the Image Staging Subsystem and the Target Detection and Identification Subsystem. In non-real-time operations the analyst would need to refer all the way back to the SRS (and hence through this data base) for data. A prime example of that very situation is when the ATC misses a target that an outside intelligence source later indicates needs investigation.

Index records can be added, updated and deleted from this data base. Entries will be created as data is placed in the SRS and deleted when that data is removed. The capability will be provided so that before deleting data from the MIES ADM, if it needs to be kept, it can be placed on some form of portable media for storage. There currently exists a standard NATO format for recording sensor data on computer compatible tapes that is the prime candidate for achieving this purpose.

5.6.5

Cartographic Data Base

The requirements for the cartographic data base must be carefully considered as the acquisition and storage of such a data base can be a significant expenditure.

Further study should be given to the following points:

- a. What types of map projection(s) will be required.
- b. If more than one type of map projection is required, should the data be stored as latitude-longitude points and conversion software be used, or should "inverse projections" be stored requiring a larger data base.
- c. What resolution is required for the situation display and what are the resolutions available in existing cartographic data bases.
- d. Will contour mapping be required; if so, this requires two-dimensional interpolation software.

5.6.5.1

Structure of Cartographic Data Bases

The two major types of cartographic data bases presently used are the gridded data base and the vector data base.

5.6.5.1.1

Gridded Cartographic Data Bases

Gridded data bases are the easier of the two to use, but generally more expensive to process and they impose a minimum resolution that could be inconvenient. In the gridded format, map data are stored as matrices with each grid cell a uniform size and (rectangular) shape. This type of information is represented by an array, with the row and column location of a cell being an explicit geographic location.

The reasons for using gridded data bases are two-fold. One is the simplicity of grids as data structures--they are easy to store and manipulate. The second reason is that this structure readily lends itself to image scanning in a grid or raster format.

5.6.5.1.2 Vector Format Cartographic Data Bases

The second major approach in handling cartographic data is the use of vector data structures. This type of storage relates to keeping data as line descriptions, where natural or cultural features such as coastlines, or other boundary types are captured as measured coordinates from maps describing the location of points where each line changes direction. Linear features are thus described as lists of coordinates. The amount of detail depends on how many points are chosen to represent a given line.

5.6.5.2 Existing Cartographic Data Bases

Some of the cartographic data bases which might be applicable for use on the MIES ADM are discussed in the following paragraphs.

5.6.5.2.1 World Data Bank I and II

These data bases are available from the U.S. National Technical Information Service. World Data Bank I contains cartographic data for the planet earth by countries at a scale of 1:12 million and a resolution of 12 km. World Data Bank II contains cartographic data for the planet earth--coastlines, islands, lakes, rivers and international boundaries--at a scale of 1:3 million and a resolution of 3 km.

5.6.5.2.2 Landsat Data Base

The Landsat Data Base is available from NASA. Landsat data covers the planet earth in 100 mile square frames at a resolution of 70 meters or 30 meters.

5.6.5.2.3 Digital Landmass System (DLMS) Data Base

This data base is created and maintained by the Defense Mapping Agency as an Off-Line Digital Data Base. This is a world-wide data base collected at two different levels.

a. Level 1

1. Terrain: Relief information in DMA standard digital format on a three seconds of latitude arc (approximately 100 meters (300 feet)) matrix.
2. Culture: A generalized description and portrayal, in DMA standard digital format, of planimetric features. The Level 1 data base is intended to cover large

expanses of the earth's surface and has relatively large minimum size requirements for portrayal of planimetric features.

b. Level 2

1. Terrain: Relief information in DMA standard digital format on a one second of latitude arc (approximately 30 meters (100 feet)) matrix.

2. Culture: A highly detailed description and portrayal, in DMA standard digital format, of planimetric features. The Level 2 data base is intended to cover small areas of interest and has small minimum size requirements for portrayal of planimetric features.

Data which might be extracted from this data base is given below:

- a. Geographic area covered (latitude and longitude plus the changes in both directions).
- b. Feature analysis code.
- c. Feature type (point, linear or areal).
- d. Feature identification code number.
- e. Surface material category code number.

- f. Number of digitized coordinates of feature.
- g. Latitude and longitude of each coordinate.
- h. For points: length (or radius) and width.
- i. For linear symbols: directivity and width.
- j. For areal symbols: number of structures in a specified region.
- k. Geopolitical boundaries.
- l. Prioritized levels, indicating what features are to be displayed at different resolutions.

5.6.5.3 Cartographic Data Base Conclusions

The information given in the previous paragraphs points out the need for an in-depth study of the cartographic data base. This data base is considered to be government furnished, but a better definition of the data base elements--i.e., scale, resolution, codes, etc., must be carefully addressed.

5.6.6 Voice Pattern Data Base

The voice pattern data base is needed to match the operators' voice commands with the correct option chosen. In order to do this, there will have to be two files in the data base--one relating alphanumeric commands to command numbers, and another relating a particular operator's voice pattern to the command numbers. Records will be entered in these files when new commands are offered as options in the MIES ADM, whenever a new operator begins working on it or when the voice recognizer unit no longer recognizes an operator's input (there are various reasons for this happening--one example might be if an

operator is sick, causing a change in the voice patterns). In turn, records will be deleted as operator options are removed and when one or more operators discontinue using the system.

The voice input management function will maintain the information in this data base. The recommended data elements in these two files are as follows--in the voice command file:

- a. Alphanumeric command.
- b. Command number.

And in the operator voice pattern file:

- a. Operator's identifier.
- b. Command pattern number.
- c. Command reference pattern.

In normal operation, the operators' voice pattern files are downloaded to the voice input processor in the DCS (see Section 5.5.5) for input purposes.

The alphanumeric command is the command itself as it would appear in the menu. Each operator has an operator voice pattern file with an entry for each command. The command reference pattern is the actual digitized command.

Access to this data base is via any of the data elements. There are basically three combinations of elements used to get into the data base: when an operator orally enters a command, the operator identifier and command reference pattern elements are used; if an update to the data base is needed, either an operator identifier and a command number or an operator identifier and an alphanumeric command can indicate which entry to update.

As previously mentioned, records in this data base can be added, updated or deleted.

5.6.7

Help and Error Messages Data Base

The help and error messages data base is exactly that--a collection of alphanumeric messages designed to notify the operators when an error has occurred and provide a helpful message when needed. There are only two data elements required in this data base:

- a. Message identifier.
- b. Message text.

