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NOTE N-842

EFFECT OF WEATHER AT HANNOVER, FEDERAL REPUBLIC OF GERMANY, ON PERFORMANCE OF ELECTROOPTICAL IMAGING SYSTEMS

The Calculation Methodology for a FLIR Using a FORTRAN Program

Lynne N. Seekamp
Computer Group

August 1977

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION
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@25@ LOWTRAN.

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@27@This paper documents the computer program (called Program FLIR) to calculate the probabilities of detection and recognition of a target by an observer using a FLIR sensor. It was written to summarize the basic concepts behind the calculation procedures in Program FLIR and to outline those procedures. (Author)

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This paper documents the computer program (called Program FLIR) to calculate the probabilities of detection and recognition of a target by an observer using a FLIR sensor. It was written to summarize the basic concepts behind the calculation procedures in Program FLIR and to outline those procedures.

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CONTENTS

The views expressed herein are those of the author only. Publication of this Note does not indicate endorsement by IDA or the Department of Defense.

ACKNOWLEDGMENTS

The mathematical model used in this study was created cooperatively by a number of people with the support of their various parent organizations.

The basic model of the forward-looking infrared (FLIR) device was developed by Robert L. Sendall of the Hughes Aircraft Company, and by Lucien M. Biberman of the Institute for Defense Analyses (IDA). A study entitled "Effect of Weather at Hannover, Federal Republic of Germany, on Performance of Electrooptical Imaging Systems" has been published describing this model.

Part 1 (Ref. 1) of this study, which established the methodology and data base, and Part 2 (Ref. 2), which applies this to the FLIR technology, were done as part of the Central Research Program of IDA. The work reported in Parts 3, 4, and 5 (Refs. 3, 4, 5) was done under IDA Task T-136 for the Office of Research and Technology, Director of Defense Research and Engineering (ODDR&E).

The original overall computer program design for this study was accomplished by George DuMais and later updated by Mary L. Sullivan of IDA. The program was developed under IDA Independent Research Program. It was documented under Task T-136, ODDR&E (Research and Advanced Technology).

PREFACE

In 1973, the Aerospace Applications Studies Committee (AASC) of the Advisory Group for Aerospace Research and Development (AGARD), North Atlantic Treaty Organization (NATO), sponsored a study on the application of *night vision devices* to fast combat aircraft. During the study it became apparent that the assumed weather conditions -- highly smoothed 10-year averages -- were far too uniform to give realistic results. Curiosity about the variations of unsmoothed weather data led to a proposal to the AASC by L. M. Biberman of the Institute for Defense Analyses (IDA) and M. H. A. Deller of the Royal Aircraft Establishment (RAE), Farnborough, that the problem be investigated in some detail to learn the effects of terrain masking, cloud obscuration, and hour-by-hour weather variations at a number of European locations.

The resulting study,[1] published in five parts, contains estimates of the hourly, daily, and seasonal effects of the actual weather at Hannover, Federal Republic of Germany, in 1970 on the performance of electrooptical imaging sensors. The questions we hope to answer are how great these effects are and when and how often they occur.

Part 1 of the study discusses methodology and samples the results of calculations. Part 2, in another, classified volume (IDA Paper P-1124), presents complete results for a forward-looking infrared (FLIR) device in the 8.5-11 μm band and analyzes the impact of weather on operations and operational planning. Part 3 (IDA Paper P-1128) compares FLIR performance in the 3.4-4.2 μm and 8.5-11 μm bands. Part 4 (IDA

[1] "Effect of Weather at Hannover, Federal Republic of Germany, on Performance of Electrooptical Imaging Systems", References 1-5.

Paper P-1202) reports on calculations for active and passive television. Part 5 (IDA Paper P-1203) compares the performance of active television and several different FLIRs.

This note was written as an explanatory addendum to the Study and thus it bears the same title. The note documents the computer program (called Program FLIR) to calculate the probabilities of detection and recognition of a target by an observer using a FLIR sensor. It was written to summarize the basic concepts behind the calculation procedures in Program FLIR and to outline those procedures. For more details about the physics, bar-pattern criteria and role that weather plays in the calculations refer to Parts 1-5 of the Study mentioned above.

I. SUMMARY OF PROGRAM FLIR

Program FLIR was written to calculate the probabilities of detection and recognition of a given sized target by an observer employing an 8.5-11 μm forward-looking infrared (FLIR) sensor. The probabilities are calculated for various ranges given transmission data at those particular ranges. A basic outline of the program follows including necessary inputs, types of calculations performed and the output.

The input of Program FLIR includes specifying the base field of view (FOV) of the sensor, scaling factors for subsequent FOV's, and the appropriate curves which relate spatial frequency to minimum resolvable temperature (MRT) and characterize the design of the sensor (Figure 1). Target characteristics to be input are critical dimension, differential temperature (ΔT) between the target and its background and aspect factors. The ranges for which probabilities are to be calculated are also entered. Most of the data input to program FLIR consists of transmission values which were previously calculated and written onto tape. The transmissions must be computed for the ranges specified as input to Program FLIR and are usually calculated hour by hour for a particular month.[2] The transmissions are based on the weather (such as air temperature, dew point and visibility) recorded for those hours for that month for the location under consideration. One method for obtaining the transmission from weather statistics is by using the model Lowtran 3B,[1] an atmospheric transmittance model developed by the Air Force Geophysics Laboratory (Ref. 6).

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[1] Lowtran 3B includes several additions and updates to the Lowtran 3 and 3A models reported in Ref. 1. The major additions are the inclusion of water vapor continuum attenuation in the 3.5 to 4.2 μm region, and a temperature dependence to the H_2O continuum attenuation coefficient in both the 4 μm and 10 μm regions.

[2] This data becomes columns 1 and 2 in Table 2.

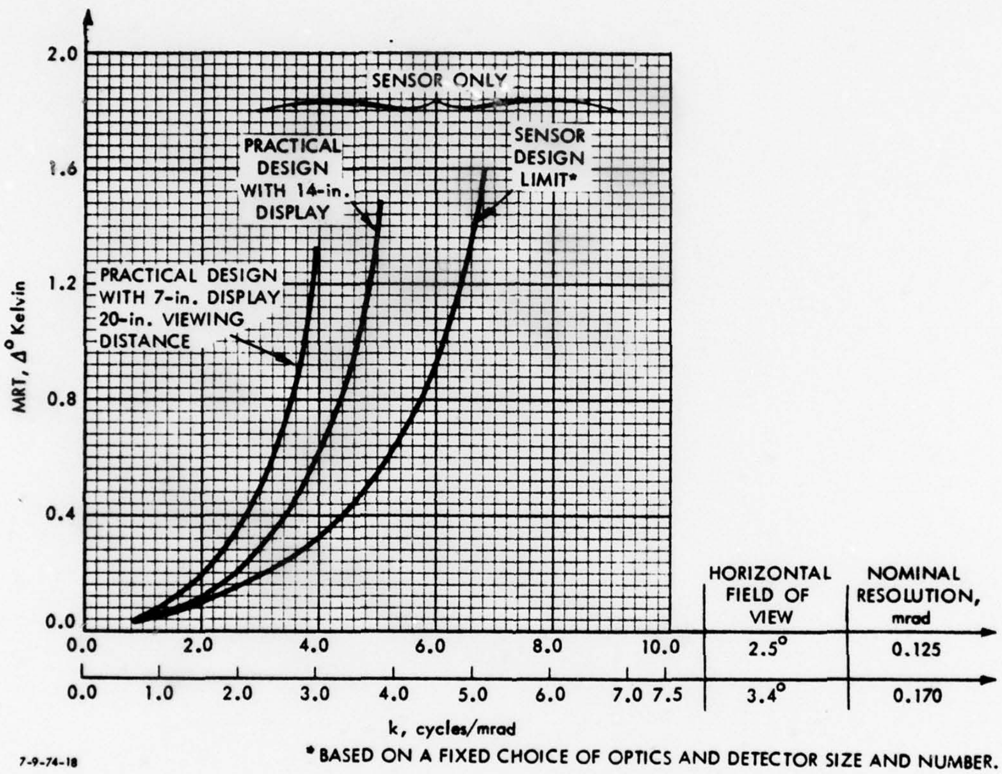

Figure 1. EXAMPLE OF THREE MRT CURVES AND FOV SCALING FACTORS

The calculations performed by Program FLIR using the input variables are summarized here. For greater detail refer to Chapter III, Users Guide to Program FLIR and Chapter IV, A Listing (with documentation) of Program FLIR.

