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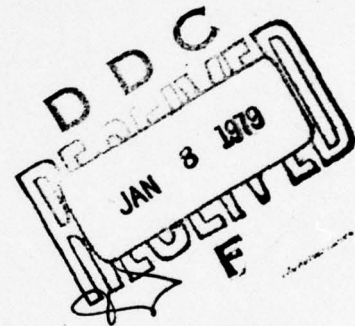


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EVALUATION OF A RADAR MOVING TARGET EXTRACTOR (MOTE)

Robert W. Delaney

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NOVEMBER 1978

FINAL REPORT

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Prepared for

**U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
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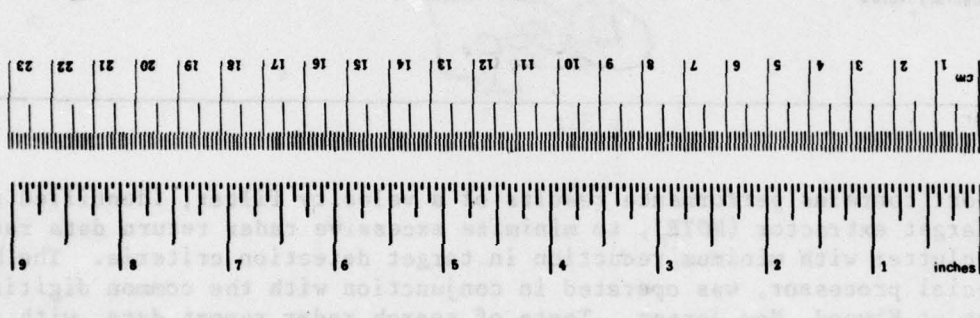
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16. Abstract <p>This report contains performance results of a velocity filter, identified as a moving target extractor (MOTE), to minimize excessive radar return data rates from weather clutter with minimum reduction in target detection criteria. The MOTE, part of a special processor, was operated in conjunction with the common digitizer (CD) equipment at Elwood, New Jersey. Tests of search radar report data, with and without the filter, employed clear-air and weather tapes which were processed by computer programs for comparison. An additional MOTE design, providing for enhancement of target detection, was tested with a limited number of sample weather tapes.</p> <p>Results of tests with low-intensity weather data showed a reduction in target detection of 4 percent, while false targets were reduced by 41 percent. Test results from high-intensity weather data showed a reduction in target detection of 15 percent with false target reduction of 44 percent.</p>		13. Type of Report and Period Covered 9 Final rept. June - October 1977	
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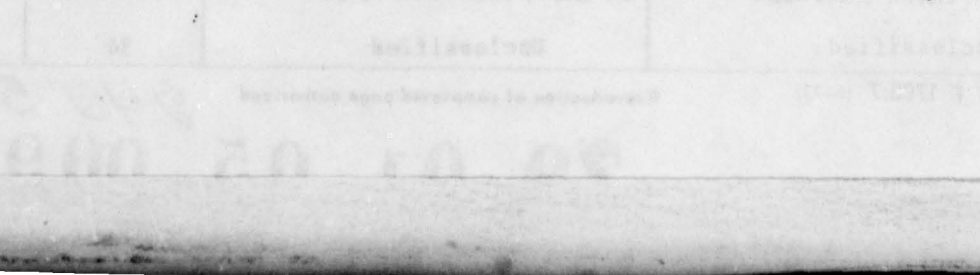
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METRIC CONVERSION FACTORS

When You Know	Multiply by	To Find
LENGTH		
millimeters	0.04	inches
centimeters	0.4	inches
meters	3.3	feet
meters	1.1	yards
kilometers	0.6	miles
AREA		
square centimeters	0.16	square inches
square meters	1.2	square yards
square kilometers	0.4	square miles
hectares (10,000 m ²)	2.5	acres
MASS (weight)		
grams	0.035	ounces
kilograms	2.2	pounds
tonnes (1000 kg)	1.1	short tons
VOLUME		
milliliters	0.03	fluid ounces
liters	2.1	pints
liters	1.06	quarts
liters	0.26	gallons
cubic meters	35	cubic feet
cubic meters	1.3	cubic yards



When You Know	Multiply by	To Find
LENGTH		
inches	*2.5	centimeters
feet	30	centimeters
yards	0.9	meters
miles	1.6	kilometers
AREA		
square inches	6.5	square centimeters
square feet	0.09	square meters
square yards	0.8	square meters
square miles	2.6	square kilometers
acres	0.4	hectares
MASS (weight)		
ounces	28	grams
pounds	0.45	kilograms
short tons (2000 lb)	0.9	tonnes
VOLUME		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.03	cubic meters
cubic yards	0.76	cubic meters
TEMPERATURE (exact)		
Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature



*1 in = 2.54 (exact). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Heights and Measures, Price \$2.25, SO Catalog No. C-73-10286.

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INTRODUCTION

PURPOSE.

The purpose of this project is to determine the effectiveness of a search radar moving target extractor (MOTE) in conjunction with a common digitizer (CD) and special processor in the reduction of excessive weather clutter data with a minimum loss in target detection.

BACKGROUND.

In order to minimize excessive data rates caused by weather clutter and permanent echoes (PE's) which meet aircraft target detection criteria, a special processor (model D2214), commonly identified as the "D Machine," was provided by the Burroughs Corporation to interface with the CD. A part of the D Machine, a velocity filter identified as MOTÉ, was initially demonstrated at the manufacturer's plant in April 1973. This enhancement feature was added under supplement 13 of contract DOT-FA74WA-3426. The D Machine was installed together with a MOTÉ control box and a digital tape recorder, all of which were interfaced with the CD at Elwood, New Jersey. The installation of MOTÉ 1 was completed in May 1975 and accepted on July 3, 1975. A modified version of MOTÉ (MOTÉ 2), which included an additional 1,024 words of memory and program changes, was installed in the D Machine in January 1977 to provide enhancement of target detection capability. MOTÉ 2 was debugged during February to March 1977, acceptance tests were completed April 27, 1977, and system tests (using weather tape inputs) were completed October 1977.

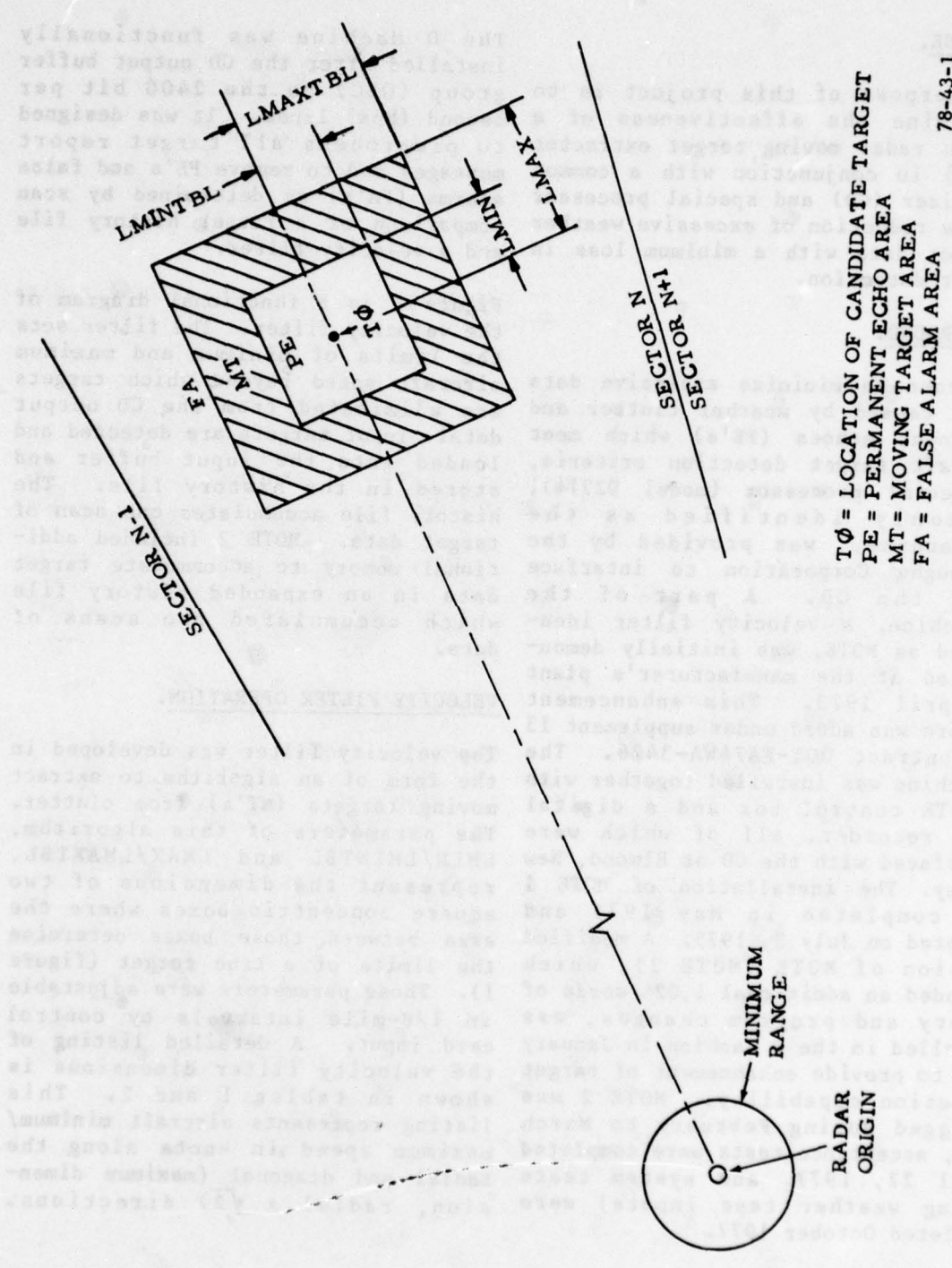
DESCRIPTION OF MOTÉ

The D Machine was functionally installed after the CD output buffer group (OBG) on the 2400 bit per second (bps) lines. It was designed to preprocess all target report messages and to remove PE's and false alarms (FA's) as determined by scan comparison of a target history file and a velocity filter.