The system management function will be responsible for data access, update and maintenance. Access into this data base is through the message identifier. Records can be added, updated and deleted as needed.

5.7

Point Position Data Base

A block diagram of the Point Position Data Base (PPDB) is shown in Figure 5.7. The PPDB processor provides data base access and target location processing. The PPDB Mass Storage device provides the necessary storage to hold the PPDB required by the MIES ADM.

5.7.1

PPDB Processing

The point position data base (PPDB) is to be used for locating targets by transferring points from a reconnaissance image to a PPDB reference image. This data base is considered to be government furnished consisting of mono perspective imagery. The area covered by this data base may be determined by storage technology and the requirements of the MIES ADM. Images within the PPDB and the associated

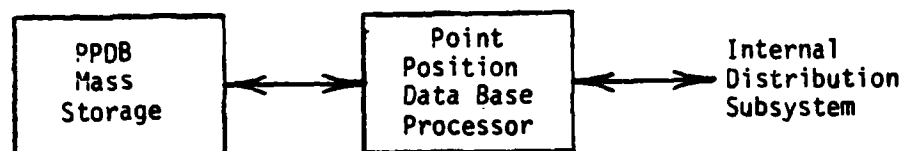


Figure 5.7. Point Position Data Base Block Diagram.

digital terrain elevation data are to be accessible by latitude, longitude and area size within 60 seconds from the receipt of a retrieval request.

The resolution required of these images is currently unknown, with the following under consideration. There appears to be three primary sources of error involved in the point positioning process: the point transfer error, the PPDB error, and the elevation data error. The result of these three errors must be less than or equal to 50 feet CEP 90 percent in order to fulfill the requirements set forth in the statement of work. When the appropriate experiments have been conducted and the point transfer and elevation data errors have been determined, then the PPDB error can be determined. From this value the required resolution of the PPDB can be constructed.

Current technology cannot support a 90,000 square mile PPDB as specified in the SOW and provide access within a reasonable time period. A PPDB segment covering a smaller geographic area could be supported with current technology. It appears that current technology could support an area of approximately 100 square miles and still maintain reasonable access times. The only technology currently projected which will support a full size PPDB is the optical multiple disk jukebox system such as the one RCA is currently developing.

5.8 Internal Distribution Subsystem

A block diagram of the Internal Distribution Subsystem is shown in Figure 5.8. The IDS provides control and data flow between the sub-frame processing portion of the MIES ADM.

5.8.1 IDS Architecture

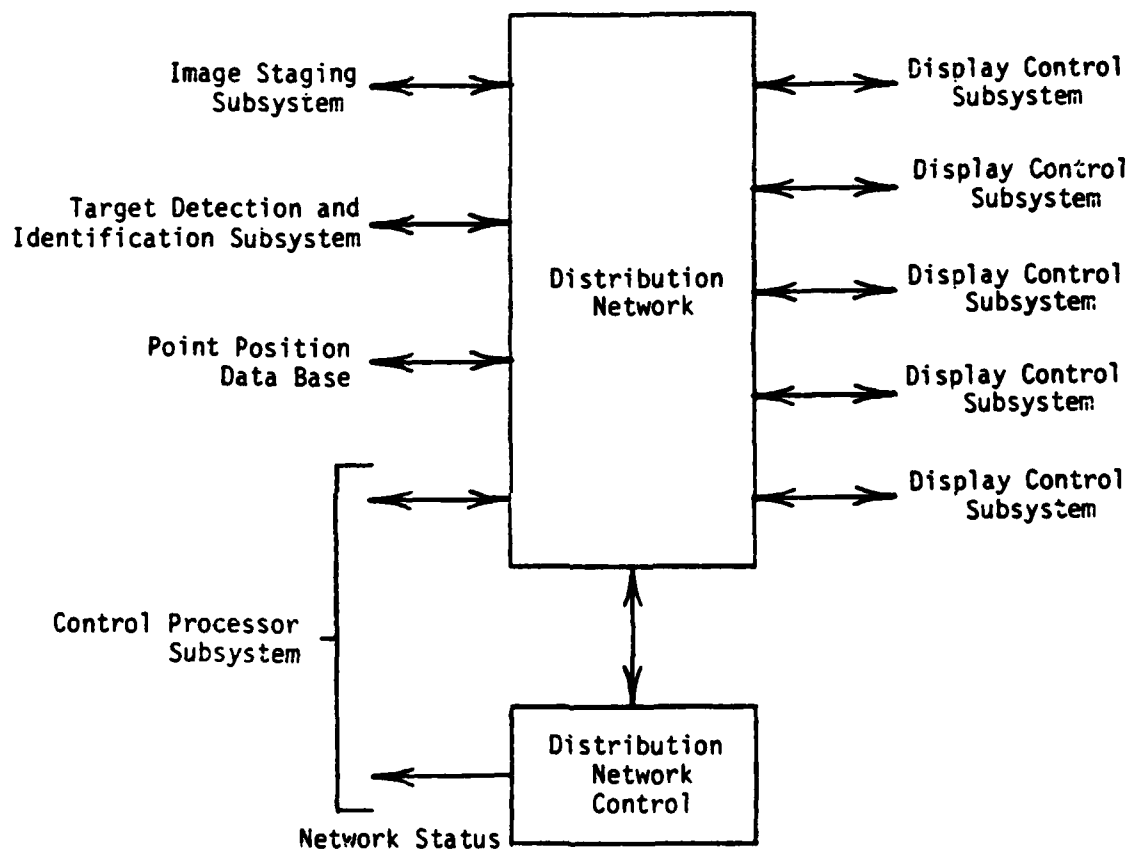


Figure 5.8. Internal Distribution Subsystem Block Diagram.

The IDS must provide non-blocking interconnection between any two ports with data transfer rates of 50 Mbits/second/port. These requirements can be met by two candidate approaches, a Time Domain Multiplexed (TDM) packet bus or a digital matrix switch. We feel that the TDM packet bus is an immature technology which needs refinement before it is committed to a system such as the MIES ADM. The digital matrix switch, however, is a very well established technology which can perform these requirements easily and is cost effective. Therefore, it is our current recommendation that the matrix switch be used for the IDS. However, this decision must be re-evaluated before the hardware build phase.

6.0 ARCHITECTURE ANALYSIS

6.0

ARCHITECTURE ANALYSIS

After arriving at a system architecture, that architecture was analyzed to determine the throughput, flexibility, reliability, maintainability, and transportability. The human factors requirements and the manning requirements were considered. Development considerations were outlined including testing and scheduling.