First a subroutine (Spatial) calculates the angular subtense of the target (in milliradians) and returns the values of the spatial frequencies in cycles/milliradian for both detection and recognition at a given range. Given the computed spatial frequency for each range another subroutine (Resolve) scales it according to desired FOV. The scaled spatial frequency is then used to find the corresponding MRT value by linear interpolation between points on the MRT curve input to the subroutine. This approximation is used when the MRT value is not available for the FOV of interest, but is available for an FOV of relatively close size. The MRT value so determined is then corrected for aspect ratio of the target (Ref. 1, *Appendix D, "First Order* Corrections to Bar-Pattern Data").

Next, by hour and by range the transmission data is read in and the apparent target temperature (ΔT_{app}) is calculated by multiplying the transmittance (τ_{atm}) by the ΔT of the target which has been input.[1] Finally, given the ratio $\Delta T_{app}/MRT$ corrected for aspect, which is the normalized displayed-signal-to-noise ratio, the probability of detection (or recognition) is determined by calling the last subroutine (Cuprob). This subroutine determines the probability of looking up the signal-to-noise ratio on a cumulative normal probability curve where the value $\Delta T_{app}/MRT = 1.0$ corresponds to a probability of detection of 50 percent.

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[1] $\Delta T_{app} = \Delta T \cdot \tau_{atm}$.

The output of Program FLIR is a computer tape which has written on it tables which look like Tables 1 and 2. Table 1 is a header table to the FLIR tape and contains the MRT data for each range and FOV. Table 2 contains the probability of detection and recognition data for two hours by range and FOV. There is a table for every hour of a month on a typical output tape. Using this FLIR output tape various plots and other outputs can be made (see Chapter V. Examples of Outputs Which Can Be Generated From the Output Tape of Program FLIR).

RANGE IN KM	ANGLE IN MILLIRAD	CYCLES PER MR	MRT(2.5 DEG FOV) DET	REC	MRT(5.0 DEG FOV) DET	REC	MRT(7.5 DEG FOV) DET	REC	MRT(10.0 DEG FOV) DET	REC	MRT(15.0 DEG FOV) DET	REC
.5	7.800	.128	.010	.010	.010	.084	.010	.168	.010	.282	.010	.713
1.0	3.900	.256	.010	.084	.010	.282	.010	.712	.118	1.640	.238	1.640
1.5	2.600	.385	.010	.168	.010	.712	.148	1.640	.238	0.000	.519	0.000
2.0	1.950	.513	.010	.282	.118	1.640	.238	0.000	.398	0.000	1.009	0.000
2.5	1.560	.641	.010	.462	.178	0.000	.345	0.000	.653	0.000	2.163	0.000
3.0	1.300	.769	.010	.712	.238	0.000	.518	0.000	1.007	0.000	2.320	0.000
3.5	1.114	.897	.010	1.103	.298	0.000	.725	0.000	1.560	0.000	0.000	0.000
4.0	.975	1.026	.118	1.640	.398	0.000	1.008	0.000	2.320	0.000	0.000	0.000
4.5	.867	1.154	.148	0.000	.518	0.000	1.417	0.000	0.000	0.000	0.000	0.000
5.0	.780	1.282	.178	0.000	.653	0.000	2.160	0.000	0.000	0.000	0.000	0.000
5.5	.709	1.410	.208	0.000	.801	0.000	2.320	0.000	0.000	0.000	0.000	0.000
6.0	.650	1.538	.238	0.000	1.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.5	.600	1.667	.268	0.000	1.272	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	.557	1.795	.298	0.000	1.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.5	.520	1.923	.345	0.000	2.159	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.0	.487	2.051	.398	0.000	2.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.5	.459	2.179	.458	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.0	.433	2.308	.518	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.5	.411	2.436	.581	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	.390	2.564	.653	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 1. EXAMPLE OF HEADER TABLE CONTAINING MRT DATA OUTPUT FROM PROGRAM FLIR

MONTH = 1 DAY = 1 HOUR = 0

RANGE IN KM	APPARENT TARGET TEMP	2.5 FOV DET	2.5 FOV REC	5.0 FOV DET	5.0 FOV REC	7.5 FOV DET	7.5 FOV REC	10. FOV DET	10. FOV REC	15. FOV DET	15. FOV REC
.5	1.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.0	1.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.61	1.00	.61
1.5	1.74	1.00	1.00	1.00	1.00	1.00	.56	1.00	0.00	1.00	0.00
2.0	1.68	1.00	1.00	1.00	.52	1.00	0.00	1.00	0.00	.94	0.00
2.5	1.61	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	.28	0.00
3.0	1.55	1.00	1.00	1.00	0.00	1.00	0.00	.91	0.00	.22	0.00
3.5	1.49	1.00	.81	1.00	0.00	1.00	0.00	.46	0.00	0.00	0.00
4.0	1.44	1.00	.40	1.00	0.00	.86	0.00	.18	0.00	0.00	0.00
4.5	1.38	1.00	0.00	1.00	0.00	.48	0.00	0.00	0.00	0.00	0.00
5.0	1.33	1.00	0.00	1.00	0.00	.18	0.00	0.00	0.00	0.00	0.00
5.5	1.29	1.00	0.00	.93	0.00	.14	0.00	0.00	0.00	0.00	0.00
6.0	1.24	1.00	0.00	.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.5	1.20	1.00	0.00	.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	1.16	1.00	0.00	.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5	1.12	1.00	0.00	.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.0	1.08	1.00	0.00	.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.5	1.04	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.0	1.01	.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5	.97	.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0	.94	.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

MONTH = 1 DAY = 1 HOUR = 100

RANGE IN KM	APPARENT TARGET TEMP	2.5 FOV DET	2.5 FOV REC	5.0 FOV DET	5.0 FOV REC	7.5 FOV DET	7.5 FOV REC	10. FOV DET	10. FOV REC	15. FOV DET	15. FOV REC
.5	1.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.0	1.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.61	1.00	.61
1.5	1.74	1.00	1.00	1.00	1.00	1.00	.56	1.00	0.00	1.00	0.00
2.0	1.68	1.00	1.00	1.00	.52	1.00	0.00	1.00	0.00	.94	0.00
2.5	1.61	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	.28	0.00
3.0	1.55	1.00	1.00	1.00	0.00	1.00	0.00	.91	0.00	.22	0.00
3.5	1.49	1.00	.81	1.00	0.00	1.00	0.00	.46	0.00	0.00	0.00
4.0	1.44	1.00	.40	1.00	0.00	.86	0.00	.18	0.00	0.00	0.00
4.5	1.38	1.00	0.00	1.00	0.00	.48	0.00	0.00	0.00	0.00	0.00
5.0	1.33	1.00	0.00	1.00	0.00	.18	0.00	0.00	0.00	0.00	0.00
5.5	1.29	1.00	0.00	.93	0.00	.14	0.00	0.00	0.00	0.00	0.00
6.0	1.24	1.00	0.00	.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.5	1.20	1.00	0.00	.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	1.16	1.00	0.00	.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5	1.12	1.00	0.00	.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.0	1.08	1.00	0.00	.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.5	1.04	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.0	1.01	.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5	.97	.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0	.94	.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. EXAMPLE OF HOURLY TABLES OUTPUT BY PROGRAM FLIR

II. CAVEATS

This section reiterates the caveats regarding the data produced by Program FLIR, the input data which had been calculated by Program LOWTRAN and the masking effects as discussed in Part 1 of this study.

1. Data Calculated by Program FLIR

The data computed by this program are necessary but insufficient for assessing the overall effectiveness of electrooptical imaging sensors aboard attack aircraft used against ground targets. It must be recognized, however, that the data will almost always represent an upper bound of performance, since the computed probabilities of detection and recognition at given ranges assume that the observer is already looking at the area of the display that coincides with the position of the target within the field of view. Realistic assessments of the observer's capabilities will require better data than are currently available on his display search time, on his dynamic task performance (including his target recognition and weapon aiming time), and on the degradations to be expected from both the airborne environment and the actual operational environment.

No matter how good the viewing conditions and equipment, a drowsy or disinterested observer will not do very well. It was not within the province or competence of this study to ascertain motivation or interest on the part of the observer. Our calculations are based on more than 200,000 data points for the performance of serious observers looking at a variety of targets displayed against various noisy backgrounds but we do not know how much to degrade our results to cover various tactical situations or observers who are not very attentive.

We have also excluded degradations due to exposure of airborne observers to buffeting or g-loading. Preliminary experiments completed in May 1975,[1] showed that both buffeting and g-loading degrade observer performance, but no analysis of the frequency and severity of these effects suitable for use in modifying our results is yet available.