Figure 1 is a functional diagram of the velocity filter. The filter sets the limits of minimum and maximum aircraft speed beyond which targets are eliminated from the CD output data. Input targets are detected and loaded into the input buffer and stored in the history file. The history file accumulates one scan of target data. MOTÉ 2 included additional memory to accommodate target data in an expanded history file which accumulated two scans of data.

VELOCITY FILTER OPERATION.

The velocity filter was developed in the form of an algorithm to extract moving targets (MT's) from clutter. The parameters of this algorithm, LMIN/LMINTBL and LMAX/LMAXTBL, represent the dimensions of two square concentric boxes where the area between those boxes determine the limits of a true target (figure 1). These parameters were adjustable in 1/8-mile intervals by control card input. A detailed listing of the velocity filter dimensions is shown in tables 1 and 2. This listing represents aircraft minimum/maximum speed in knots along the radial and diagonal (maximum dimension, radial x $\sqrt{2}$) directions.



$T\phi$ = LOCATION OF CANDIDATE TARGET
 PE = PERMANENT ECHO AREA
 MT = MOVING TARGET AREA
 FA = FALSE ALARM AREA

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FIGURE 1. FUNCTIONAL DIAGRAM OF NOTE 1

TABLE 1. LMIN VELOCITY FILTER DIMENSIONS FOR DETERMINATION OF PROBABLE AIRCRAFT REJECTION

<u>LMIN (nmi)</u>	<u>RADIAL VELOCITY (knots)</u>	<u>DIAGONAL VELOCITY (Radial $\times\sqrt{2}$) (knots)</u>
0	not rejected	not rejected
1/8	47	66
1/4	94	133
3/8	140	198
1/2	187	264

For LMIN selected, an aircraft may be rejected as a permanent echo if radial/diagonal velocity is less than indicated.

TABLE 2. LMAX VELOCITY FILTER DIMENSIONS FOR DETERMINATION OF PROBABLE AIRCRAFT REJECTION

<u>LMAX (nmi)</u>	<u>RADIAL VELOCITY (knots)</u>	<u>DIAGONAL VELOCITY (knots)</u>
0	not rejected	not rejected
3/8	140	198
1/2	187	264
5/8	234	331
3/4	281	397
7/8	328	464
1	374	529
1 1/8	421	595
1 1/4	468	662
1 3/8	515	728
1 1/2	562	795
1 5/8	609	861
1 3/4	656	928
1 7/8	702	993
2	749	1059
2 1/8	796	1126

For the LMAX selected, an aircraft may be rejected as a false alarm if radial/diagonal velocity is greater than indicated.

For the case of MOTE 2, the algorithm may be considered as three concentric boxes (figure 2) where the area between the middle and outer boxes represents the second previous radar scan. This feature enables a potential moving target, not present during the first previous scan, to be compared with the current scan target for detection as a true moving target. For a marginal radar coverage situation where every other search target was not detected, MOTE 2 would enable continuous detection, while MOTE 1 would permit no detection. This will occur in the MOTE 1 design, as a target report must be in the previous scan for comparison with the current scan. In the MOTE 2 design, the selected LMAX/LMAXTBL dimensions were simply double the dimensions of the original MOTE (MOTE 1). A description of the velocity filter function and a general flow diagram of the MOTE 1 velocity filter operation are presented in appendix A.

MOTE CONTROL BOX.

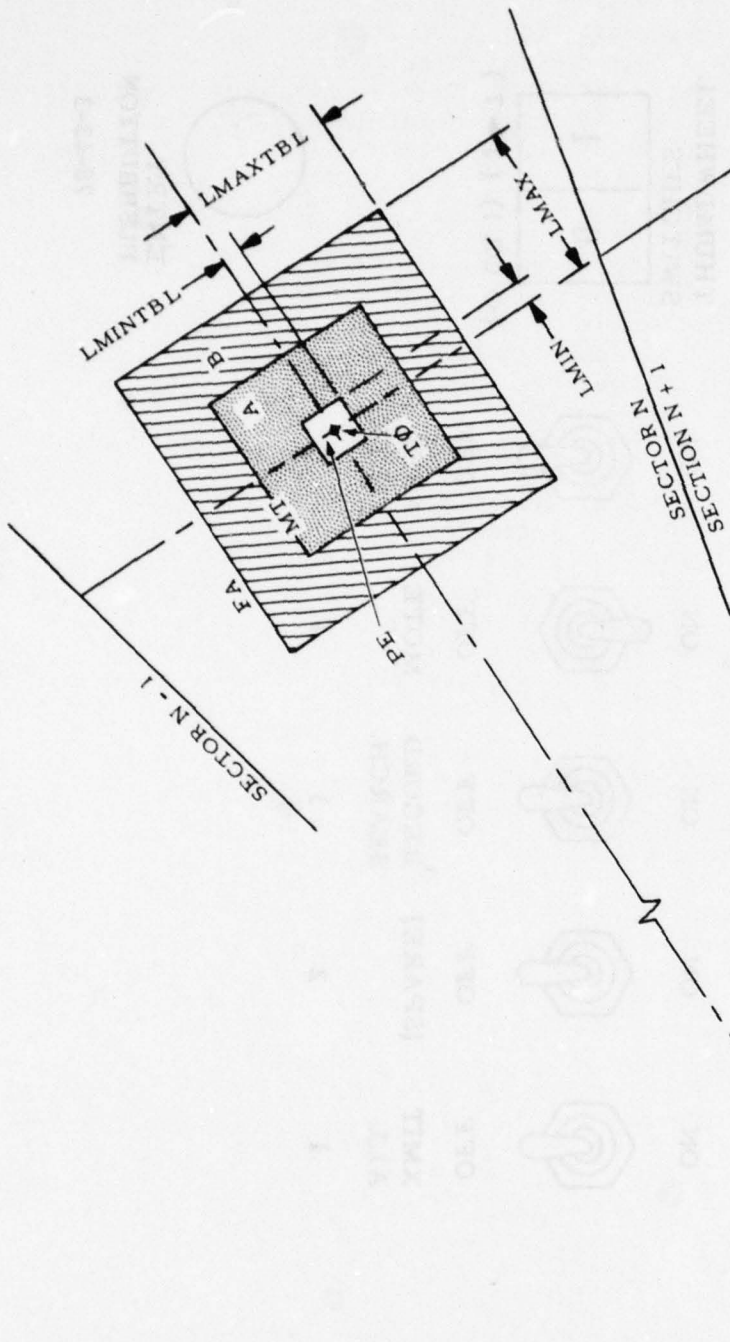
The MOTE control box was a special feature of the MOTE modification which monitored the MOTE performance. This was accomplished by means of the dynamic display of various target counts of several MOTE parameters and other MOTE functions. These parameters were selectable by thumbwheel switches, toggle switches, and a pushbutton interrupt switch (figure 3). The control box interrupt switch, by way of inputs to the D Machine system level routine, provided accumulated target totals of any one of eight MOTE parameters in the MOTE control box display window. These parameters, by switch number, are:

- (00) Total targets rejected
- (01) Total targets transmitted
- (02) Total targets within constrained zone
- (03) Total PE's
- (04) Total FA's
- (05) Total minimum range rejects
- (06) Total MT's
- (07) Total search targets examined

The total targets examined (07) represent the sum of targets transmitted (01), MT's (06), plus the total targets rejected (00). The rejected targets (00) were the sum of PE (03), FA (04), and minimum range targets (05). The constrained zone, activated by control box switch (02), was a special area controlled by range and azimuth start/stop boundary parameters. Target reports inside this constrained zone were automatically accepted by MOTE. All other target reports outside this selected area were processed by the velocity filter. A listing of all MOTE control box switches and functions is presented in table 3.

D MACHINE.

The D Machine was composed of an interpreter, a system memory control unit, a system memory, and device dependent ports. A general description of the D Machine elements including a block diagram is presented in appendix B. The D Machine which was provided for the CD enhancement program included the velocity filter and correlation functions for MOTE. The D Machine basically incorporated "minimally committed" logic or hardware which was operated by control signals from firmware (the microprogram) and from input/output interfaces.