6.1

Throughput Analysis

A throughput analysis can be accomplished if certain assumptions are made about the nature of the sensor data. The following cases are analyzed:

- a. Three sensors, target dependent selection,
three analysts.
- b. Three sensors, location dependent selection,
three analysts.

In all cases the maximum sensor input rate is assumed. This is a worst case assumption.

6.1.1

Target Dependent Selection

The case of three sensors, target dependent selection, and three analysts is diagramed in Figure 6.1.1-1. This diagram depicts the delay in getting one target from one sensor to one screen. The delays are based on two other targets making the same path. Worst case assumptions are made. This timing is based on the candidate implementations of Section 5.0. This time delay does not include system configuration time which is assumed to have been previously accomplished.

Data is passed through the Sensor Input Subsystem

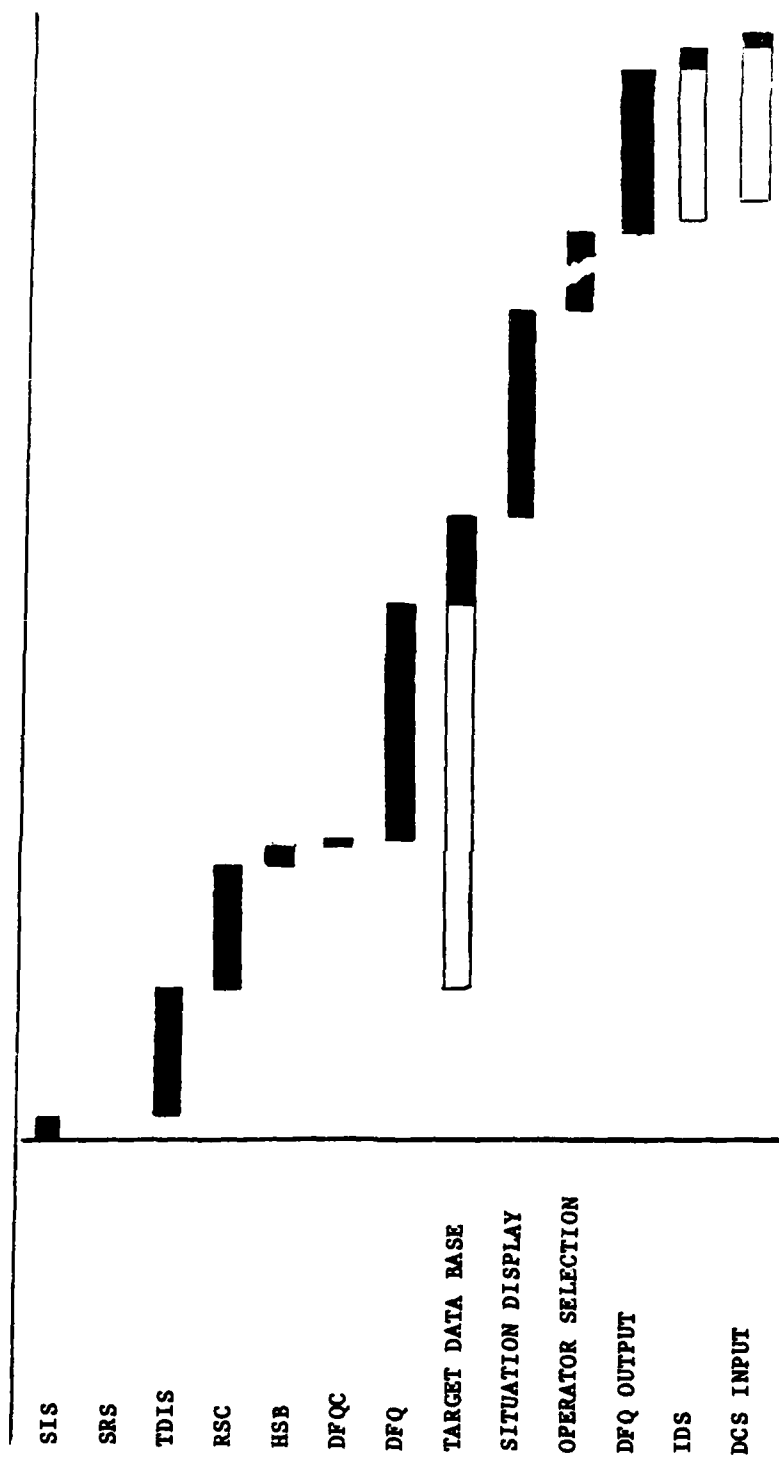


Figure 6.1.1-1. Critical Path Timing, Target Dependent Selection.

at the maximum rate. The time delay through SIS will depend on the sensor type. The time delay may be considered as two parts, synchronization delay and buffer delay. The synchronization delay is the time required for the SIS to synchronize on the input signal while the buffer delay is the remainder of the delay. For most sensors the buffer delay will be slightly longer than a line time since it is expected that double line buffers will be utilized to support the reformatting function of the SIS. FLIR sensors will require frame buffers as discussed in Section 2.1. A frame time of delay will be encountered for the FLIR sensors. In no case is it expected that this buffer delay will exceed 67 milliseconds.

The data from the SIS is passed to the Storage and Retrieval Subsystem where it is recorded. Since all of the data rate required of the SRS is being taken up by input from the SIS, no output from the SRS can be supported. The SRS can support this input rate for eight minutes, during which time it will have recorded 69 Gbits. In this case the SRS contributes no delay. A potential for a significant delay contribution from the SRS involves the startup of the Wide Band Tape. To bring the Wide Band Tape up to full speed from a complete stop requires 10 seconds. If the tape is started at the same time as the data enters the SIS then over 9 seconds of data will be lost while the tape comes up to speed. This can be avoided by having the tape already up to speed when the data arrives at the SIS. In the case where sensor data is being input from tape (such as the HBR 3000), this can be easily accomplished. In the case of data received via radio links, accurate time synchronization would be required. This start-up time is unique to the tape medium. This throughput analysis will assume that if tape is used, the unit is up to speed when the sensor data is first received.

At the same time that the SRS is recording the input data, the same data from the SIS is passed to the Image Staging Subsystem. Within the ISS, the Buffer Input Processor accepts the full sensor rate and writes it into the High Speed Buffer. In the target dependent mode the Resolution and Sub-frame Control receives target locations from the Target Detection and Identification Subsystem and pulls those sub-frames containing targets. These sub-frames are then stored in the Designated Frame Queue.