Arguments about the modeling of recognition range and about how to define "identification" remain unresolved. Semantics gain in importance as the tactical problem shifts from detection to identification. In military operations, recognition of an electro-optical image of a target is very closely related to circumstances. Given the appropriate background intelligence, a senor operator can positively translate a series of unresolved specks moving along a road into a column of trucks or tanks, poor optical quality notwithstanding.

For detection of tactical vehicular targets, we use the criterion of two lines[2] across the minor dimension of the target, on which there is generally good agreement. For recognition we use four resolvable line pairs across the minor dimension of the target. In undemanding situations, some people elect to use three line pairs as a criterion for recognition. In bad clutter, some use a criterion of four and a half or five line pairs, but we prefer to stay with four line pairs and to increase the signal-to-noise threshold (Refs. 7, 8).

In the computational program presented herein we treat in depth only data on FLIR.

---

[1]Discussed in Appendix H, Reference 1.

[2]Two lines, one line pair, and one cycle are synonymous.

2. Computation Model Lowtran

In our computations we were bothered by four problems:

1. The overly pessimistic predictions of Lowtran 3 for the water vapor continuum. We have solved this, bringing calculated results into line with measured values, by correcting the Lowtran predictions for the continuum and its temperature coefficient. The Lowtran 3B version incorporating this change is now being used (Ref. 6).
2. The weakest part of Program FLIR is the aerosol model used in Lowtran for low visibility conditions. Existing Lowtran aerosol models can yield a large variation in computed detection and recognition range for a given FLIR. Our best recommendation for now is to use the Lowtran 3B maritime aerosol model for Central Europe. We at IDA are attempting to develop suitable subroutines for aerosols elsewhere in the world and will publish these as they become available.
3. The vertical lapse rate for mists and fogs. The conditions on which we have based our calculations are valid for ground-to-ground observations. If an airborne sensor is looking down from 200 feet above ground, however, and if there is a fog layer 100 ft thick, the path through fog is only half what we have used in our computations. At present, we have almost no data on the layering of fog and haze at Hannover or anywhere else.
4. By international convention, visibility exceeding 10 km is reported as infinite in aviation weather data. We have examined the effect of truncating visibility at 10 km by recomputing for 20 km. Almost no change in the statistics could be found, since visibility dominates only when its values are small.

3. Masking Effects

The effects of cloud masking and terrain masking are not included in our models of probability of detection or recognition but must be considered in operations.

III. USERS GUIDE TO PROGRAM FLIR

Program FLIR is written in FORTRAN designed to run on a CDC 6400 computer. The deck is punched BCD (on a 026 IBM keypunch). Tape 1 is read as input, Tape 2 is written as output. Line numbers referred to in the following sections correspond to numbers assigned to each line of Program FLIR and its subroutines. The lines and numbers are listed in the next section of this report, Chapter IV.

A. INPUTS AND FORMATS

1. Inputs by Data Card

	Format	Variable Name	Description of Variable
Card 1 (Line 41):	I5	NMO	No. months for which FLIR is to be run.
	F5. 0	FOV1	Base field of view.
	I5	NF	No. multiples of FOV1 to be considered.
	F5. 0	RMAX	Maximum range in km - can be either 10. or 20. (If RMAX=10. range=. 5 to 10. km in steps of . 5 km. If RMAX=20. range=1. to 20. km in steps of 1 km).
Card 2 (Line 61):	I1	ICURVE	MRT curve selector; MRT values are input in data statements in Subroutine Resolve; ICURVE=1 unless more than one MRT curve is listed in Resolve - if more than one, ICURVE equals the no. the MRT curve desired occupies in the list of MRT curves (see next Section).
	4X		
	F10. 0	SIZE	Minor dimension of target (in meters).
	F10. 0	TARGT	Temperature (deg. K) differential of target from background (ΔT).

Format	Variable Name	Description of Variable
F10.0	ASPECT (1)	$\sqrt{\xi/7}$ for detection.
F10.0	ASPECT(2)	$\sqrt{\xi/7}$ for recognition. ξ is aspect ratio of one bar in the equivalent bar pattern (Figure 28, p. 51, Ref. 1). For front aspect tank detection the tank is about square and the bar aspect is due to one-half a square or 2:1 aspect. For recognition there are four line pairs so one bar represents 1/8 of a square or 8:1 aspect ratio.

2. Input by Data Statement

The MRT curve points are input by a data statement in the program deck in Subroutine Resolve (lines 27R - 36 R). The following is an example of the data statement when it contains five curves at the same time.

```
DATA CURVE/1.,2.,3.,4.,5.,6.,7.,8*0.,                                T-1 X
-          .02,.046,.081,.111,.26,.51,1.,8*0.,                       T-1 Y
-          1.,2.,3.,4.,5.,6.,7.,8.,7*0.,                             T-2 X
-          .007,.018,.034,.06,.102,.2,.4,1.,7*0.,                    T-2 Y
-          1.,2.,3.,4.,5.,6.,7.,8.,9.,6*0.,                          T-3 X
-          .002,.0042,.008,.013,.026,.042,.08,.175,.52,6*0.,         T-3 Y
-          2.,4.,6.,8.,10.,10*0.,                                    H-1 X
-          .0062,.014,.036,.057,.088,10*0.,                          H-1 Y
-          1.,1.8,2.,2.4,2.8,3.0,3.2,3.4,3.6,3.8,3.9,3.99,3*0.,      PDD X
-          .06,.16,.2,.3,.42,.5,.6,.72,.84,1.08,1.24,1.32,3*0./      PDD Y
```

Five is the maximum number of MRT curves that may be entered at one time. However, only one curve is used per run of Program FLIR. The curve to be used is specified by the variable ICURVE (see Input Card 1 above). In the example shown above ICURVE=1 would select MRT curve T-1, ICURVE=5 would select MRT curve PDD, where T-1 and PDD are our code names for actual FLIR equipments.

There are two lines of data punched per MRT curve entered. The first line labeled "X" contains the X-coordinates of the curve which are the spatial frequency values in cycles/mrad. The second line labeled "Y" contains the Y-coordinates or the MRT values (see Figure 1 in Summary).

3. Data Input by Magnetic Tape

The previously calculated transmissions are read from tape (Tape 1 on program card). The transmission tape contains one file per month to be processed. Usually a maximum of two files are on one transmission tape. Each month's file contains three lines of heading or title information to be skipped over when being read. Format 105 in the program does the skipping:

		Line
	Read(1, 105)IBLANK	132
105	Format (//A10)	133

The headings are followed by one line for each hour in the month. Each hour's record consists of 3 integer values representing month, day, and hour, and 20 real values representing the fractional transmittance for ranges of .5 to 10. km in steps of .5 km or 1. to 20. km in steps of 1. km. RMAX on input card 1 above indicates which ranges are on the tape. The read statement for one hour's data in this form is:

		Line
	Read (1, 1000)MDH, TRANS	154
1000	Format (2I2, I4, 2X, 20F6.3)	155

If a transmission tape of another format is used the two read statements and formats mentioned here will have to be revised. If different ranges are to be used and the number of ranges are changed, dimension statements may have to be changed along with DO LOOP counters (e.g., Line 80 is now set for 20 ranges) and scaling of range values (e.g., Line 81).

B. PROGRAM FLIR DIVIDED INTO SEGMENTS

Lines

34-66 Input and printing of 2 data cards.

70-74 Write headings on output tape (Tape 2).

80-123 Do Loop 5 is executed once for each range.

- 81 Define range for this execution of loop.
- 87 Call Subroutine Spatial which calculates angular subtense of target (in mrads) and the spatial frequency (cycles/mrad) of the detection and recognition criteria.
- 95-116 Do Loop 2 is executed once for each FOV.
  - 100-116 Do Loop 2 is executed once for detection and once for recognition for each FOV.
    - 106 Call Subroutine Resolve
      - 27R-36R Input MRT curve X and Y coordinates in data statement.
      - 44R Scale spatial frequency calculated in Subroutine Spatial for the FOV being considered in this pass through Loop 2.
      - 51R-83R Linear interpolation along MRT curve to find correct MRT value corresponding to the scaled spatial frequency.
    - 112 Correct MRT value returned from Subroutine Resolve for aspect ratio.
- 121 Write table as heading to output tape. One line per range contains the following data: angular subtense of target, spatial frequency (cycles/mrad) for detection, MRT values for detection and recognition for the fields of view considered.

131-213 Do Loop 50 is executed once for each file (or month) to be written on Tape 2.