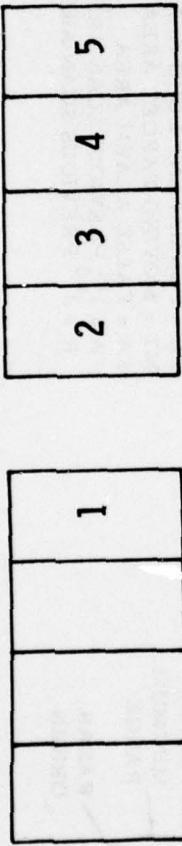


$T\phi$ = LOCATION OF CANDIDATE TARGET
 PE = PERMANENT ECHO AREA
 MT = MOVING TARGET AREA (2 OUTER BOXES)
 FA = FALSE ALARM AREA
 A = 1st PREVIOUS SCAN AREA
 B = 2nd PREVIOUS SCAN AREA

78-43-2

FIGURE 2. FUNCTIONAL DIAGRAM OF NOTE 2

SELECTED COUNTER DATA DISPLAY



TOGGLE SWITCHES



FIGURE 3. MOTE CONTROL BOX

TABLE 3. MOTE CONTROL BOX SWITCH FUNCTIONS

<u>Thumbwheel Setting</u>	<u>Display Data</u>
00	Total No. Targets Rejected
01	Total No. Targets Transmitted
02	Total No. Targets Within Constrained Zone
03	Total No. Permanent Echoes
04	Total No. False Alarms
05	Total No. Minimum Range Rejects
06	Total No. Moving Targets
07	Total No. Search Targets Examined by MOTE
10	99999 (used to zero out system counters)
11	Total No. Magnetic Tape Parity Errors
12	Write "End of File" on Tape, 77777 Displayed
13 - 17	Future Expansion

NOTE: Five 8's (88888) appearing on the control box display signifies an azimuth range pulse alarm; that is, the hardware and software are asynchronous.

<u>Toggle Switch No.</u>	<u>Function</u>
1	Transmits all targets regardless of rejection by MOTE
2	Spare
3	Only effective during beacon recording (mode 2), records search targets as well as beacon targets
4	Enable MOTE
5	Enables area filter function of MOTE (only effective when MOTE is enabled)
Entry Pushbutton	Provides an interrupt of S-level routine indicating status of thumbwheel and toggle switches

TEST PROCEDURES AND RESULTS--MOTE 1

DESCRIPTION OF TESTS.

The test and evaluation effort was conducted utilizing clear-air and weather clutter tapes which were recorded on the (Ampex FR-950) video tape recorder at the Elwood radar facility. Repeatable tests using the video tapes at selected time intervals were conducted for interface with the CD and processing by the D machine. Different parameter changes of the D machine, which were accomplished by card reader input (figure 4) or switches on the D machine operation panel (figure 5), were used with each repeated tape playback to determine the performance of the MOTE velocity filter function. The essential features of the filter were examined to determine the reduction in data rates by minimizing FA's and PE's with the degradation of target detection held to a minimum. A description of the tests is as follows:

1. Verification of MOTE control box readout functions using controlled inputs.
2. Establishment of optimum size of the LMIN and LMAX parameters of the MOTE algorithm.
3. Investigation of MT's, PE's, and FA's using MOTE control box.
4. Investigation of MOTE probability of detection (P_d).
5. Investigation of false targets (FT's) using the track analysis and display (TAD) computer program.
6. Establishment of MOTE performance with low-altitude aircraft only using clear-air and weather tapes.

A detailed description of the method and the results of these tests for MOTE 1 are presented below.

VERIFICATION OF MOTE CONTROL BOX READ-OUT FUNCTIONS USING CONTROLLED INPUTS.

METHOD. Tests were conducted to verify contractor test demonstration of the velocity filter function in accordance with paragraph 3.10.4, supplement 13 of contract DOT-FA7WA-3426. In these tests, the CD variable and fixed target generators were used to insert a pattern of MT's and fixed targets, respectively, to display and eliminate generated targets on the radar console unit (RCU) and to display target counts of the MOTE control box functions (figure 3). Software parameter changes were made by way of cards in order to select a 270° area within which the MOTE operated and the remaining 90° area where MOTE was inoperative. This arrangement permitted several checks of the MOTE velocity filter performance by observation of ring-target counts on the random access plan position indicator (RAPPI) console unit and at the MOTE control box when changes in target range and azimuth were initiated. These range/azimuth changes of the target with less than, within, and more than the velocity filter algorithm parameters (LMIN, LMAX, LMIMTBL, and LMAXTBL) were used to exercise the MOTE performance.

RESULTS. All of the demonstration test procedures for MOTE were performed satisfactorily. However, data reduction of random aircraft tracks derived from video tapes showed that aircraft at ranges in excess of 82 nautical miles (nmi) were rejected by MOTE. This was noted by the MOTE flag being printed continuously whenever the aircraft range exceeded 82 nmi. An investigation of the

