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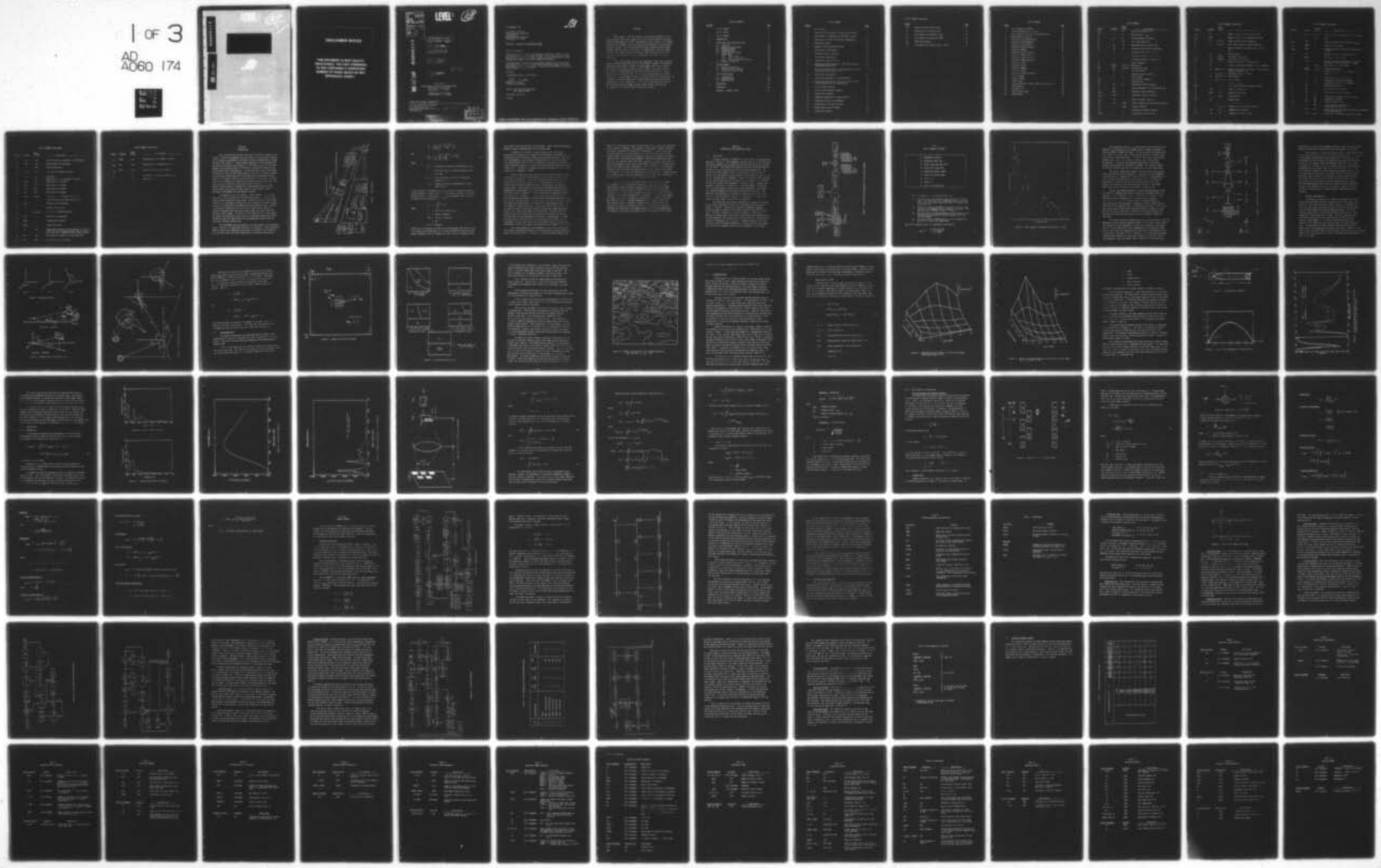

LEVEL II

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INFRARED SEARCH AND TRACK EVALUATION MODEL (IRSTEM)

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FINAL REPORT

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SAI-A64-995-199

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L. N. Peckham
L. L. Doran

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August 1978

Submitted to:
Electro-Optical Technology Program Office
Naval Research Laboratory
Washington, D. C. 20375

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Contract N00173-77-C-0236

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13 September 1978

Dr. Richard Steinberg
Electro-Optical Technology
Program Office
Naval Research Laboratory
Washington, D.C. 20375

Reference: Contract No. N00173-77-C-0236

Dear Dr. Steinberg:

Enclosed is the Final Report for Contract No. N00173-77-C-0236, Infrared Search and Track Evaluation Model (IRSTEM). This report, which documents the code development and includes a sample listing of IRSTEM, also incorporates your comments about the 15 August draft version.

Since the original contract has been recently modified, this report does not signify the completion of the contract but rather completion of only the original contract requirements. If you have any questions, please feel free to phone me at 505-265-7658.