- 154 Read transmission tape, one hour's data at a time.
- 163-170 Write headings on Tape 2 for each hour's table.
- 174-209 Do Loop 30 is executed once for each range.
  - 175 Define the range for this execution of loop.
  - 179 Calculate apparent target temperature.
  - 183-205 Do Loop 20 is executed once for column of probabilities (number of columns equals 2 times number of FOVs).
    - 196 Calculate signal-to-noise ratio.
    - 201 Call Subroutine Cuprob
      - 15C Input cumulative normal probability curve coordinates.
      - 34C-37C Interpolate between points on normal curve to determine probability of detection (or recognition) corresponding to calculated signal-to-noise ratio.
  - 207 Write on Tape 2 one line per range with the following information: range, apparent target temperature, (probability of detection, probability of recognition for each FOV).
- 211 Go back to 154 to read transmission for next hour.

214 STOP

IV. LISTING OF PROGRAM FLIR

```
      PROGRAM FLIR(INPUT,OUTPUT,TAPE1,TAPE2)
C
C     PROGRAM FLIR WAS WRITTEN AS A BASIC MODEL OF THE FORWARD-LOOKING
C     INFRARED (FLIR) DEVICE.  THE DEVELOPMENT OF THE MODEL AND RESULTS
C     OBTAINED FROM ITS USE ARE REPORTED IN IDA PAPER P-1123, EFFECT OF
C     WEATHER AT HANNOVER, FRG, ON PERFORMANCE OF ELECTROOPTICAL IMAGING
C     SYSTEMS, PART 1 (REFERED TO IN THE DOCUMENTATION OF THIS PROGRAM
C     AS *REPORT*).
C     PROGRAM FLIR WAS WRITTEN TO READ AN HOUR BY HOUR TAPE OF TRANSMISSIONS;
C     TO   SCALE   MRT VALUES FOR DETECTION AND RECOGNITION AT SELECTED
C     RANGES FOR SELECTED FIELDS OF VIEW (FOV) AND TO WRITE THEM IN TABLE
C     FORM AT THE BEGINNING OF THE FLIR TAPE; TO CALCULATE HOUR BY HOUR FOR
C     EACH RANGE AND FOR EACH FOV THE APPARENT TARGET TEMPERATURE AND
C     PROBABILITY OF DETECTION AND RECOGNITION.   THIS PROGRAM MAY BE
C     SEGMENTED INTO THREE PARTS--
C       PART 1.  INPUT VALUES NECESSARY FOR EXECUTION OF THE PROGRAM.
C       PART 2.  LOOP 5--CALCULATES THE MRT VALUES AND WRITES THEM AS A
C                        HEADER TABLE TO THE FLIR TAPE.
C       PART 3.  LOOP 50--CALCULATES AND WRITES ON THE FLIR TAPE THE APPARENT
C                         TARGET TEMPERATURE AND PROBABILITIES ONE FILE
C                         (A MONTHS DATA USUALLY EQUALS ONE FILE) AT A TIME
C                         HOUR BY HOUR.
C     FOR MORE DETAILS SEE LINE BY LINE DOCUMENTATION OF THE PROGRAM.
C
      DIMENSION ISTOP(10),FOV(5),ASPECT(2),CPM(2),RTMP(10,20)
      DIMENSION MDH(3),TRANS(20),PROB(10)
      REAL MRT
C
C     ISTOP WILL CONTAIN FILLED LENGTHS OF COLUMNS IN MRT TABLE.
C     IEND WILL CONTAIN LENGTH OF LONGEST COLUMN IN MRT TABLE.
C
      DATA ISTOP/10*20/, IEND/0/
C
C     INPUT CARD 1:
C     READ THE FOLLOWING QUANTITIES FROM FIRST INPUT CARD--
C     NMO=NUMBER OF MONTHS FOR WHICH FLIR TAPE IS TO BE MADE
C     FOV1=BASE FIELD OF VIEW
C     NF=NUMBER OF MULTIPLES OF FOV1 TO BE CONSIDERED
C     RMAX=MAXIMUM RANGE IN KM--CAN BE EITHER 10. OR 20.
C
      READ 500, NMO,FOV1,NF,RMAX
  500 FORMAT(2(I5,F2.0))
      IF(NF.GT.5) NF=5
      DO 1 IF=1,5
    1 FOV(IF)=IF*FOV1
C
C     INPUT CARD 2:
C     READ IN THE MRT CURVE SELECTOR, TARGET SIZE, TARGET DIFFERENTIAL
C     TEMPERATURE (DELTA T), AND ASPECT FACTORS:
C       ICURVE=MRT CURVE SELECTOR--CHOOSE 1 OF THE CURVES SPECIFIED IN DATA
C              STATEMENTS IN SUBROUTINE RESOLVE
C       SIZE=TARGET SIZE--HEIGHT OF TGT  (IN METERS)  SMALLEST DIMENSION
C       TARGT=TARGET TEMP.--DELTA DEG. K OF TARGET FROM THE BACKGROUND
C       ASPECT=TO CORRECT VALUE OF ASPECT RATIO,E,FOR DETECTION AND
C              RECOGNITION, CORRECT VALUE OF MRT BY THE FACTOR 1/SQRT(E/7).
C              INPUT HERE THE VALUE SQRT(E/7) FOR DETECTION (ASPECT(1)) AND
C              RECOGNITION (ASPECT(2)).  E IS BAR LENGTH-TO-WIDTH RATIO.
```

```
C          I.F., 2:1 DET ASPECT RATIO, 8:1 REC.  BELOW MRT IS CORRECTED
C          BY DIVIDING BY THESE INPUT VALUES.
C
      READ 102, ICURVE,SIZE,TARGT,ASPECT(1),ASPECT(2)
  102 FORMAT(I1,9X,4F10.4)
      PRINT 103, NMO,FOV1,NF,RMAX,ICURVE,SIZE,TARGT,ASPECT
  103 FORMAT(*-INPUT CARD VALUES*/*0CARD 1-- NMO=*,I3,*   FOV1=*,F5.1,*
     -  NF=*,I3,*   RMAX=*,F5.1/*0CARD 2-- ICURVE=*,I3,*   SIZE=*,F6.3,*
     -  TARGET TEMP=*,F6.3,*   ASPECT FACTORS: DET=*,F7.4,* REC=*,F7.4)
C
C     WRITE HEADINGS OF TABLE TO BE PLACED AT THE BEGINNING OF OUTPUT TAPE
C
      WRITE(2,100) FOV
  100 FORMAT(1H1,4X,*RANGE*,5X,*ANGLE IN*,5X,*CYCLES*,2X,5(3X,*MRT(*,
     - F4.1,* DEG FOV)*))
      WRITE(2,101)
  101 FORMAT(5X,*IN KM      MILLIRAD      PER MR   *,5(6X,*DET*,7X,*REC *))
C
C     RANGE CAN BE FROM .5 TO 10. KM IN STEPS OF .5 KM (RMAX=10.)
C                 OR FROM 1. TO 20. KM IN STEPS OF 1. KM (RMAX=20.)
C     GO THROUGH LOOP 5 ONCE FOR EACH RANGE
C
      DO 5 I=1,20
      DIST=FLOAT(I)*RMAX/20.
C
C     FIND THE ANGULAR SUBTENSE (THETA) OF THE TARGET (IN MILLIRADIANS),
C     AND THE DETECTION AND RECOGNITION CRITERIA (THEIR SPATIAL FREQS IN
C     CYCLES/MRAD) AT A GIVEN RANGE BY CALLING SUBROUTINE SPATIAL