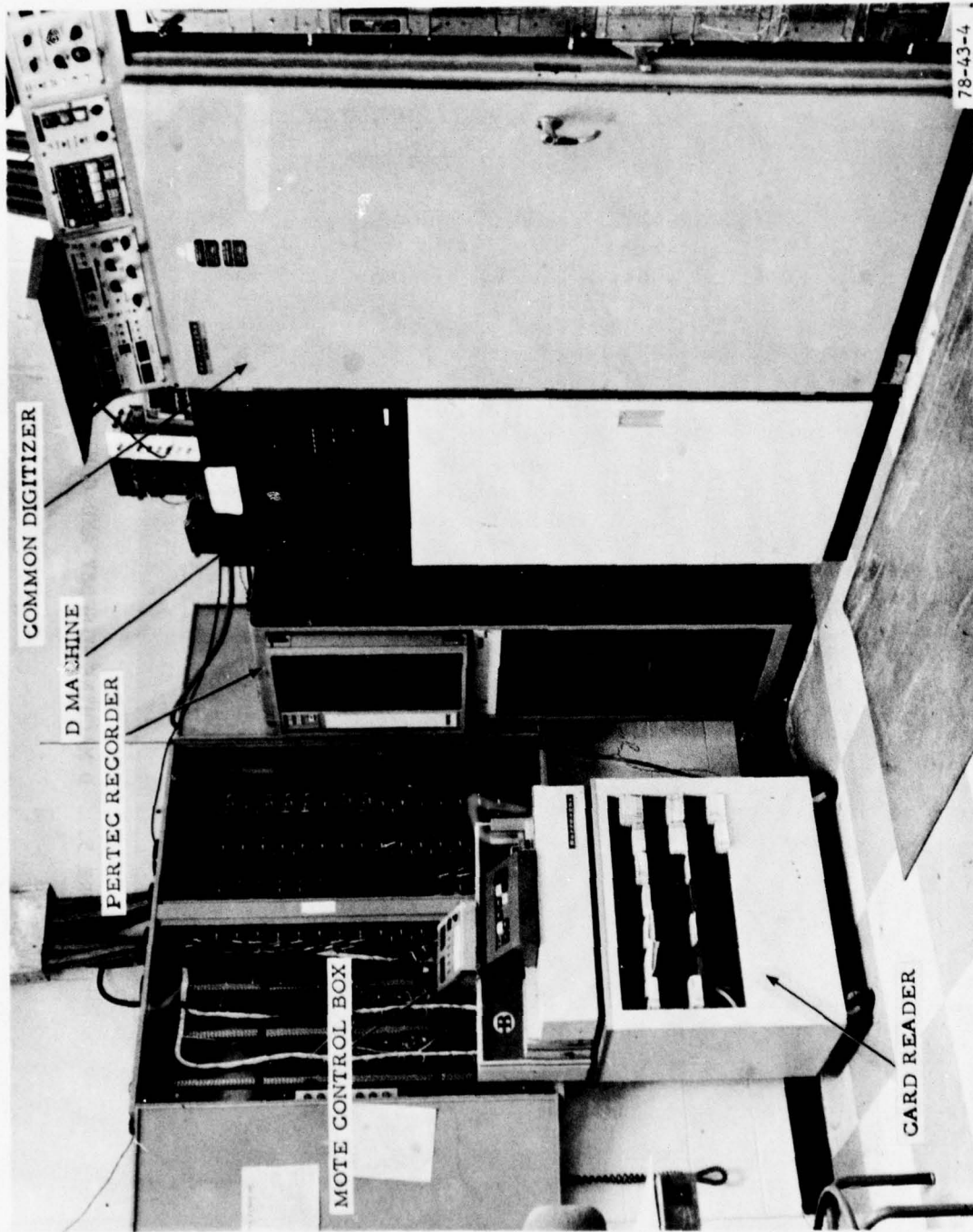


FIGURE 4. MOTE TEST ENVIRONMENT

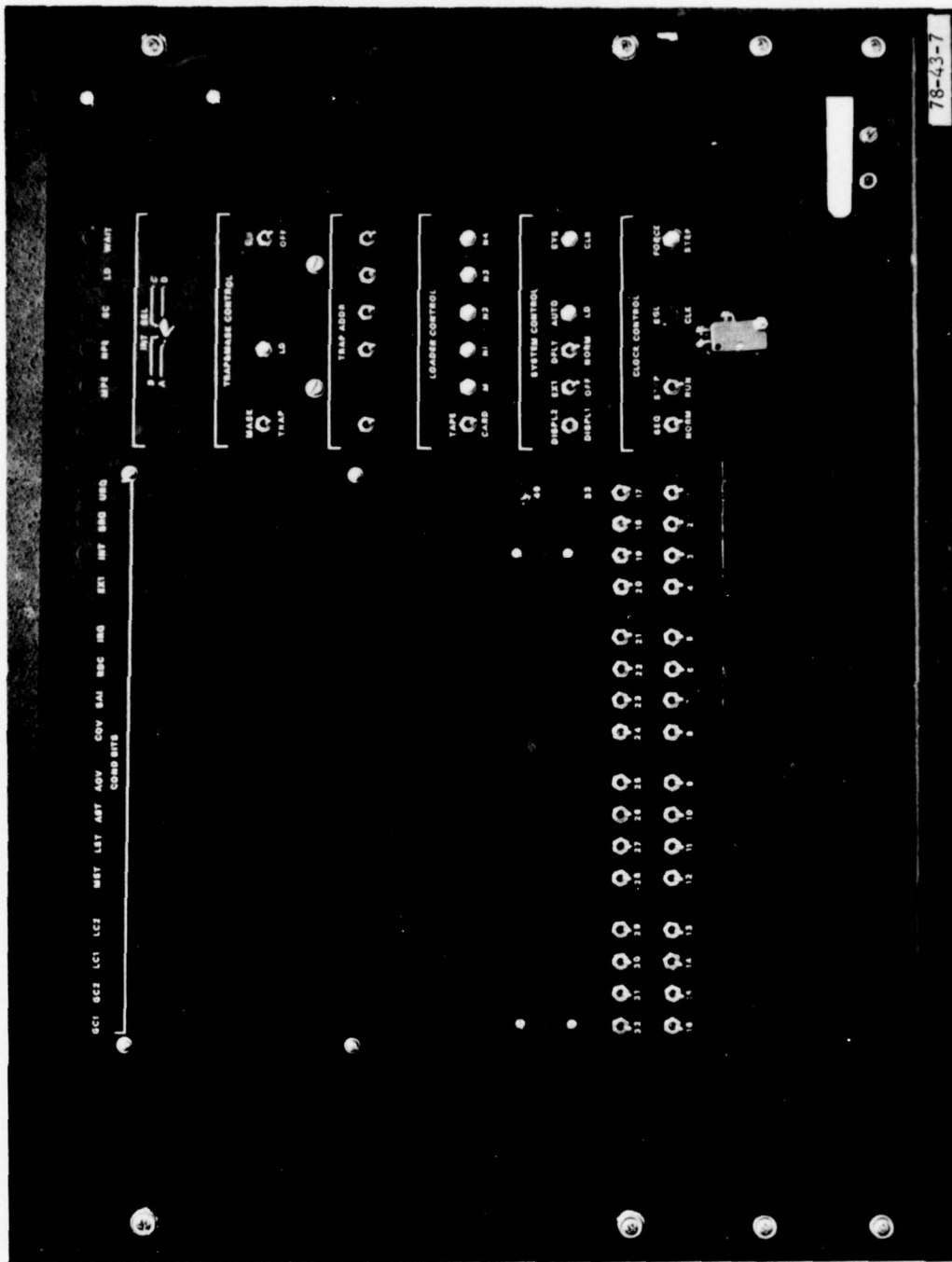


FIGURE 5. D MACHINE DISPLAY AND CONTROL PANEL

velocity filter performance using the test target generators at the Elwood CD showed that, for a range of up to 81.5 nmi, the filter performed in accordance with referenced specifications. However, beyond this range, the MOTE rejected the target test ring. This situation was corrected, and the velocity filter performed normally after the contractor provided a software modification to the system level routine to prevent overflow of the MOTE azimuth register.

ESTABLISHMENT OF OPTIMUM SIZE OF LMIN AND LMAX OF THE MOTE ALGORITHM.

METHOD. The MOTE LMAX parameter setting of the D Machine system level routine was modified several times, via inputs to the card reader, over a range from 1/4 to 4 nmi. A clear-air tape of beacon and search data was used on a video tape recorder, Ampex model FR-950, in order to provide repeatable aircraft target data. These data were processed by the CD and D Machine for recording on digital tape. (See figure 4.)

The beacon reports were delayed 1/2 nmi at the CD to permit the corresponding search target to be processed by MOTE. The digital recorder (Ampex model FR-1800) provided inputs to the NAS en route central computer complex, where a CD RECORD program (FAA-4006F) and a COMDIG program (FAA-4006B) were used to track 19 aircraft over a 7-minute period. The COMDIG program was modified so that the MOTE flag, which is set in bit 25 of the CD message format, was converted to an asterisk (*) which was positioned adjacent to the search message of the corresponding beacon tracked target. This arrangement facilitated data reduction for determining P_d with and without MOTE. This technique was repeated

for each MOTE LMAX modification of the D Machine. The MOTE test configuration of the hardware and software interface is shown in figure 6.

RESULTS. The composite average of 19 random aircraft from the clear-air tape at the various MOTE LMAX settings is shown in table 4. The composite MOTE P_d average at a LMAX setting of smaller than 1 1/2 nmi starts to degrade significantly. From tables 1 and 2, the radial/diagonal distances of the LMIN-LMAX concentric boxes of 1/8 and 1 1/2 nmi represent an aircraft velocity of 47/66 knots and 562/795 knots, respectively. Targets traveling beyond these limits will be inhibited, or accepted and "flagged."

This optimum (LMAX) setting is more clearly demonstrated by a rearrangement of these random (beacon reference) targets within speed categories where transition point of MOTE P_d becomes significantly reduced. The higher speed aircraft recorded (over 520 knots) show no degradation of MOTE P_d at the LMAX setting of 1 1/2 nmi. The underlined percentages, indicated in table 4, show the threshold of MOTE P_d degradation at the different aircraft speeds. An LMIN parameter setting of 1/8-nmi was selected as being optimum, although some aircraft with speed less than 152 knots and all aircraft with speed less than 108 knots would be rejected by the MOTE filtering by being considered a PE.

INVESTIGATION OF MT'S, PE'S, AND FA'S USING MOTE CONTROL BOX.

METHOD. With MOTE LMIN and LMAX parameter settings of 1/8 and 1 1/2 nmi, respectively, considered

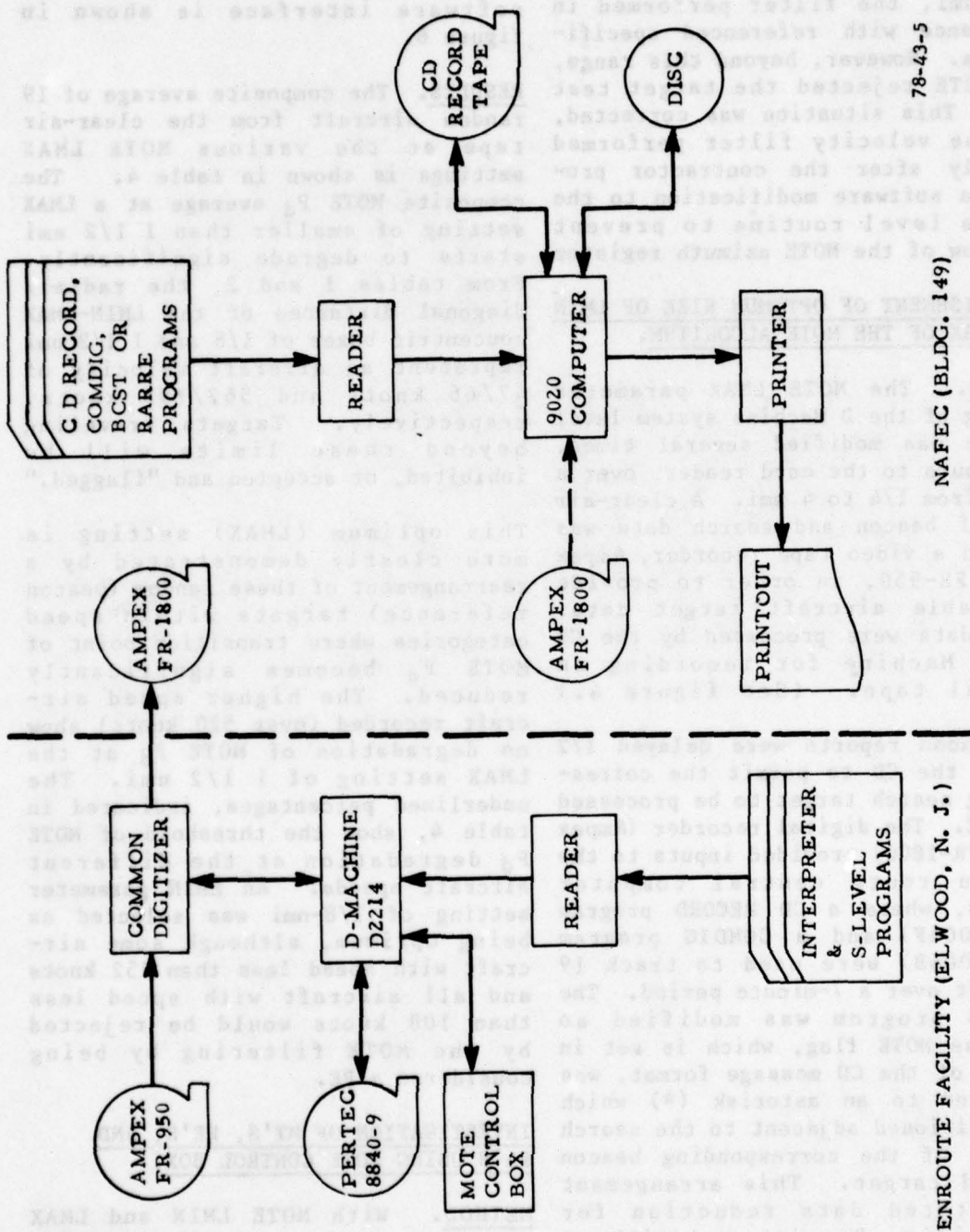


FIGURE 6. MOTE TEST CONFIGURATION

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TABLE 4. AVERAGE PERCENTAGE OF PROBABILITY OF DETECTION WITH MOTE INSTALLED AT VARIOUS LMAX VELOCITY FILTER SETTINGS AND AIRCRAFT SPEEDS