The delay through the BIP, the High Speed Buffer, and into the DFQ is dependent on the ISS implementation. The number of independent ports on the HSB is an important factor for the throughput and delay. With three sensors operative, then as many as six ports into the HSB could be active. This is three sensor ports and three decimated major frame ports, one for each of the sensor ports. As many as six ports could be active on the output of the high speed buffer. If a single HSB is utilized with a single port shared among the twelve contending inputs then the delay could be long. If three separate HSB's are used then the delay can be reduced correspondingly. The delay is also a function of the buffer sizes. The delay into the HSB is probably less than the delay through the Target Detection and Identification Subsystem. Since the loading of the HSB and the searching for targets by the TDIS are operated in parallel then the delay through the HSB is not in the critical path.

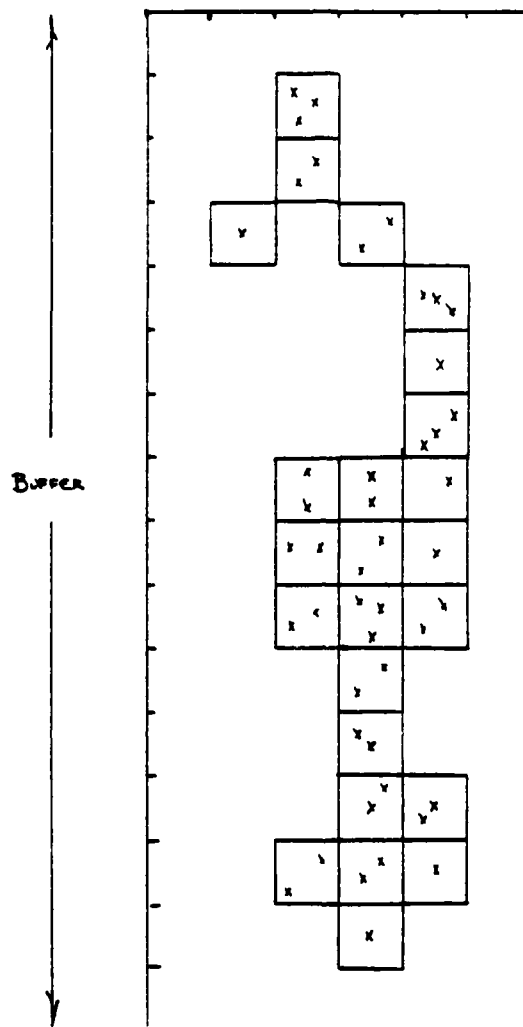
The delay through the TDIS consists of the time to load the data into memory, the processing of that data, the decision, and the output of that decision to the ISS. It seems likely that the target search will require more time than the loading of the HSB. The time delay through the TDIS is partially a function of the target size.

Very large targets will require more processing and more time simply in data input.

After the TDIS outputs the target class, location, confidence, and size, the sub-frame boundaries algorithm calculates the sub-frame boundaries. If a single computer is calculating sub-frame boundaries for all three sensors then the delay for a given sensor could be three times what it would be for one. The algorithm time delay ends when an sub-frame boundary is output.

The next time delay is the latency time for the actual frame pull. This time also depends on the implementation of the ISS. The worst case is where the sensor channels are prioritized and the activity is such that the low priority channel never receives access. Another implementation involves a sequential service ordered by requests. Again the delay is dependent on the number of targeted sub-frames. In fact in any implementation the throughput of the RSC depends on the density of the targets contained within the sensor data.

At this point a concept of the targeted sub-frame density is helpful. The targeted sub-frame density is the ratio of the number of sub-frames containing targets to the total number of sub-frames received. Figure 6.1.1-2 illustrates this concept. It should be noted that a targeted sub-frame may contain numerous targets. The algorithm for selection of sub-frames in this mode seeks to include as many targets within the sub-frame as possible. The efficiency of this algorithm impacts the targeted sub-frame density. Since it is likely that targets will occur in clusters, it is probable that the targeted sub-frame density will be a small number when considering the entire mission. The targeted sub-frame density must be considered in two cases:



TOTAL SUB-FRAMES/BUFFER = 96

SUB-FRAMES CONTAINING TARGETS = 24

TARGETED SUB-FRAME DENSITY = $24/96 = 0.25$

Figure 6.1.1-2. Targeted Frame Density.

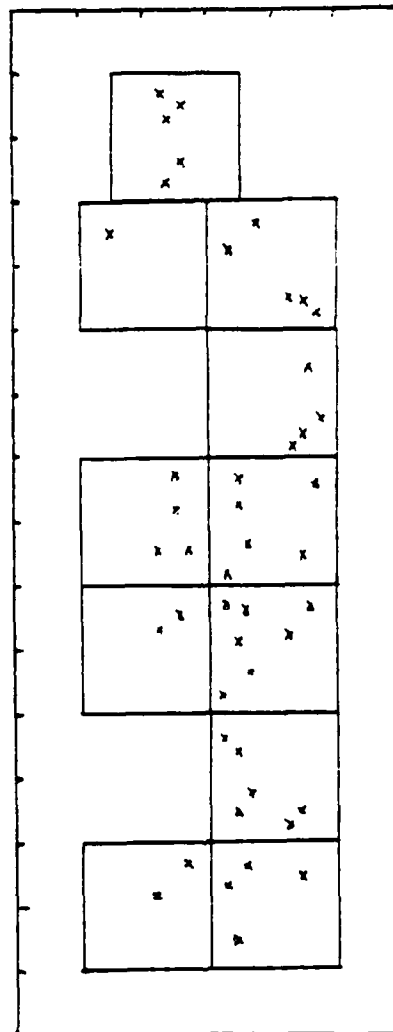
- a. Averaged over a buffer.
- b. Averaged over a mission.

The targeted sub-frame averaged over a buffer is a key figure in the calculation of the necessary DFQ input rate. The targeted sub-frame density averaged over a mission is a factor in the amount of storage required of the DFQ. A post-stage decimator contained in the RSC enters into both calculations.

If decimation is used, the decimation ratio reduces the DFQ input rate and the amount of storage required. The degree of this reduction is also a function of the clustering of the targeted sub-frames. If targeted sub-frames are adjoining to form a square then the amount of input rate reduction and the amount of storage reduction is just the decimation ratio. Yet, in the case of single targeted sub-frame with no neighboring sub-frames, the decimation ratio of the post stage decimator has no effect on the input data rate or the total storage requirement of the DFQ.