C
      CALL SPATIAL(DIST,SIZE,DET,REC,THETA)
      CPM(1)=DET $ CPM(2)=REC
      J=0
C
C     GO THROUGH LOOP 2 TO SCALE MRT FOR FOV OTHER THAN THE ORIGINAL MRT
C     DATA FROM A SPECIFIC GIVEN SET OF IMPACT MRT DATA AND CORRECT IT
C     FOR ASPECT RATIO ONCE FOR EACH FOV (SEE REPORT P. 54-55).
C
      DO 2 IF=1,NF
      SCALE=FLOAT(IF)
C
C     THEN ONCE FOR DETECTION AND ONCE FOR RECOGNITION
C
      DO 2 IDR=1,2
      J=J+1
C
C     SCALE THE MRT FOR SOME FOV OTHER THAN THE ORIGINAL MRT DATA
C     BY CALLING SUBROUTINE RESOLVE
C
      CALL RESOLVE(CPM(IDR),ICURVE,SCALE,MRT,IFLAG)
C
C     CORRECT MRT FOR ASPECT RATIO (DIVIDE MRT BY INPUT CORRECTION FACTOR
C     FOR ASPECT-SEE EXPLANATION FOR ASPECT ON INPUT CARD 2 AND REFER TO
C     REPORT P.56-59 AND APPENDIX D).
C
      RTMP(J,I)=MRT/ASPECT(IDR)
      IF(IFLAG.EQ.1.AND.ISTOP(J).EQ.20) ISTOP(J)=I
      IF(IFLAG.EQ.1.AND.ISTOP(J).LT.I) RTMP(J,I)=0.0
      IF(ISTOP(J).GT.IEND) IEND=ISTOP(J)
```

```
    2 CONTINUE
C
C     WRITE TABLE CONTAINING MRT DATA FOR EACH RANGE AND FOV AS A
C     HEADER TO THE FIRST FILE OF THE NEW FLIR TAPE (20 LINES TOTAL)
C
      WRITE(2,104) DIST,THETA,DET,(RTMP(K,I),K=1,J)
  104 FORMAT(6X,F4.1,7X,F5.3,6X,F5.3,6X,10F10.3)
    5 CONTINUE
C
C     KOL IS TOTAL NO. OF COLUMNS OF PROBABILITIES TO BE WRITTEN ON TAPE
C
      KOL=J
C
C     GO THROUGH LOOP 50 ONCE FOR EACH FILE TO BE WRITTEN ON NEW TAPE
C
      DO 50 MO=1,NMO
      READ(1,105) IBLANK
  105 FORMAT(//A10)
C
C     FOR EACH NEW FILE ON THE NEW FLIR TAPE
C     WRITE A HOLLERITH 1 ON NEXT LINE OF THE NEW TAPE (WHEN LISTING NEW
C     TAPE IT SKIPS TO A NEW PAGE--WHEN READING THE NEW TAPE READS
C     A BLANK LINE)
C
      WRITE(2,110)
  110 FORMAT(1H1,10X)
C
C     READ TRANSMISSIONS (PREVIOUSLY CALCULATED BY SUBROUTINE LOWTRAN AND
C     WRITTEN ON TAPE1).
C     THE TRANSMISSION TAPE CONSISTS OF ONE FILE FOR EACH MONTH TO BE
C     PROCESSED.  ONE MONTHS FILE CONTAINS THREE LINES OF HEADING OR TITLE
C     INFORMATION WHICH ARE SKIPPED OVER WHEN BEING READ, FOLLOWED BY ONE
C     LINE FOR EACH HOUR IN THE MONTH.  ONE HOURS DATA IS COMPOSED OF INTEGER
C     VALUES REPRESENTING MONTH, DAY AND HOUR, AND 20 REAL VALUES REPRESENTING
C     THE FRACTIONAL TRANSMISSION FOR RANGES OF .5 TO 10 KM IN STEPS OF .5 KM
C     OR 1 TO 20 KM IN STEPS OF 1 KM.
C     THE FORMAT FOR ONE HOURS DATA IS (2I2,I4,2X,20F6.3).
C
   10 READ(1,1000) MDH,TRANS
 1000 FORMAT(2I2,I4,2X,20F6.3)
      IF(EOF,1) 40,11
C
C     FOR EVERY HOURS DATA ON THE NEW TAPE WRITE THE FOLLOWING LINES---
C *       WRITE A BLANK LINE
C *       WRITE 2 LINES OF HEADINGS FOR COLUMNS OF THE TABLE
C *       WRITE 20 LINES OF DATA (ONE LINE/RANGE)
C
   11 WRITE(2,111) MDH
  111 FORMAT(//,10X,*MONTH = *,I2,10X,*DAY = *,I2,10X,*HOUR = *,I4)
      WRITE(2,112)
  112 FORMAT(10X)
      WRITE(2,113) FOV
  113 FORMAT(1X,*RANGE*,5X,* APPARENT *,10X,5(F4.1,* FOV*,12X))
      WRITE(2,114)
  114 FORMAT(1X,*IN KM*,5X,*TARGET TEMP*,5(7X,*DET*,7X,*REC*))
C
C     GO THROUGH  LOOP 30 ONCE FOR EACH RANGE (ONE RANGE PER ROW IN TABLE)
C
```

```
      DO 30 I=1,IEND
      RANGE=FLOAT(I)*RMAX/20.
C
C   APTMP IS APPARENT TARGET TEMPERATURE
C
      APTMP=TRANS(I)*TARGT
C
C   GO THROUGH LOOP 20 ONCE FOR EACH COLUMN OF PROBABILITIES
C
      DO 20 J=1,KOL
      PDET=1.0
      IF(RTMP(J,I).EQ.0.0) GO TO 15
C
C   NORMALIZED SIGNAL TO NOISE RATIO = APPARENT TARGET TEMP. (DELTA T)/MRT
C   (CORRECTED FOR ASPECT BY DIVIDING BY SQRT(E/7) ).
C   P. 64 HANNOVER REPORT,PART I : SINCE THE MRT IS THAT VALUE OF INCREMENTAL
C   TEMPERATURE THAT PRODUCES A VALUE OF SIGNAL-TO-NOISE RATIO SUFFICIENT
C   TO ALLOW AN OBSERVER TO BREAK OUT THE MRT TEST BAR PATTERN AT 50 PERCENT
C   PROBABILITY,(DELTA T/MRT) CORRESPONDS TO THE NORMALIZATION FACTOR
C   RELATING SIGNAL-TO-NOISE TO PROBABILITY, WHERE DELTA T IS THE INCRE-
C   MENTAL DIFFERENCE IN TEMPERATURE BETWEEN THE TARGET AND ITS BACKGROUND
C
      SNR=APTMP/RTMP(J,I)
C
C   CALL SUBROUTINE CUPROB TO DETERMINE THE PROBABILITY OF DETEC. (OR RECOG.)
C   GIVEN THE NORMALIZED SIGNAL TO NOISE RATIO
C
      CALL CUPROB(SNR,PDET)
      PROB(J)=PDET
C
   15 IF(ISTOP(J).LT.I) PROB(J)=0.0
   20 CONTINUE
C
      WRITE(2,130) RANGE,APTMP,(PROB(J),J=1,KOL)
  130 FORMAT(2X,F4.1,8X,F5.3,3X,10(5X,F5.2))
   30 CONTINUE
C
      GO TO 10
   40 END FILE 2
   50 CONTINUE
      STOP
      END
```

```
      SUBROUTINE SPATIAL(DIST1,SIZE,DET,REC,THETA)
C
C     SUBROUTINE SPATIAL  FINDS THE ANGULAR SUBTENSE (THETA, IN MILLIRADS)
C     REQUIRED FOR RESOLVING ONE BAR IN THE EQUIVALENT BAR CHART (SEE REPORT
C     P.49-51) FOR EACH RANGE TO THE TARGET
C     AND THE DETECTION AND RECOGNITION CRITERIA (SPATIAL FREQ. IN CYCLES/MRAD)
C
C     CONVERT RANGE TO METERS
C
      DIST=DIST1*1000.
C
C     FIND THE ANGLE THETA BY TAKING THE TANGENT OF HALF THE TGT. SIZE
C     (IN METERS)/RANGE (METERS), DOUBLING IT TO GET THE WHOLE ANGLE,
C     AND THEN CONVERTING IT TO MILLIRADIANS
C
      THETA=2.*ATAN(SIZE/(2.*DIST))*1000.
C
C     THE CRITERIA OR SPATIAL FREQ.  FOR DETECTION IS 1 CYCLE PER THE