Estimated Aircraft Speed (Knots)	0*	<u>4</u>	<u>3 1/2</u>	<u>3</u>	<u>2 1/2</u>	<u>2</u>	<u>1 1/2</u>	<u>1 1/4</u>	<u>1</u>	<u>3/4</u>	<u>1/2</u>	<u>3/8</u>	<u>1/4</u>
390-520 (4)	90.1	88.4	91.2	86.2	84.9	90.1	90.5	<u>32.2</u>	6.3	0	0	0	0
348-390 (2)	92.3	88.1	87.2	77.5	87.4	80.2	81.0	87.1	<u>62.1</u>	32.3	19.9	8.8	0
260-348 (7)	83.9	83.6	84.9	85.0	84.4	84.6	86.6	84.3	78.8	<u>44.1</u>	10.0	7.7	2.6
174-260 (6)	84.6	82.7	79.4	80.9	77.0	81.0	80.4	81.0	82.4	82.2	<u>47.5</u>	15.8	4.8
Composite Average	86.3	84.8	84.7	83.2	82.5	84.1	84.8	72.6	62.9	45.6	16.9	5.9	2.9

NOTES: 19 aircraft tracks were analyzed for MOTE Pd over a 40-scan period extracted from a clear-air video tape. Numbers underlined are the critical LMAX settings where MOTE Pd degradation is significant. Numbers in parenthesis are the aircraft tracks sampled.

* LMAX setting not in operation.

optimum, a series of tests was conducted using clear-air and weather tapes. The MOTE control box was used to count the several target parameter totals (referenced in table 3) from a clear-air tape and three weather tapes, which were processed by the CD and D Machine.

RESULTS. Table 5 shows the gross accumulation of total target counts of the MOTE functions displayed on the MOTE control box when using clear-air or weather tapes over a period of 7 or 10 minutes of video tape recording time.

After discounting the number of Min Range rejects from table 5 and using the counts/scan as reference, the MOTE filtering percentages of these tapes were determined as shown in table 6. As expected, the clear-air tape shows the fewest false alarms. From the table, note that two of the weather tapes (WX75-04 and WX75-14) show a higher percentage of MT's. This is considered the result of weather clutter meeting target detection criteria and therefore not eliminated by the velocity filter.

INVESTIGATION OF MOTE P_d .

METHOD 1. A repeat of the technique of employing an asterisk symbol was used in the COMDIG program (explained under Optimum Size of LMIN and LMAX test) to determine if an MT was rejected by MOTE. A total of 24 discrete beacon targets from weather tape WX75-13 were selected and the COMDIG track box printout of these discrete targets provided a scan count for comparative probability of detection. With the Transmit-All switch selected on the MOTE control box (and system processing as shown in figure 6), the COMDIG track

box printout of the selected discrete beacon targets showed the total scans, the scans in which targets were detected, and targets not detected shown by the asterisk symbol. From this printout, a direct comparison of P_d and MOTE P_d was established.

METHOD 2. An alternate method for achieving the same result of P_d and MOTE P_d comparison without extensive manual reduction was established by using the RARRE (FAA-4006M) program. This program provided beacon and search percentages of total or individual beacon selected targets. This test was conducted twice, with and without MOTE operation, using the same beacon discrete targets selected. The RARRE printout data provided a direct output of beacon and search comparisons from which P_d versus MOTE P_d was directly available.

RESULTS. Comparison of P_d , using either the RARRE program or the COMDIG asterisk method, showed from table 7 that degradation of P_d using MOTE is significant. Data reduction indicated that P_d is degraded by 7.5 percent in the clear-air and by 10.7 percent in weather.

INVESTIGATION OF FT'S USING THE TRACK ANALYSIS AND DISPLAY PROGRAM.

METHOD. A software program identified as Track Analysis and Display (TAD) was utilized to determine whether a report classified as FT was actually a false report or a true target report which was "flagged" by MOTE. The TAD program operated in conjunction with the 7090 computer. It was operated with a light gun which activated special switches on a cathode-ray tube (CRT) display

TABLE 5. MOTE CONTROL BOX COUNTS OF CLEAR-AIR AND WEATHER TAPES

MOTE Control Box Functions	Control Box No.	Clear-Air Tape WX75-02		Weather Tape Wx75-13		Weather Tape Wx75-14		Weather Tape WX75-04	
		Total Counts (7 min)	Counts Per Scan	Total Counts (10 min)	Counts Per Scan	Total Counts (10 min)	Counts Per Scan	Total Counts (10 min)	Counts Per Scan
Tgts rejected	00	13,104	300	15,233	244	7,050	113	12,484	200
Tgts Transmitted	01	19,415	444	26,976	432	15,452	247	23,784	381
Permanent echoes	03	4,035	92	6,949	111	2,626	42	743	12
False Alarms	04	1,591	36	4,123	66	4,096	66	8,568	137
MinRange Rejects	05	7,478	171	4,161	67	320	5	3,051	49
Moving Tgts	06	6,369	146	11,683	187	8,528	136	11,554	185
Sch. Tgts Exam	07	19,472	445	26,916	431	15,574	249	24,032	385

TABLE 6. MOTE FILTERING PERCENTAGES OF CLEAR-AIR AND WEATHER TAPES

Mote Filtering Percentages	Video Tapes		
	Clear-Air Tape WX75-02	Weather Tape WX75-13	Weather Tape WX75-04
Moving Tgts	53.3	51.2	55.7
False Alarms	13.1	18.4	27.1
Perm. Echoes	33.6	30.4	17.2

CD = ACE 3
MOTE Parameters
LMIN = 1/8 nmi
LMAX = 1 1/2 nmi
MinRange = 18 nmi

TABLE 7. DEGRADATION OF PROBABILITY OF DETECTION BY MOTE 1 USING RARRE PROGRAM

Video Tape Type No.	No. Targets	MOTE Settings		P_d	P_d With MOTE	Percent MOTE Degradation
		LMIN	LMAX (nmi)			
Clear Air WX75-02	19	1/8	1 1/2	92.3	84.8	7.5
Weather WX75-13	24	1/8	1 1/2	86.1	75.4	10.7

to correlate target tracks. Ten-minute video recordings of the same three weather tapes were processed by the CD/D Machine and recorded on FR-1800 digital tapes.

During recordings of the weather data, the "Xmit-All" switch of the MOTE control box was activated, which permitted the TAD reduction program to print out MOTE rejected (flagged) messages. FT data only were established when all tracked targets in weather were removed by careful light gun switch action of the TAD program. The reduction in FT's was then determined by the ratio of these FT data and the MOTE rejected false alarm (FA) data determined by "flags" provided on the 7090 computer printouts. The test configuration for acquisition of the FT data is shown in figure 7.

RESULTS. The FT data derived from the three weather tapes show a significant reduction in FT's (table 8). Analysis of these data, reduced to FA messages per scan (9.6-second scan period), indicated a 65-percent reduction from weather tapes WX75-13 and WX75-14, and a 55-percent reduction from weather tape WX75-04.

ESTABLISHMENT OF MOTE PERFORMANCE WITH LOW-ALTITUDE AIRCRAFT ONLY FROM CLEAR-AIR AND WEATHER TAPES.