A convenient way of handling the decimation ratio consideration is by integrating it into the definition of the targeted sub-frame density. In this way, if there is no decimation then the targeted frame density is the ratio of the number of 1K x 1K pixel sub-frames containing targets to the number of 1K x 1K pixel sub-frames contained in the High Speed Buffer. If the decimation ratio is 2:1, then the targeted sub-frame density is the ratio of the number of 2K x 2K frames containing targets to the number of 1K x 1K frames within the buffer. If the decimation ratio is 4:1, the target frame density would be in terms of 4K x 4K frames containing targets to the number of 1K x 1K frames within the buffer, and so on.

Figure 6.1.1-3 shows the previous target density



TOTAL SUB-FRAMES/BUFFER = 96

SUB-FRAMES CONTAINING TARGETS = 11

TARGETED SUB-FRAME DENSITY = $11/96 = 0.11$

Figure 6.1.1-3. Targeted Frame Density with Decimation.

case of Figure 6.1.1-2 but with a 2:1 decimation ratio. Note that the target density improves due to the clustering of the targets.

What is the expected target density? It seems likely that the target density will be found to be much less than 0.25. Hard data on target densities is not available to this study and may not be available at all. Yet this figure is a real cost driver for the ADM. A Designated Frame Queue designed for worst case target density of 1.0 would be 15 times as large and have 15 times the input bandwidth of a system designed for a target density of 0.06. Thus it is recommended that the ADM configuration be sized for the smaller target density and that controls be incorporated to handle overflow cases through the priority schemes already suggested. Because the SRS provides storage for all input data, the loss of frames at the DFQ only requires that, at the end of the mission, the missing portion be recovered from tape. With the possibility of overflow of the DFQ built into the system operation, the ADM could be used to empirically determine the probability of DFQ overflow in the presence of real sensor data.

If the targeted sub-frame density is taken to be 0.06, then, with a full input rate of 144 Mbits/second, the Designated Frame Queue must be capable of inputting 1.1 Mbytes/second continuously. Bandwidth must also be included in the DFQ for output of requested sub-frames to the operator. If it is assumed that the operators can remove and verify frames at the same rate that frames are coming in to the DFQ then 1.1 Mbytes/second is required for output. This makes a total of 2.2 Mbytes/second. Also using the 0.06 targeted sub-frame density for the average over a mission indicates that 528 Mbytes of storage will be required for a mission. These requirements can be met by using three Ampex parallel transfer drives. If this drive can operate at 5

Mbytes/second and up to nine 1 Mbyte images can be queued ahead of the image of interest, then the throughput delay of the image would be approximately 2 seconds. At a 0.06 target density, the delay will be less than this on the average.

Transmission over the Internal Distribution Subsystem will require little delay other than establishing the connection. The rate of the data transfer over the IDS is more significant. Since the volume of data to be transferred (1 Mbyte) is significant it is desirable to take this onto the console disk simultaneous with the transfer to the display device. This limits the transfer rate to around 450 Kbytes/second in standard serial transfer disks.

6.1.2 Location Dependent Selection

The timing for location dependent selection is shown in Figure 6.1.2. The difference between the location dependent selection and the target dependent selection is the method of selecting sub-frames from the HSB. In location dependent selection the sensor model must be evaluated to determine if the current sensor data includes data of the desired location. If the desired data is included then the sub-frame boundaries must be determined. After this point, the frame pull and data transfer to the console is the same as in the target dependent case.

6.2 Flexibility

An important consideration in the development of an ADM is its capability to adjust to changing conditions. A number of system parameters will be determined by performing experiments on the

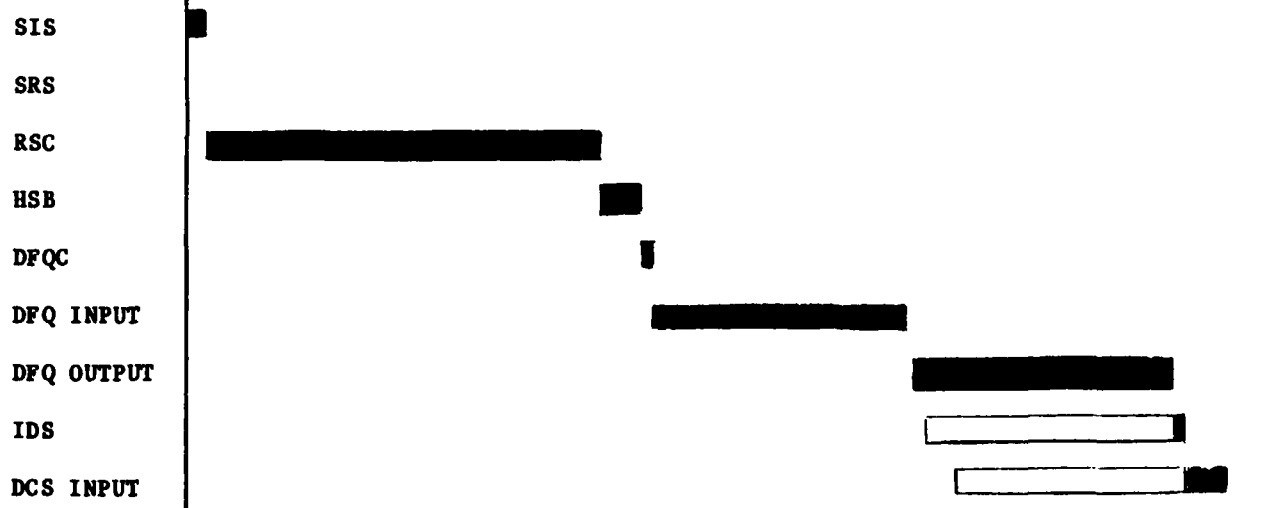


Figure 6.1.2. Critical Path Timing, Location Dependent Selection.

ADM.

The use of general purpose computers with modular, structured programs increases the flexibility of the ADM. A flexible sensor interface scheme is required so that new sensors can be incorporated without impacting the remainder of the system. The WBT's of the SRS are expandable to accommodate longer missions. The High Speed Buffer and the RSC are expandable to accommodate a higher target frame density. The IDS is expandable to allow the addition of consoles.

6.3 Reliability

The reliability model of the MIES ADM was constructed at the subsystem level and approximate MTBF figures were derived by comparing candidate implementations with equivalent systems whose MTBF's are known. The reliability model is shown in Figure 6.3 and is described below. The MTBF approximation is 155 hours.