C     ANGLE THETA. FOR RECOGNITION IS 4 CYCLES FOR THE ANGLE.
C
      DET=1./THETA
      REC=4./THETA
      RETURN
       END
```

```
      SUBROUTINE RESOLVE(RESO,ICURVE,SCALE,MRT,IFLAG)
C
C     SUBROUTINE RESOLVE INPUTS GIVEN KNOWN MRT CURVES AND SCALE FACTORS OF THE
C     SPATIAL FREQ. BASED ON FOV.  GIVEN THE SPATIAL FREQ. CALCULATED IN
C     SUBROUTINE SPATIAL, THIS SUBROUTINE SCALES IT AND FINDS THE
C     CORRESPONDING MRT VALUE BY LINEAR INTERPOLATION BETWEEN TWO POINTS ON THE
C     GIVEN MRT CURVE.  THIS APPROXIMATION IS USED WHEN THE MRT IS NOT
C     AVAILABLE FOR A FIELD OF VIEW OF INTEREST BUT IS AVAILABLE FOR SOME
C     NOT VERY DIFFERENT SIZED FIELD OF VIEW.
C
C     ICURVE INDICATES MRT CURVE TO BE USED
C     RESO IS THE CRITERIA FOR EITHER DET. OR REC. (CYCLES/MRAD)=SPATIAL
C        FREQUENCY=RESOLUTION OF THE SENSOR
C
      DIMENSION CURVE(15,2,5)
      REAL MRT
C
C     INPUT GIVEN MRT CURVE POINTS HERE IN DATA STATEMENTS -- ONE LINE
C                FOR THE X COORDINATES (SPATIAL FREQ. IN CYCLES/MRAD) AND ONE LINE
C                FOR THE Y COORDINATES (MRT VALUES) -- 2 LINES FOR EACH MRT CURVE.
C     UP TO 5 MRT CURVES MAY BE ENTERED IN THE DATA STATEMENT AT ONE TIME
C     HOWEVER ONLY ONE MRT CURVE IS USED PER RUN.  THE DESIGNATIONS AT THE
C     END OF EACH LINE OF THE DATA STATEMENT REFER  TO WHICH MRTS ARE AVAILABLE
C     IN THE PROGRAM AT THE CURRENT TIME.  TO SELECT ONE OF THESE MRT CURVES
C     SET ICURVE EQUAL TO THE POSITION THE DESIRED MRT OCCUPIES IN THE LIST.
C
      DATA CURVE/1.,2.,3.,4.,5.,6.,7.,8*0.,                            T-1 X
     -           .02,.046,.081,.111,.26,.51,1.,8*0.,                    T-1 Y
     -           1.,2.,3.,4.,5.,6.,7.,8.,7*0.,                          T-2 X
     -           .007,.018,.034,.06,.102,.2,.4,1.,7*0.,                 T-2 Y
     -           1.,2.,3.,4.,5.,6.,7.,8.,9.,6*0.,                       T-3 X
     -           .002,.0042,.008,.013,.026,.042,.08,.175,.52,6*0.,      T-3 Y
     -           2.,4.,6.,8.,10.,10*0.,                                 H-1 X
     -           .0062,.014,.036,.057,.088,10*0.,                       H-1 Y
     -           1.,1.8,2.,2.4,2.8,3.0,3.2,3.4,3.6,3.8,3.9,3.99,3*0.,   PDD X
     -           .06,.16,.2,.3,.42,.5,.6,.72,.84,1.08,1.24,1.32,3*0./   PDD Y
C
      IFLAG=0
C
C     RESS EQUALS SPATIAL FREQUENCY AT BASE FIELD OF VIEW SCALED FOR THE
C     MULTIPLE OF FOV BEING CALCULATED AT THIS TIME
C     (SEE P. 55 HANNOVER REPORT, PART 1)
C
      RESS=RESO*SCALE
C
C     LOOK UP RESS ALONG X-AXIS (CYCLES/MRAD)--WANT TO FIND CORRESPONDING
C     Y VALUE (MRT)
C
      K=ICURVE
C
C     IF RESS (SCALED SPATIAL FREQ.) IS LESS THAN THE SMALLEST X COORDINATE (SMX)
C     SET RESS=SMX AND SET MRT=SMALLEST Y COORDINATE (SMY).
C
      SMX=CURVE(1,1,K)
      SMY=CURVE(1,2,K)
      IF(RESS.GE.SMX) GO TO 5
      RESS=SMX
```

```
      MRT=SMY
      RETURN
C
C  COUNT HOW MANY POINTS THERE ARE ALONG THE CHOSEN MRT CURVE.
C
    5 DO 10 N=1,15
      IF(CURVE(N,1,K).EQ.0.0) GO TO 11
   10 CONTINUE
      N=16
   11 NN=N-1
C
C  NN= NO. POINTS ON GIVEN MRT CURVE IN DATA STATEMENT
C  N= THE POINT ALONG THE GIVEN MRT CURVE FOR WHICH RESS IS BEING
C   TESTED TO SEE IF ITS VALUE LIES BETWEEN THE VALUE OF POINT N AND POINT
C   N-1 ON THE MRT CURVE
C
      DO 20 N=2,NN
      IF(RESS.GT.CURVE(N,1,K)) GO TO 20
C
C  AT THIS POINT THE X-COORDINATE INTERVAL HAS BEEN FOUND.  INTERPOLATE BETWEEN
C  THE Y-COORDINATES TO FIND THE EXACT MRT VALUE.
C
      MRT=(CURVE(N,2,K)-CURVE(N-1,2,K))*(RESS-CURVE(N-1,1,K))/
     -     (CURVE(N,1,K)-CURVE(N-1,1,K))+CURVE(N-1,2,K)
      RETURN
   20 CONTINUE
C
C  IF RESS CANNOT BE FOUND ALONG THE GIVEN MRT CURVE AND ITS VALUE IS OFF
C  THE CURVE AT THE HIGH END THEN SET IFLAG=1 AND SET MRT=THE HIGHEST
C  Y-COORDINATE ON THE GIVEN MRT CURVE
C
      IFLAG=1
      MRT=CURVE(NN,2,K)
      RETURN
      END
```

```
      SUBROUTINE  CUPROB(SNR,CMPHB)
C
C  THIS SUBROUTINE DETERMINES THE PROBABILITY OF DETEC. (OR RECOG.)
C  FOR A GIVEN SIGNAL TO NOISE RATIO BY LOOKING UP THE  SNR VALUE ON A
C  CUMULATIVE NORMAL (GAUSSIAN) PROBABILITY CURVE WHERE THE
C  VALUE DELTA T/MRT=1.0 CORRESPONDS TO A PROBABILITY OF DETECTION OF
C  50 PERCENT
C  (SEE P. 53 AND 61 HANNOVER REPORT, PART 1)
C
      DIMENSION SRATIO(10),PROB(10)
      DATA NN/10/
C
C  INPUT CUMULATIVE NORMAL PROBABILITY CURVE COORDINATES
C
      DATA SRATIO/0.,.5,.65,.88,1.,1.1,1.25,1.5,1.75,2./
      DATA PROB/0.,.1,.2,.4,.5,.6,.75,.9,.96,1./
      IF(SNR.GT.SRATIO(1)) GO TO 2
      CMPHB=PROB(1)
      RETURN
    2 CONTINUE
      N1=NN-1
      DO 3 J=1,N1
      K=J
       IF(SNR.GE.SRATIO(J).A.SNR.LT.SRATIO(J+1)) GO TO 4
    3 CONTINUE
      CMPHB=PROB(NN)
      RETURN
C
C  INTERPOLATE BETWEEN 2 POINTS ON NORMALIZED CURVE TO DETERMINE
C  PROBABILITY OF DET. (OR RECOG.) CORRESPONDING TO CALCULATED
C  SIGNAL TO NOISE RATIO
C
    4 CONTINUE
      XX=SRATIO(K+1)-SRATIO(K)
      YY=PROB(K+1)-PROB(K)
      XP=SNR-SRATIO(K)
      CMPHB=(YY*XP/XX)+PROB(K)
      RETURN
      END
```