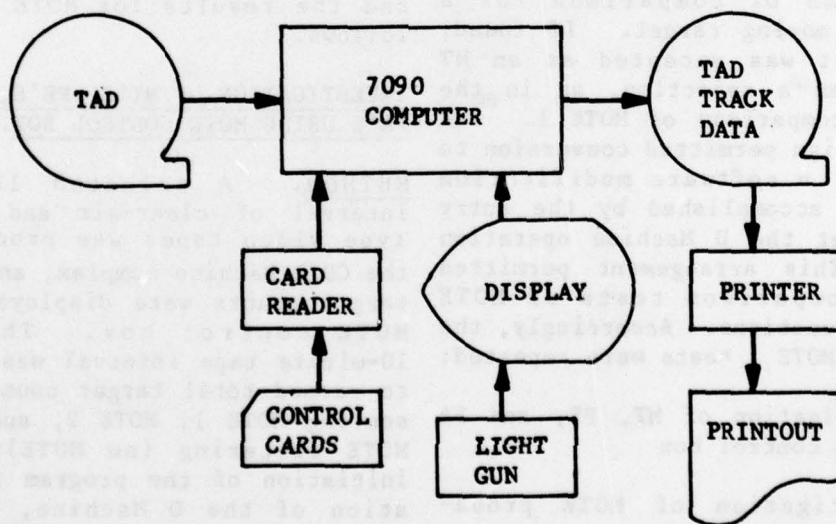
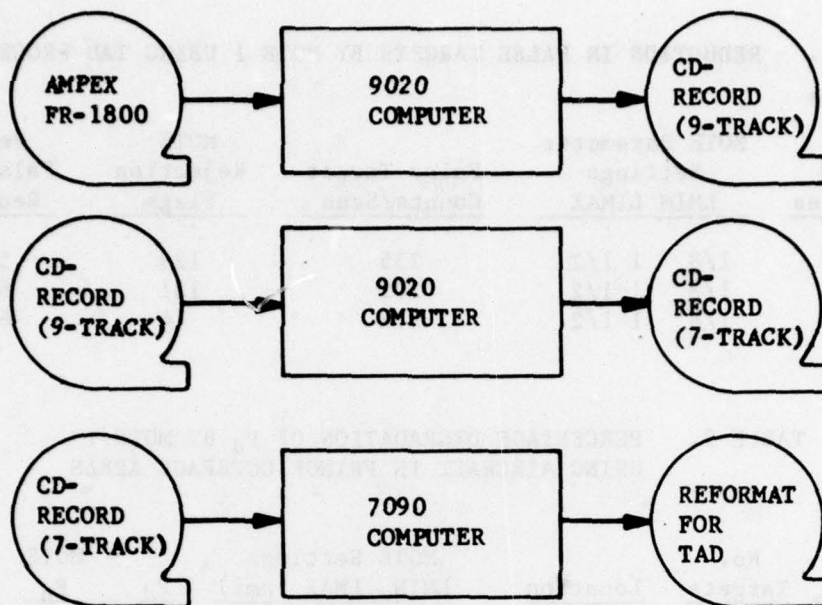
METHOD. The BCST program (FAA-4006H) was used to process beacon weather tapes on the 9020 computer to determine the low-altitude aircraft (below 18,000 feet). The RARRE program was used to process these selected low-altitude beacon aircraft with associated search targets and to provide a direct printout of P_d . Repeatable tests, with and without MOTE, provided direct P_d comparison.

RESULTS. Selected low-altitude beacon targets (33) with associated search targets processed by BCST and RARRE programs showed that the composite average percentage of MOTE P_d performance was degraded by approximately 13 percent (table 9).

TEST PROCEDURES AND RESULTS--MOTE 2

DESCRIPTION OF TESTS.

The MOTE modification (MOTE 2) was implemented in an attempt to improve



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FIGURE 7. TRACK ANALYSIS AND DISPLAY SOFTWARE CONFIGURATION

TABLE 8. REDUCTION IN FALSE TARGETS BY MOTE 1 USING TAD PROGRAM

Weather Tapes	MOTE Parameter Settings		False Target Counts/Scan	MOTE Rejection Flags	Percent False Target Reduction
	LMIM	LIMAX			
WX75-04	1/8	1 1/2	235	129	54.9
WX75-13	1/8	1 1/2	202	131	64.9
WX75-14	1/8	1 1/2	114	74	64.9

TABLE 9. PERCENTAGE DEGRADATION OF P_d BY MOTE 1 USING AIRCRAFT IN FRINGE COVERAGE AREAS

Video Tape Type No.	No. Targets	Location	MOTE Settings		P_d	MOTE P_d	MOTE Degradation
			LMIN	LMAX (nmi)			
Weather	33	Low Altitude (less than 18,000 ft)	1/8	1 1/2	77.3	64.5	12.8
WX75-13							

P_d by provision of a second previous scan of comparison for a potential moving target. If found, the target was accepted as an MT rather than a rejection, as in the one-scan comparison of MOTE 1. The MOTE 2 design permitted conversion to MOTE 1 by a software modification which was accomplished by the entry switches at the D Machine operation panel. This arrangement permitted direct comparison tests of MOTE 1/MOTE 2 functions. Accordingly, the following MOTE 1 tests were repeated:

1. Investigation of MT, PE, and FA using MOTE control box
2. Investigation of MOTE probability of detection, P_d
3. Investigation of FT using TAD program

A detailed description of the method and the results for MOTE 1/MOTE 2 follows.

INVESTIGATION OF MT'S, PE'S, AND FA'S USING MOTE CONTROL BOX.

METHOD. A selected 10-minute interval of clear-air and weather-type video tapes was processed by the CD/D Machine complex, and various target counts were displayed on the MOTE control box. This same 10-minute tape interval was repeated to record total target counts representing MOTE 1, MOTE 2, and without MOTE filtering (no MOTE). After initiation of the program for operation of the D Machine, the MOTE parameter data and the MOTE 1/MOTE 2 status information were entered via the switches on the D Machine panel (figure 5). Combinations of MT, FA, and PE data, using five video tapes

as input (see table 10), show the filtering percentage of the MOTE algorithms (table 11). Detailed target counts of the MOTE control box functions using five video tapes for MOTE 1, MOTE 2, and no MOTE are included in appendix C.

RESULTS. From table 11, MOTE 1/MOTE 2 filtering percentages, the clear-air tape and the two low-intensity weather tapes (Nos. 1, 2, and 4) show that the FA's were reduced by approximately two-thirds (64.8, 57.7, and 63.6 percent) and that the high-intensity weather tapes (Nos. 3 and 5) were reduced by less than half (48.7 and 42.8 percent). Analysis of the MT data in this table shows that the percentage increase in MT for the clear-air and low-intensity weather tapes varied between 16 and 21 percent, while the high-intensity weather tapes show an increase of over 30 percent. This was attributed to excessive clutter returns which passed the CD and MOTE target criteria. The information from table 11 was extracted from the detailed MOTE control box target counts shown in appendix C.

INVESTIGATION OF MOTE P_d .

METHOD. Selected 10-minute video tape recordings of two weather tapes (Nos. 2 and 5) which contained log and beacon data were used as inputs to the CD/D Machine complex for recording on a FR-1800 digital machine. Each tape was used three-times for a MOTE 1, MOTE 2, and no MOTE configuration on the D Machine. The accumulated data on the FR-1800 tape were then processed by the 9020 computer in operation with the RARRE program. Extraction of search target percentages from the RARRE printout data for the three MOTE conditions of each video tape is shown in table 12. This table presents the percentage degradation

of P_d when using MOTE 1 or MOTE 2 compared to a no MOTE condition.

RESULTS. From table 12, the low-intensity weather tape (No. 2) shows that with the implementation of the MOTE 2 design, P_d is improved from a value of 6.2-percent degradation (MOTE 1) to 4.1-percent degradation (MOTE 2). However, in the case of the high-intensity weather tape (No. 5), the significant P_d degradation of MOTE 1 (18.3 percent) shows only a minimal improvement with MOTE 2 (14.6 percent).

INVESTIGATION OF FT'S USING THE TAD PROGRAM.

METHOD. The basic method for this test is discussed under the method of the same test for MOTE 1. Two weather tapes (No. 3 and 4) were used twice for the MOTE 1 and the MOTE 2 configuration. The 9020 computer printouts of a low- and a high-intensity weather tape from the light gun operated TAD program were compared to determine the reduction in FT. This information of MOTE 1/MOTE 2 FT comparison is presented in table 13 which includes total clutter per scan, flagged targets per scan, and percentage reduction of FT.

RESULTS. Table 13 shows that there is a significant reduction in false targets. For the two weather tapes tested, using TAD, the MOTE modification shows an improvement from 54.9-percent FT reduction (MOTE 1) to 41.1-percent FT reduction (MODE 2) for the low-intensity weather tape. Similarly, FT reductions were 58.5 percent (MOTE 1) and 43.7 percent (MOTE 2) for the high-intensity weather tape. These data show that when MOTE 2 is compared to MOTE 1, the "tradeoff" by the use of the two-scan history of MOTE 2 for improved P_d results in an increase of FT by approximately 25 percent.

TABLE 10. VIDEO TAPES USED FOR MOTE 1/MOTE 2 TESTS

<u>Tape No.</u>	<u>Type</u>	<u>Ident</u>	<u>Video</u>	<u>Max Strength (dB)</u>
1	Clear Air	77-03	Log/Bcn	--
2	Low Intensity	77-12	Log/Bcn	20
3	High Intensity	77-13	MTI/Log	35
4	Low Intensity	77-11	MTI/Log	15
5	High Intensity	77-20	Log/Bcn	30

TABLE 11. MOTE 1/MOTE 2 FILTERING PERCENTAGES

<u>MOTE Filtering Percentages</u>	<u>Video Tapes</u>				
	<u>1</u> <u>(Clear Air)</u>	<u>2</u> <u>(Low Int)</u>	<u>3</u> <u>(High Int)</u>	<u>4</u> <u>(Low Int)</u>	<u>5</u> <u>(High Int)</u>
Moving Targets	69.5/84.3	58.0/68.1	49.6/64.7	63.3/73.5	50.7/66.2
False Alarms	25.0/8.8	24.8/10.5	38.6/19.8	22.0/8.0	40.9/23.4
Perm. Echoes	5.5/6.9	17.2/21.4	11.8/15.5	14.7/18.5	8.4/10.4

TABLE 12. DEGRADATION OF PROBABILITY OF DETECTION BY MOTE 1/MOTE 2 USING RARRE PROGRAM

<u>Video No.</u>	<u>Tapes Type</u>	<u>Search Percentages From RARRE</u>			<u>Percentage Degradation of Pd</u>	
		<u>Without MOTE</u>	<u>MOTE 1</u>	<u>MOTE 2</u>	<u>MOTE 1</u>	<u>MOTE 2</u>
2	Low Int	73.0	68.5	70.0	6.2	4.1
5	High Int	57.4	46.9	49.0	18.3	14.6

TABLE 13. REDUCTION IN FALSE TARGETS BY MOTE 1/MOTE 2 USING TAD PROGRAM

<u>Tape No.</u>	<u>Type</u>	<u>Total Clutter/Scan</u> <u>(10 min)</u>	<u>Flagged Targets/Scan</u> <u>(10 min)</u>	<u>Percentage FT</u> <u>Reduction</u>
		<u>MOTE 1/MOTE 2</u>	<u>MOTE 1/MOTE 2</u>	<u>MOTE 1/MOTE 2</u>
4	Low Int	149.8/158.7	82.2/65.2	54.9/41.1
3	High Int	270.8/286.5	158.4/125.3	58.5/43.7

SUMMARY OF RESULTS

1. The MOTE optimum LMIN and LMAX parameter settings were established at 1/8 and 1 1/2 nmi, respectively. This permits filtering of targets traveling at velocities less than 47 knots or more than 562 knots.