6.4 Maintainability

In the ADM the use of commercial off-the-shelf equipment with available service contracts should be emphasized. The developed hardware should provide for board level fault isolation and replacement.

6.5 Transportability

The ADM must be transportable by commercial means. It is envisioned that the ADM will not be shelterized and would be installed in a secure lab.

6.6 Human Factors

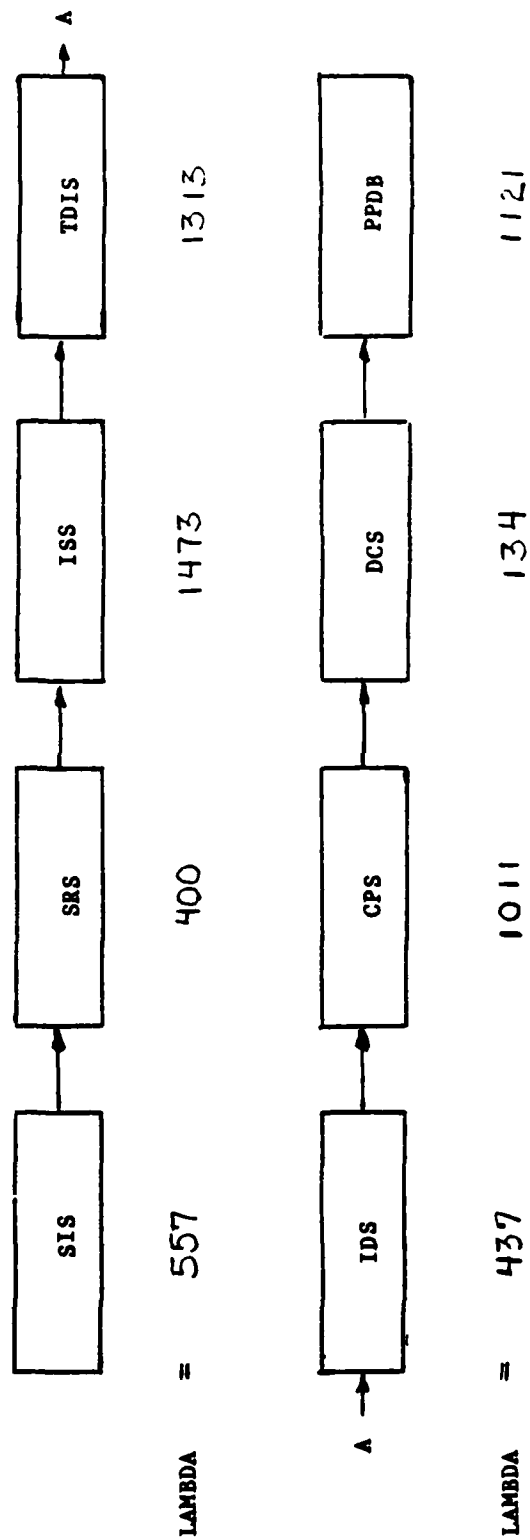


Figure 6.3. Reliability Model.

This paragraph establishes some of the Human Engineering/Safety requirements and criteria for the MIES ADM. These Human Engineering requirements should be applied to assure uniformity of controls, displays, marking, coding, labeling, and arrangement schemes (equipment and panel layout) for common functions of equipment. Adherence to the design guidelines specified below ensure that the following general objectives are considered:

- a. Considerations of the unique capabilities and requirements of the human element are incorporated into system design.
- b. Through proper design, personnel hazards are minimized.
- c. Efficient, reliable and safe procedures are established to operate and maintain the equipment.
- d. System availability is increased by design features which aid decision making and preclude human error.

A set of guidelines with respect to the human engineering considerations for physical interface with the hardware are outlined in Appendix A paragraphs 3.0, 4.0, 5.0 and 6.0.

6.7 Manning Requirements

The information required for determining the number of personnel needed to operate the MIES ADM efficiently, and the number of analysts needed to process real-time missions within an acceptable time span, is not immediately available. Results from the Data Handling and Recording System (DHRS) will provide some of the needed information.

In section 6.1, Throughput Analysis, three analyst and three consoles were used as a candidate configuration for the discussion of throughput analysis. This is not meant to imply that analysis has yet been done to arrive at this number. Manning requirements analysis will be included in the MIES Validation Study.

6.7.1 Operations Supervisor

This person would be responsible for overall supervision of the imagery interpretation analysts. The following activities should be included in the supervisor's job description:

- a. Responsibility for overall supervision of imagery interpretation analysts.
- b. Analyzes mission requirements and configures the computer equipment in accordance with these requirements.
- c. Planning, organizing and directing imagery interpretation activities.
- d. Ensures timely completion and delivery of all intelligence products.
- e. Edits intelligence products for quality workmanship.
- f. Analyzes performance history of specific missions and prepares and presents recommendations on inefficiencies in operation.

6.7.2 Imagery Interpretation Analysts

The people performing imagery interpretation should

be responsible for the following types of activities:

- a. Interprets imagery to determine quality, air crew procedures, number, type, and location of target subjects.
- b. Interactively operates the imagery display terminal and the situation display terminal to accomplish the image interpretation.
- c. Operates the color hard copy terminal to produce photographs of softcopy imagery as deemed necessary.
- d. Produces reports as they are required.

6.7.3

Computer Maintenance Personnel

Computer maintenance personnel would have the responsibility to run routine computer maintenance on the hardware equipment. They would also be responsible for fault isolation and repair of any down equipment. The following types of activities should be performed by these personnel:

- a. Directs the inspection and evaluation of system performance, to include use of test and diagnostic programs, and recommends improvement in operation, maintenance, and training.
- b. Directs corrective action to solve problems concerned with system malfunctions.
- c. Advises appropriate agencies of the operational status of electronic data processing

systems and equipment.

- d. Coordinates maintenance schedules.
- e. Studies and evaluates programs to determine improvements for operational effectiveness.

6.8 Development Considerations

The development of the MIES ADM may proceed after the finalization of the A level specification. A tentative schedule is shown in Figure 6.9.

The test and evaluation requirements are included in the A level specification in section 4.0. This section includes the Verification Cross Reference Matrix which defines verification of each requirement of the specification.