V. EXAMPLES OF OUTPUTS WHICH CAN BE GENERATED FROM THE OUTPUT TAPE OF PROGRAM FLIR

There are many ways of using the data that has been written on the output tape from Program FLIR (hereafter referred to as the FLIR tape). For the most part it has been used at IDA to generate graphical displays of the data. The following are some examples of plots that can be made with this data.

1. Probability vs. Time Plot

Figure 2 shows probability of detection (or it can show recognition) plotted against days of a given month. This particular plot was done for one FOV and two ranges (thus two curves). The data necessary to make this plot was extracted from the hourly tables of the FLIR tape. One point per hour of the month was plotted. The *hour of the month* was the X-coordinate of the point.

The Y-coordinate value of the point was determined by specifying the following parameters:

- File (or month) on FLIR tape.
- FOV.
- Detection or recognition.
- Range(s).

The FOV and choice of detection or recognition define which column of the hourly table (see Table 2) the probability is to be taken from. The range specifies which row. Thus the probability value occupying that position in each hourly table for the month is extracted.

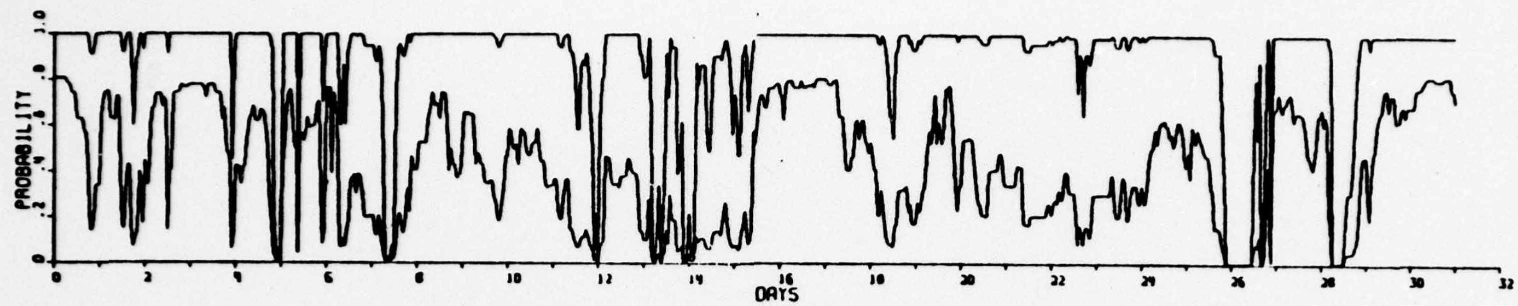

Figure 2. PROBABILITY VS. TIME PLOT

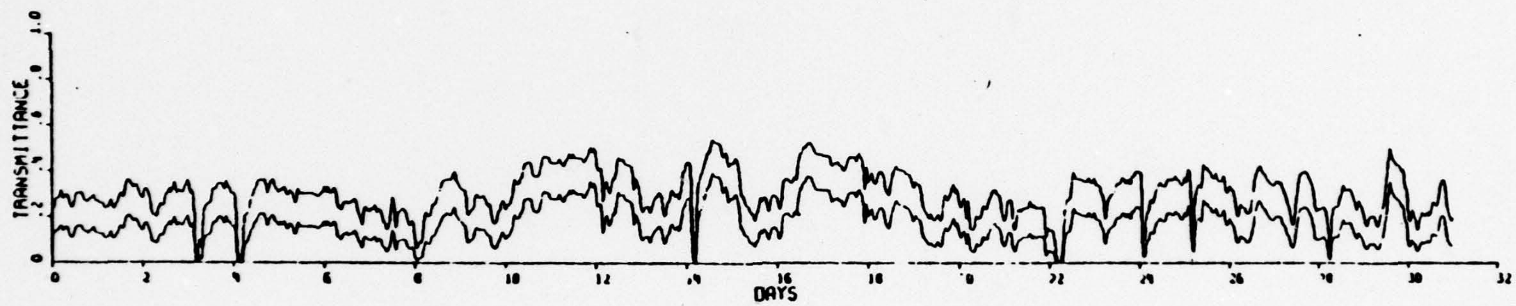

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Figure 3. TRANSMITTANCE VS. TIME PLOT

Figure 3 is a plot very similar to Figure 2. In this case transmittance is plotted versus time. Because transmittance is plotted instead of probability it is known that the data was extracted from the apparent target temperature column (transmission = apparent target temperature/ temperature of target) of the hourly table. Range again was selected indicating the appropriate row of the table (Figure 3 shows two ranges plotted).

2. Range at Which Probability Equals Specified Percent vs. Time Plot

Figure 4 illustrates another type of data plotted against hours of a given month. The Y-axis in Figure 4 represents the range at which probability of either detection or recognition for a given FOV equals a specified percent (e.g., 50 percent). As in Figure 2 the FOV and choice of detection or recognition defines the appropriate column of data in the hourly tables. However, the value for range to be plotted for a particular hour is now determined by scanning the entire column of probabilities and interpolating linearly between range values given in the table to get a range at which the probability is what has been specified (e.g., 50 percent).

Two curves have been plotted in Figure 4, one each for two different systems. To plot two systems on one graph two FLIR tapes will have to be read. These two FLIR tapes would have been made using the same transmission data tape but inputting different MRT curves in Subroutine Resolve of Program FLIR.

3. Probability ≥ Specified Percent at Given Ranges vs. Time

Probability greater than or equal to a certain percent at several ranges can be plotted as a broken line plot to indicate hours of delay of detection or recognition

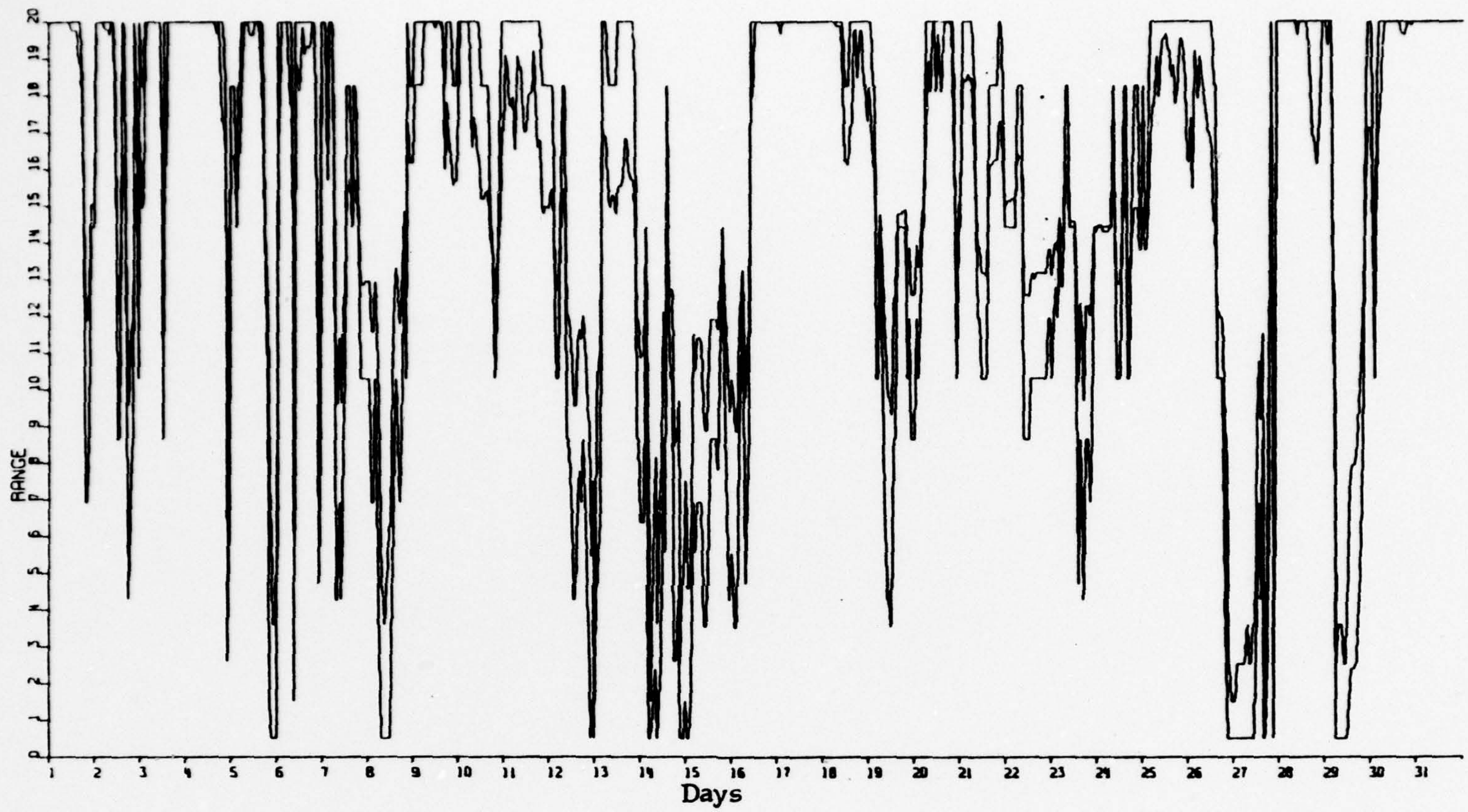

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Figure 4. RANGE AT WHICH PROBABILITY EQUALS 50 PERCENT VS. TIME PLOT

in a given month. Figure 5 shows two such plots. For the same month for a given FOV and five selected ranges one plot shows probability $\geq$ 50 percent and the other shows probability $\geq$ 90 percent. Again the FOV and choice of detection or recognition indicate which column of data to use from the FLIR tape hourly tables. Then for each range selected the probability in the correct column is measured against the probability criterion, for example 50 percent. If the probability for that range is $\geq$ 50 percent a line is drawn for that hour, if it is less than 50 percent a blank space is left for that hour. The next plot shown adds up the consecutive hours of delay and presents the data in a histogram type plot.

4. Histogram of Duration of Delay

Figure 6 is a histogram display of the same type of data presented in Figure 5. Instead of drawing a line for each hour where probability $\geq$ specified percent, count the number of consecutive hours where the probability is less than the specified percent (i.e., there was a delay). Then count the number of times a delay of that duration occurred during the month. Again the FOV and detection or recognition choices are made. One histogram is plotted per range selected.