2. Weather data of low intensity had only a small effect on the reduction of MOTE probability of detection. Loss in P_d was reduced to 4.1 percent when using MOTE 2.

3. Weather data of high intensity showed that the loss in P_d when using MOTE was significant, 18.3 percent for MOTE 1 and 14.6 percent for MOTE 2.

4. A significant false target reduction in the order of 58.5 to 54.9 percent was accomplished with MOTE 1 and 43.7 to 41.1 percent with MOTE 2. With operation of the modified MOTE (MOTE 2), results show a loss of false target reduction over MOTE 1 by approximately 25 percent.

5. MOTE 1 processing of low-altitude aircraft (below 18,000 feet) showed a loss in P_d of 13 percent (MOTE 2 not tested).

CONCLUSIONS

Based on the analysis of the data contained in this report, it is concluded that:

1. During low-intensity weather conditions, a digitizer equipped with an improved moving target extractor (MOTE 2) will enhance the National Airspace En Route System by a significant reduction in weather clutter (over 40 percent) but at the sacrifice of target detection (a loss in excess of 4 percent).

2. With MOTE 2 activated under high-intensity weather conditions (greater than 30 decibels), the loss of target detection was approximately 15 percent.

APPENDIX A

VELOCITY FILTER DESCRIPTION

As shown in figure A-1, the LMIN/LMINTBL and LMAX/LMAXTBL parameters represent the distance in nautical miles (nmi) from the edge to the center of the concentric boxes. An aircraft traveling a distance less than the inner box dimension or more than the outer box dimension in successive scans of the radar will be inhibited. A target is considered a PE if it travels less than the dimensions of the inner box, LMIN for range or LMINTBL for azimuth (a constant equal to $LMIN \times 2,048/\pi$). Similarly, a target is considered an FA if it travels greater than the dimensions of the outer box, LMAX or LMAXTBL. In addition, a target which falls below a selected minimum range fails the MOTE criteria.

MOTE permits targets that fail the velocity filter to be eliminated (not transmitted) or transmitted with a "flag" indicating "reject." All other targets are considered true moving targets, provided the current target at the center of the concentric boxes includes at least one target from the prior scan within the area between the two boxes and no history target falls within the smaller box.

For the MOTE 2 design, all in the above paragraph is the same except that a potential moving target not detected during comparison with the previous scan history file but present in the added second previous scan history file is declared a true moving target.

The formulas for computing the MOTE velocity filter algorithm are as follows:

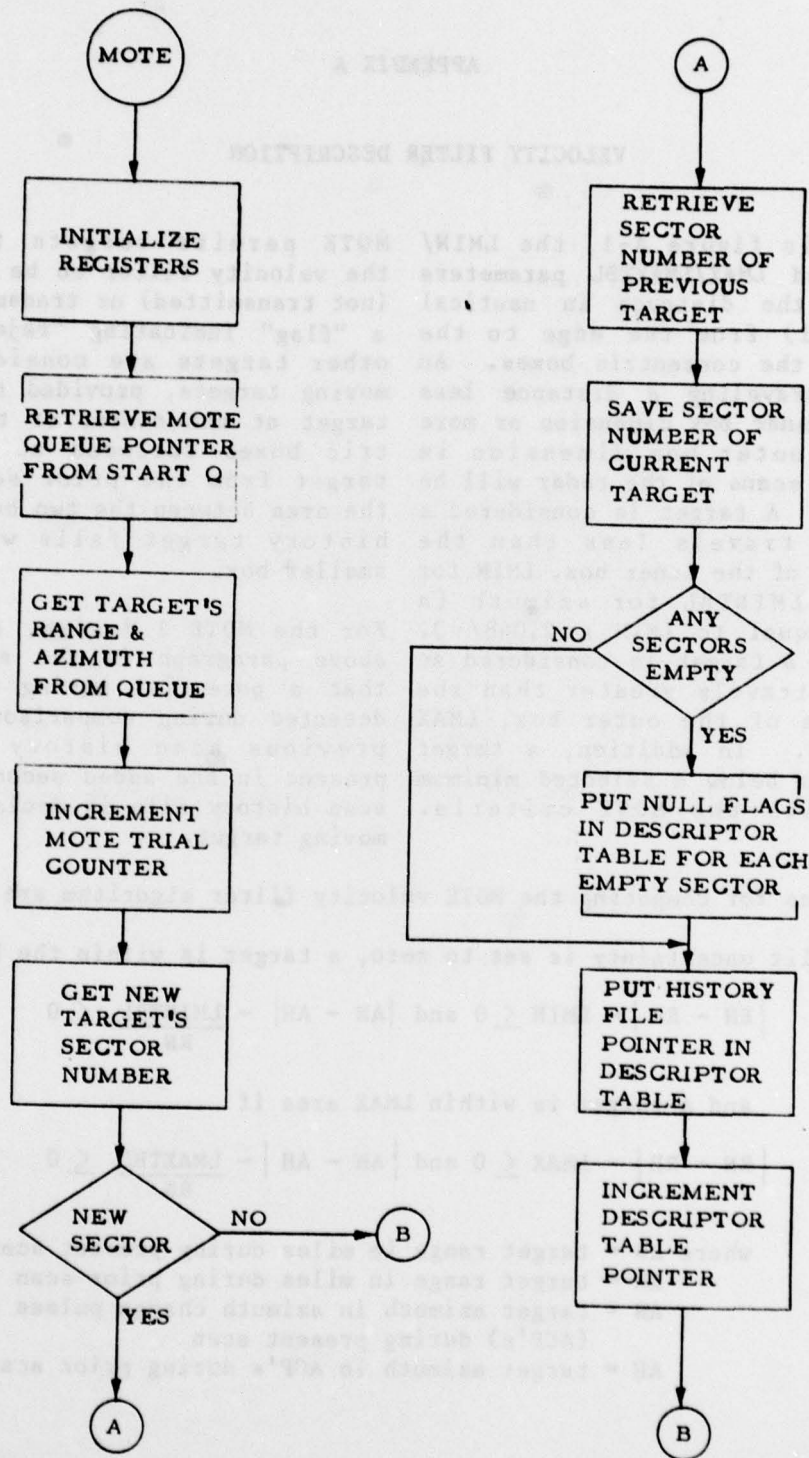
If beam split uncertainty is set to zero, a target is within the LMIN area if