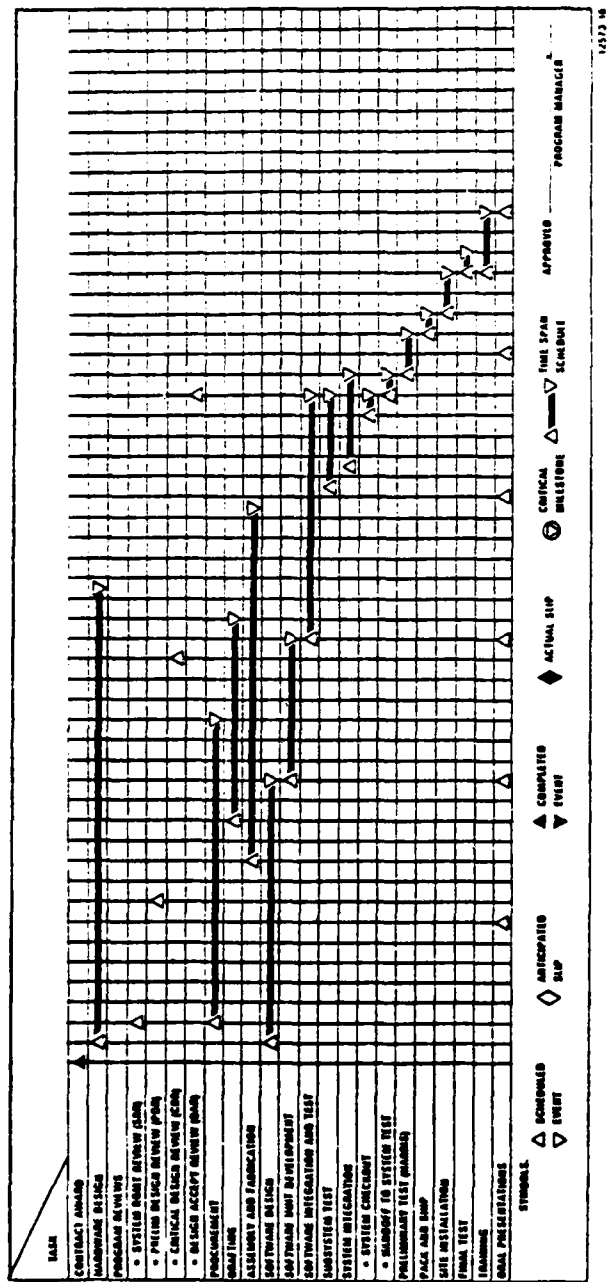


Figure 6.9. Tentative Schedule.

APPENDIX A
HUMAN ENGINEERING DESIGN GUIDELINES

Appendix A

Human Engineering Design Guidelines

The following criteria are accepted as industry standards and are recommended for guidelines for designing interactive displays.

A1.0

Interactive Display Guidelines

- a. Input sequence should be designed so that switching from one mode of entry to another (e.g., keyboard to joystick) is minimized. The length of operator inputs should be minimized. Operator typing should be kept to a minimum. Abbreviations should be supported for experienced operators. Typed input words should not exceed seven characters and should approximate or be real words. For fixed length entries, the entry length should be indicated. Often used special characters should be selected so that it is unnecessary for the operator to use the the shift key.
- b. Point-to-point cursor movement should occur at a rate of no less than 20 inches per second. When using a cursor or light-pen for display selection an operator should be able to specify his choice by selecting a point anywhere within the area of that word, number, or data point

and also in the area immediately surrounding his choice. The minimum selectable area is the length of the text itself plus a margin surrounding it equal to half the height of the text characters.

- c. Operator mistakes should be easy to correct. An operator should be able to remove and/or replace mistyped characters by use of a backspace key. It should be possible to cancel a current entry regardless of where the operator is in the entry sequence. Completed entries on the same or different display presentations should be easily recalled and changed when desired by the operator.
- d. A dedicated help function should be provided on the keyboard to assist the operator if he should forget what information to enter, become lost, or become confused about the display presentation.
- e. No more than seven chunks of information should be remembered by an operator when changing from one display presentation to a subsequent presentation.
- f. Operators familiar with the prompted entry procedures should be allowed to generate data entry strings. If an error is

entered in an input string, the system should indicate the error, default to the prompting mode at the point of error, and process the preceding input.

- g. The software system should be bullet-proof.

That is incorrect or inappropriate input by an operator should not allow the system to become inoperative nor should it confuse the operator or deny him interaction with the software.

- h. Simplicity and conciseness should be exercised in the display of information at any one time. One idea per display presentation is preferred.

- i. Displays should automatically be purged of information no longer useful to an operator. This should be done continually and should serve to keep the display uncluttered.

- j. Display formats should be consistent and as similar to one another as appropriate.

- k. Operator instructions (i.e., prompts) should be concise and unambiguous and should stand out in the display to attract an operator's attention.

- l. Error messages should contain directions on how recovery can be made. Error messages should be unambiguous English sentence

fragments which describe both the error condition and the recovery or remedial action to be taken. Coded in a standardized format somewhere in the error message should be an indication of exactly where in the software the message was generated.

- m. Data presented for comparison should be presented in graphic form. The presentation of raw data should be an option.
- n. All display data should be labeled.
- o. Clarity of display formats should be achieved through the use of columnar organization of displayed information. Numeric columns should be right (or decimal point) justified. Alphabetic data should be left justified. Short line lengths (less than 40 characters) should be used for lengthy text information. This may require partitioning into two columns for the presentation of some text information.
- p. Running text should be displayed in upper and lower case. Running text refers to more than one complete English sentence. Complete words should be used whenever possible.
- q. In a list of up to seven options, the one(s)

most probable of selection should be placed at the top. In a longer list or where no option is most likely to be chosen, alphabetical order should be used.

- r. Numbers, not letters should be used when listing selectable items.
- s. Entry fields should be organized to minimize positioning movements of the cursor.
- t. Numbered items should start with one; measurements should start with zero.
- u. Axes of graphs should always be labeled and should generally be subdivided into either 1, 2, 5, or 10 divisions.
- v. Every keyboard or cursor entry made by an operator should receive an acknowledgment on the display.
- w. If a display response cannot be initiated in two seconds or less, notice should be given to the operator within two seconds that the software function requested is being accomplished but is not ready for display.
- x. Error messages following an unacceptable input should be delayed no longer than two seconds.
- y. Highlighting of text should be done by reversing the contrast (e.g., dark

characters on light background). Blinking should be used only for urgent purposes. In such cases a rate of 2-3 Hz should be used with about equal on and off cycles.