Figure 6 shows a plot for each of four different ranges. The probability criterion in this case was 50 percent.

5. Fraction of Occurrences in Which Probability $\geq$ Specified Percent vs. Range

Figures 7 and 8 show one of the most useful types of plots from the FLIR tape data. Fraction of occurrences of probability of detection or recognition greater than or equal to a given percent (for example, 50 percent) can be interpreted as fraction of

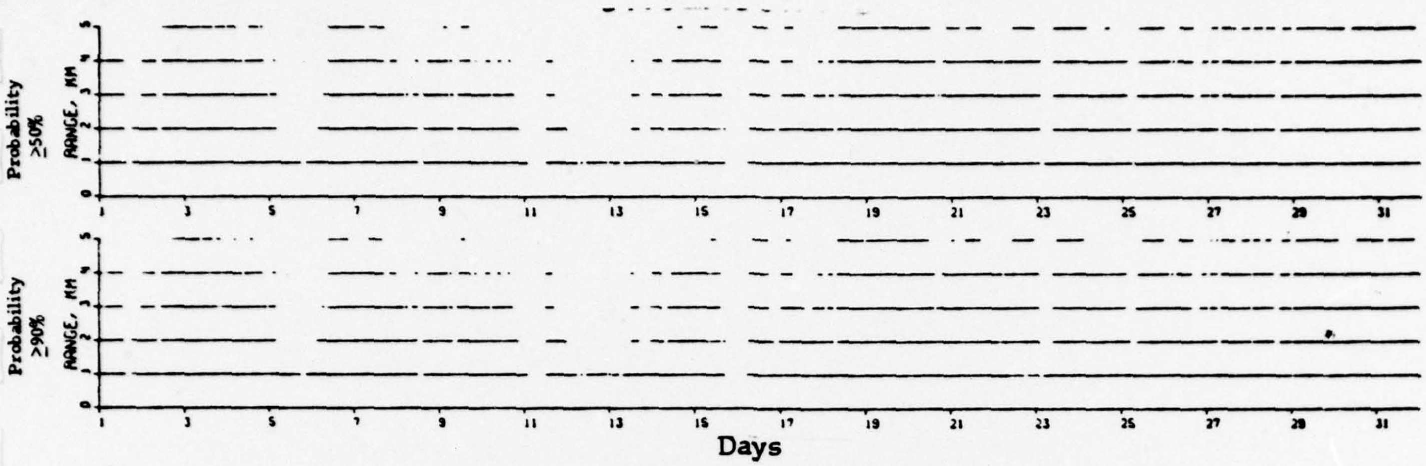

Figure 5. PROBABILITY ≥ 50 PERCENT AND PROBABILITY ≥ 90 PERCENT AT GIVEN RANGES VS. TIME PLOT

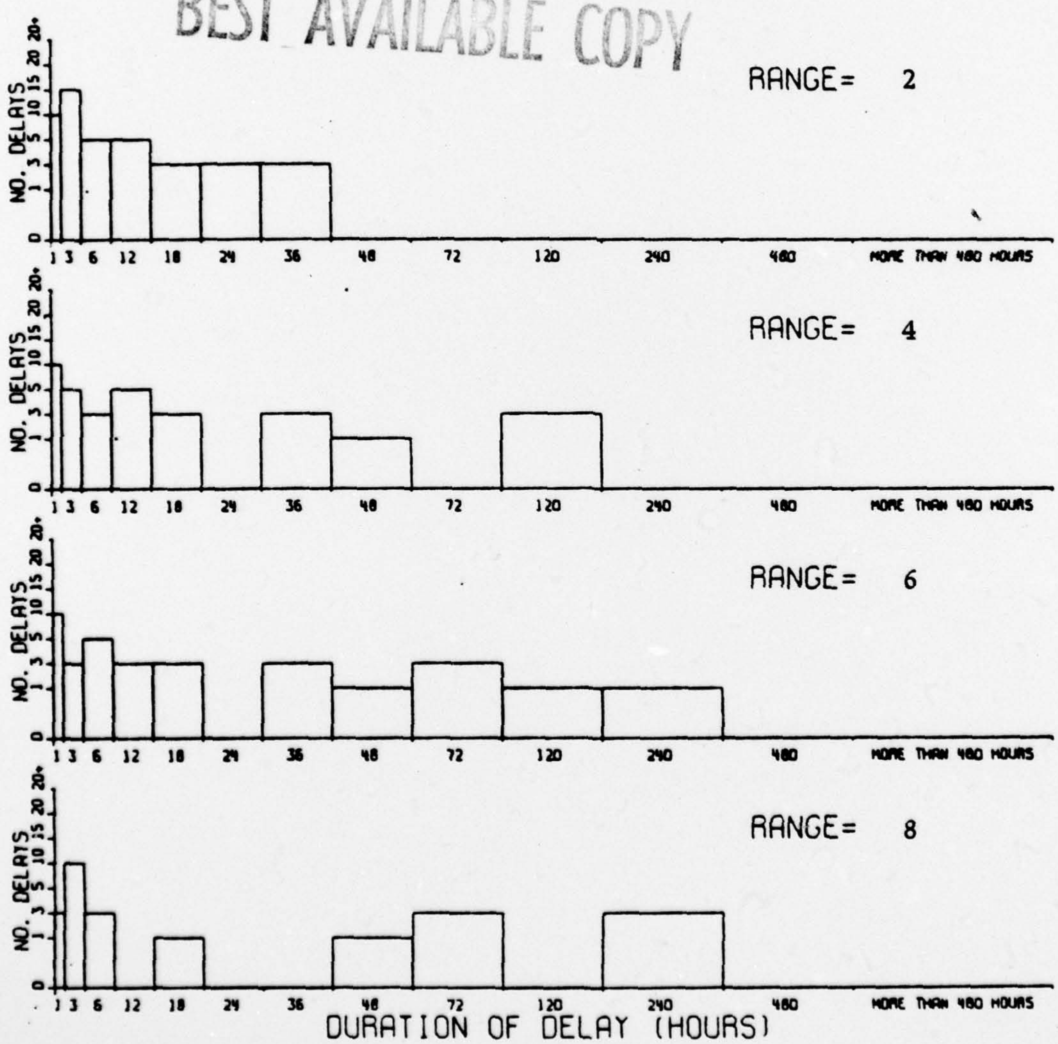

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Figure 6. DURATION OF DELAYS FOR PROBABILITY ≥ 50 PERCENT

successful events. Many sets of data can be plotted versus range in this manner.

Figure 7 compares the performance of different FLIR systems vs. range for a particular month. To plot each curve a different FLIR tape was used (i.e., each system was on a separate tape). An FOV and detection or recognition are chosen to indicate which column of the hourly table contains the correct data. For every range the probability in that column is measured against the criterion probability. Count up for every hour in the month the number of times the probability for each range is greater than or equal to the criterion probability. Plot the total number of successful occurrences for each range against the range.

Figure 8 shows basically the same type plot as Figure 7 except that it is comparing the performance of one system at two different hours of the day over a month's time. To get the data for this plot instead of summing up the number of times probability $\geq$ criterion probability is achieved for every hour of a month the data is summed once for each 6 AM hour of the month and once for each 6 PM hour of the month.

Many different comparisons of the data generated by Program FLIR can be made using the fraction of occurrences versus range type of plot. There are also many variations on the way the FLIR data can be plotted versus time. The particular types of plots shown here are only a few examples of the manner in which the FLIR data can be presented.

Figure 7. FRACTION OF SUCCESSFUL EVENTS VS. RANGE FOR THREE SYSTEMS

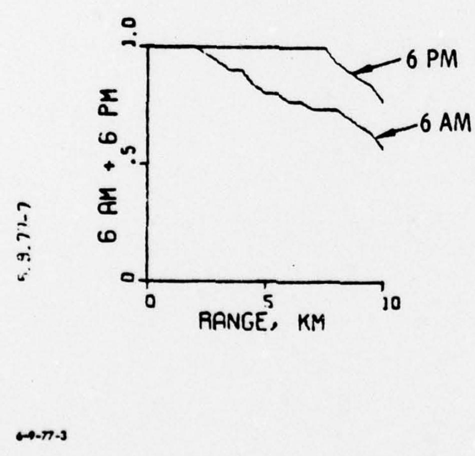

Figure 8. FRACTION OF SUCCESSFUL EVENTS VS. RANGE
FOR TWO HOURS OF A MONTH

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