$$|RN - RH| - LMIN \leq 0 \text{ and } |AN - AH| - \frac{LMINTBL}{RN} \leq 0$$

and a target is within LMAX area if

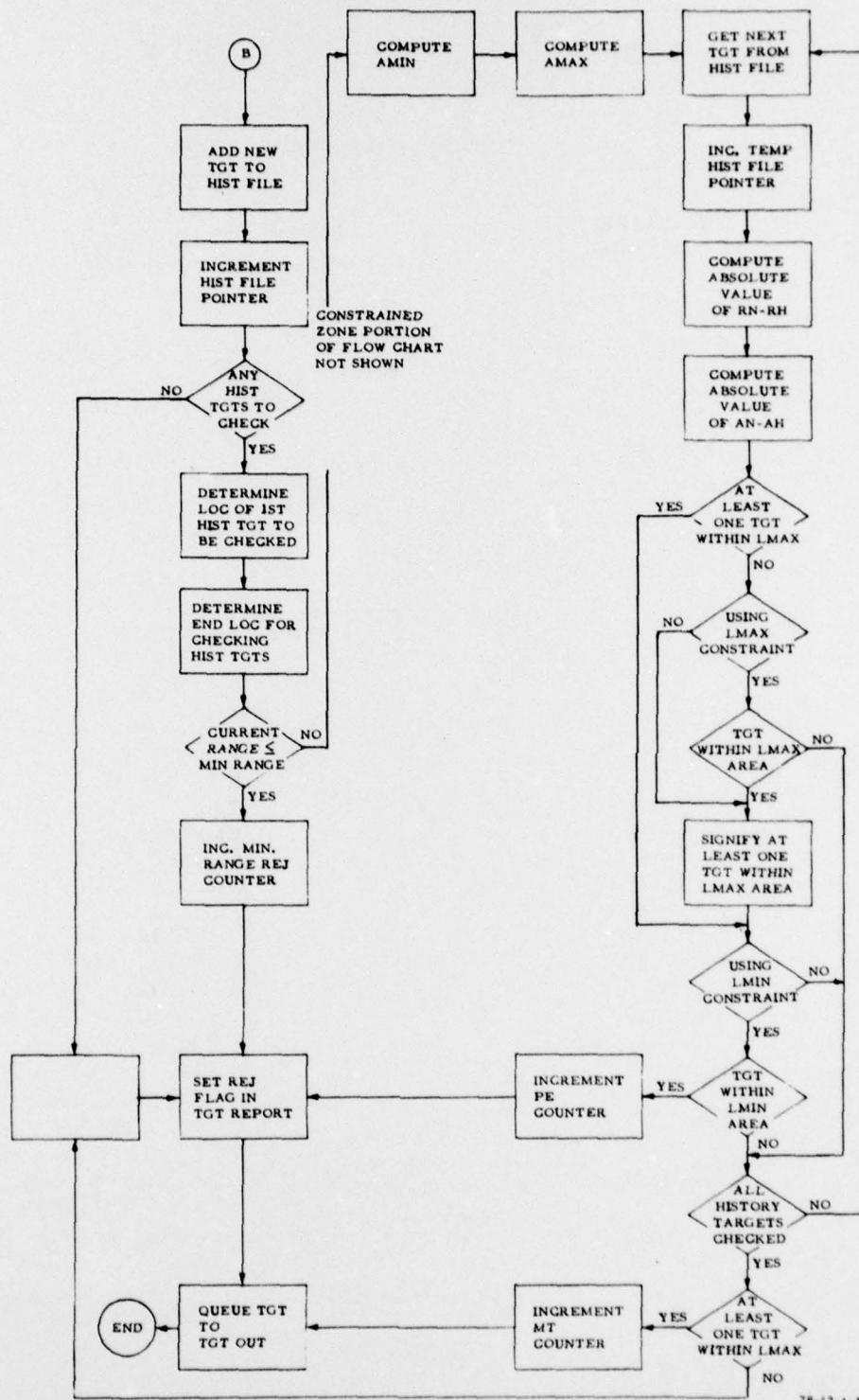
$$|RN - RH| - LMAX \leq 0 \text{ and } |AN - AH| - \frac{LMAXTBL}{RN} \leq 0$$

where RN = target range in miles during present scan
RH = target range in miles during prior scan
AN = target azimuth in azimuth change pulses (ACP's) during present scan
AH = target azimuth in ACP's during prior scan



78-43-A-1

FIGURE A-1. GENERAL FLOW DIAGRAM OF MOTE (1 of 2 sheets)



78-43-A-1

FIGURE A-1. GENERAL FLOW DIAGRAM OF MOTE 1 (2 of 2 sheets)

APPENDIX B

GENERAL DESCRIPTION OF D MACHINE

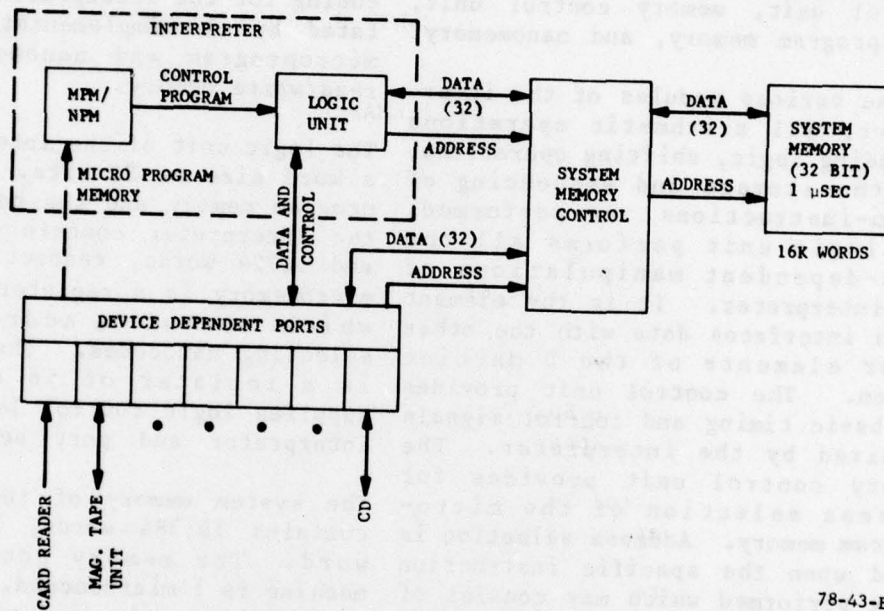
The major elements of the D Machine are the interpreter, a system memory, a system memory control, and device dependent ports (figure B-1). The basic element is the interpreter. This is functionally divided into modules identified as a logic unit, control unit, memory control unit, microprogram memory, and nanomemory.

In the various modules of the interpreter, all arithmetic operations including logic, shifting operations, and the storage and sequencing of micro-instructions are performed. The logic unit performs all the data-dependent manipulations of the interpreter. It is the element which interfaces data with the other major elements of the D Machine system. The control unit provides the basic timing and control signals required by the interpreter. The memory control unit provides for address selection of the microprogram memory. Address selection is based upon the specific instruction being performed which may consist of results of the arithmetic calculations in the logic unit and control signals derived from the control unit. The microprogram memory serves as the storage element for the microcode, and the microcode defines the step-by-step operation required

to implement a function. Each microprogram memory word selects a specific nanomemory address, and each nanomemory address defines the state of the control signals used to specify a single operation of the interpreter. Flexibility of program coding for the interpreter is facilitated by the implementation of the microprogram and nanomemory by a read/write memory.

The logic unit of the interpreter has a word size of 32 bits. The microprogram memory and the nanomemory of the interpreter contain 2,048 words and 1,024 words, respectively. The micromemory is a register of 16 bits which contains addresses for selecting nanocodes. The nanomemory is a register of 56 bits which supplies logic control levels to the interpreter and port select units.

The system memory of the D Machine contains 16,384 words, 32 bits per word. The memory access of the machine is 1 microsecond. Within the D Machine, the nanocodes (the firmware logic) are the interface between the interpreter and the microprogram firmware. The interpreter performs those operations which are directed by the microprograms which are written in Translang language.



78-43-B-1

FIGURE B-1. BASIC BLOCK DIAGRAM

APPENDIX C

MOTE PERFORMANCE DATA

LIST OF ILLUSTRATIONS

Figures

- C-1 MOTE 1 Control Box Target Counts (10 min) of Clear-Air and Weather Tapes
- C-2 MOTE 2 Control Box Target Counts (10 min) of Clear-Air and Weather Tapes
- C-3 MOTE Control Box Target Counts (10 min) of Clear-Air and Weather Tapes with MOTE Set to Zero

TABLE C-1. MOTE 1 CONTROL BOX TARGET COUNTS (10 min) OF CLEAR-AIR AND WEATHER TAPES

MOTE Control Box Functions	Control Box No.	Tape Number				
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tgts Rejected	00	8287	13518	12471	7350	17915
Tgts Transmitted	01	17926	32179	24506	19808	36223
Perm. Echoes	03	738	5527	2877	2883	3070
False Alarms	04	3440	7974	9418	4299	14801
Min RNG Rejects	05	4109*	17	176	168	41
Moving Tgts	06	9576	18572	12133	12397	18366
Sch. Tgts. Exam	07	17863	32039	24604	19747	36280

MOTE Parameters
 LMIN = 1/8 nmi
 LMAX = 1-1/2 nmi
 Min Range = 8 nmi
 *Min Range = 18 nmi

TABLE C-2. MOTE 2 CONTROL BOX TARGET COUNTS (10 min) OF CLEAR-AIR AND WEATHER TAPES

MOTE Control Box Functions	Control Box No.	Tape Number				
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tgts Rejected	00	6149	10257	8814	5333	11789
Tgts Transmitted	01	17583	32259	24706	19782	34698
Perm. Echoes	03	911	6861	3789	3598	3653
False Alarms	04	1214	3376	4846	1579	8108
Min RNG Rejects	05	4024*	20	179	156	28
Moving Tgts	06	11372	21878	15959	14388	22988
Sch Tgts Exam	07	17521	32134	24772	19721	34776

MOTE Parameters
 LMIN = 1/8 nmi
 LMAX = 1-1/2 nmi
 Min Range = 8 nmi
 *Min Range = 18 nmi

TABLE C-3. MOTE CONTROL BOX TARGET COUNTS (10 min) OF CLEAR-AIR AND WEATHER TAPES WITH MOTE SET TO ZERO

MOTE Control Box Functions	Control Box No.	Tape Number				
		1	2	3	4	5
Tgts Rejected	00	4454	20	155	161	20
Tgts Transmitted	01	17836	32178	24563	19687	34744
Perm. Echoes	03	0	0	0	0	0
False Alarms	04	20	0	0	3	0
Min RNG Rejects	05	4434*	20	0	158	20
Moving Tgts	06	13322	32091	24356	19463	34812
Sch Tgts Exam	07	17776	32111	24511	19624	34831

MOTE Parameters

LMIN = 1/8 nmi

LMAX = 1-1/2 nmi

Min Range = 8 nmi

*Min Range = 18 nmi