- z. Coding of information (e.g., shape, color, number, etc.) is dependent on a number of display information parameters and is not easily summarized without an examination of the specific application. Before choosing a coding scheme careful consideration should be given to each specific application.

A2.0

Display Format Guidelines

The user display should be designed for the range of operator capabilities expected in the operational environment.

- a. Tabular data displays should be used to present row-column data which are significant in themselves.
- b. Location of recurring data should be similar among all tabular data displayed.
- c. Tabular data should be displayed in a left-to-right, top-to-bottom array.
- d. Similar information should be displayed in groups according to the left-to-right or top-to-bottom rules. All displayed data necessary to support an operator

activity or sequence of activities should be grouped together.

- e. The update rates of system information being displayed in a tabular form should be determined by the use the operator is to make of the information, as determined by the operator.

A3.0

Controls

- a. Feedback on control response adequacy should be provided.
- b. Multitrotation controls should be used when precision is required over a wide range of adjustments.
- c. Detented controls should be selected whenever the operational mode requires control operation in discrete steps.
- d. Rotary selector switches should have not more than 24 positions nor less than three positions.
 - 1. The minimum pointer length should be one inch.
 - 2. Each position should be detented.
 - 3. The minimum separation between adjacent switches should be one inch.
- e. The minimum diameter for knobs used for continuous, low torque application

should be one inch.

- f. The minimum separation between knobs should be one inch.
- g. Pushbutton switches should have a positive indication of control activation. The switch should have either tactile feedback, audible feedback, or some visual display which signals the activation of the control.
- h. The minimum length arm for toggle switches should be not less than 0.5 inch and should have a displacement of at least 30 degrees.

A4.0

Control Display Integration

- a. Controls should be located adjacent to (under or to right of) their associated displays and positioned so that neither the control nor the hand normally used for setting the control should obscure the associated display.
- b. When the manipulation of one control requires the reading of several displays, the control should be placed as near as possible to the related displays and beneath the middle display.
- c. The precision required of control manipulation should be consistent with the precision

used in the displays. The display and control must be consistent in the units used and the accuracy required for the control must be the same level of accuracy that is displayed (e.g. if the operator inputs values accurate to two decimals the display should not display a value accurate to four decimal places).

- d. Controls/displays should be functionally grouped and labeled. The controls/displays for a particular operator function should be grouped together (e.g. power, alarm, etc.) and clearly labeled with a functional name.
- e. Functional groups of controls and displays should be located to provide left-to-right (preferred) or top-to-bottom order of use.
- f. Location of recurring functional groups and individual controls/displays should be similar from panel to panel.
- g. Providing that the integrity of grouping by function and sequence is not compromised, the more frequently used groups and the most important groups should be located in areas of easiest access.

Displays

- a. Displays with moving scales and fixed pointers should not be used.
- b. Information displayed should not require operator transposing, computing, interpolating, or mental translation in other units except in diagnostic displays.
- c. Failure of display or display circuits should be immediately apparent to the operator.
- d. Failure of the display circuit should not cause failure of the equipment associated with the display.
- e. Indicators with illuminated legend may be used to display information that requires immediate reaction by the operator.
- f. Lights, including those used in illuminated pushbuttons, should display equipment response and not merely control position.
- g. Lights and related indicators should be used sparingly and should display only that information necessary for equipment operation.
- h. Legend lights should be used in preference to simple indicator lights.
- i. The lettering on a legend indicator should be visible and legible whether or not the indicator is illuminated.
- j. The absence of a signal or visual indication

should not be used to denote a 'go', 'ready' or 'in-tolerance' condition nor should such absence be used to denote a 'malfunction', 'no-go' or 'out-of-tolerance' condition. However, the absence of a 'power on' indication shall be acceptable to indicate a 'power off' condition. (Example: Loss of signal or loss of lock should be indicated by an indicator which illuminates when the condition occurs.) Changes in display status should signify changes in functional status rather than results of control actuation alone.

- k. Master caution, master warning and summation fault lights used to indicate the condition of an entire subsystem should be set apart from the lights which show the status of the subsystem components.
- l. The brightness of the indicators with illuminated legend should be a minimum of 10 percent greater than the surrounding brightness.
- m. When indicator lights are installed on a control panel, a master lamp test control should be incorporated. When lamps with dual filaments, LED's or multiple lamps are used, a lamp test is not normally re-

quired.

n. All lamps should be replaceable from the front of the panel without use of tools.

o. Illuminated indicators should conform to the following color coding:

1. Red To indicate conditions which require immediate action by the operator to avoid equipment damage or personnel injury.
2. Amber To indicate a non-normal operation condition - a condition which requires special attention by the operator to successfully accomplish the mission, e.g., the manual portion of a split legend auto/manual switch which normally operates in the auto position.
3. White To indicate a normal operating condition. The auto portion of the above switch.
4. Green To indicate a go condition in an equipment test.

A6.0

Operator Terminals

The following guidelines pertain to the selection and use of Cathode Ray Tube (CRT) displays.

- a. Signal size. When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal should subtend not less than 20 minutes of visual angle and should subtend not less than 10 lines or resolution elements. Image quality shall be consistent with the operator's needs.
- b. Viewing distance. A 16-inch (410mm) viewing distance should be provided whenever practicable. When periods of scope observation should be short, or when dim signals must be detected, the viewing distance may be reduced to 10 inches (250 mm). Design should permit the observer to view the scope from as close as he may wish. Displays which must be placed at viewing distances greater than 16 inches (410 mm) due to other considerations should be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing and resolution.
- c. Screen luminance. The ambient illuminance should not contribute more than 25 percent of screen brightness through diffuse reflection and phosphor excitation.

- d. Faint signals. When the detection of faint signals is required and when the ambient illuminance may be above 0.25 fc (2.7 lux), scopes should be hooded, shielded, or recessed. (In some instances, a suitable filter system may be employed, subject to approval by the procuring activity.)
- e. Luminance range. The luminance range of surfaces immediately adjacent to scopes should be between 10 percent and 100 percent of screen background luminance. With the exception of emergency indicators, no light source in the immediate surround should be brighter than scope signals.
- f. Ambient illuminance. The ambient illuminance in the CRT area should be appropriate for other visual functions (e.g., setting controls, reading instruments maintenance, etc.) but should not interfere with the visibility of signals on the CRT display.
- g. Reflected glare. Reflected glare should be minimized by proper placement of the scope relative to the light source, use of a hood or shield, or optical coatings or filter control over the light source.



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