Sincerely,

SCIENCE APPLICATIONS, INCORPORATED

Lawrence N. Peckham
Principal Investigator

Copies: NRL Code 4100 (one copy)
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FOREWORD

This report is the final report covering work performed for the Electro-Optical Technology Program Office at the Naval Research Laboratory under Contract N00173-77-C-0236. The purpose of this contract is to develop a system-level computer code to evaluate the performance of Infrared Search and Track systems. The Infrared Search and Track System Evaluation Model (IRSTEM) resulting from this contract is a deterministic code which models the background scene, atmospheric effects, sensor design characteristics and allows flexibility of incorporating a variety of signal processing options.

This report summarizes the work documented in the three quarterly reports submitted under this contract and provides a summary of the theory behind the models used in IRSTEM, a program summary and a user's manual with sample programs. The authors wish to express their appreciation to Dr. Richard Steinberg, the Program Monitor, for his assistance in structuring and critiquing the code. We also wish to acknowledge the contributions of Dr. Frank Horrigan in establishing the initial code methodology, and the work of Mr. Paul Eitner and Dr. Robert Turner for the background and cloud radiance data, respectively. Similarly, we acknowledge the help of Mr. Fred Smith with the target signature data, and Mr. Jim Giles and Dr. James Griggs for their overall review and critique.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (concluded)

LIST OF TABLES

LIST OF SYMBOLS

Theory	Program	Theory Units	Description
A_{BKG}	-	cm^2	Area of background pixel
A_d	-	m^2	Detector area = L_xL_y
A_E	A_E	cm^2	Projected area of tailpipe
A_G	-	cm^2	Glint area (2500 cm^2)
A_N	A_N	cm^2	Projected area of missile nose
A_S	A_S	cm^2	Projected area of missile fuselage
A_T	A_T	m^2	Projected area of the target
c_1	c_1	$w\ \mu m^4/cm^2$	Blackbody constant = 3.713×10^4
c_2	c_2	$\mu m\text{-}^{o}K$	Blackbody constant = 1.4388×10^4
D	D	m	Optics diameter
D*	DSTRPK	cm $hz^{\frac{1}{2}}\ w^{-1}$	Detectivity
Dec	DEC	radians	Declination of sun
D_T	DT	m	Missile Diameter
d	-	-	Detector response function
F	FL	m	Focal Length
FFT	-	-	Fast Fourier Transform
FOV	-	-	Field-of-View
f_o	FO	hz	Electronics cutoff frequency
f_p	FUNC	-	Aspect dependence of the plume emission
H_{Det}	HDET	-	Detector transfer function
H_{Elec}	HELECT	-	Electronics transfer function
H_{Opt}	OTF	-	Optical transfer function
H_S	SR	w/cm^2	Solar irradiance at the reflecting surface
H_T	-	w/cm^2	Target irradiance
h_E	-	--	Electronics response function
IFOV	-	sr	Instantaneous field-of-view

LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	
I_{max}	IMAX	-	Number of pixels in vertical direction
J_{max}	JMAX	-	Number of pixels in horizontal direction
J_p	TJP	$\mathrm{w/sr/\mu m}$	Plume spectral radiant intensity
J_t	TJ	$\mathrm{w/sr/\mu m}$	Total target spectral radiant intensity
$\vec{k}$	-	-	Spatial frequency transform vector = $\hat{i}k_x + \hat{j}k_y$
L	TL	m	Missile Length
Lat	RLAT	degrees	Latitude of engagement
Lha	LHA	degrees	Local hour angle of sun
L_x	DX	m	Detector dimension in scan direction
L_y	DY	m	Detector dimension orthogonal to scan direction
N	INL	$\mathrm{mw/sr/cm^2/\mu m}$	Number of detectors fully within scene (INL) or radiance ($\mathrm{mw/sr/cm^2/\mu m}$)
N*	-	$\mathrm{w/sr/cm^2/\mu m}$	Blackbody spectral radiance.
N_A	APR	$\mathrm{mw/cm^2/sr/\mu m}$	Path radiance
N_c	-	$\mathrm{mw/cm^2/sr/\mu m}$	Cloud radiance
OVL	OVL	m	Detector overlap
PSF	-	-	Point-spread function of optical system
R_d	RD	v/w	Detector responsivity
R_g	RGLNT	m	Range to glint point
R_L	-	ohms	Load resistor
RN	RN	-	Random number
$\bar{r}$	-	-	Positional Vector
T	-	$^{o}\mathrm{K}$ or $\mathrm{w/cm^2}$	Temperature or threshold irradiance
T_E	TE	$^{o}\mathrm{K}$	Temperature of tailpipe
T_N	TN	$^{o}\mathrm{K}$	Temperature of missile nose

LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	Description
T_S	TF or TS	sec or ^{o}K	Frame time or temperature of missile fuselage
t	T	sec	Time
V_{eff}	EFF	v	Voltage response with PSF added to V_{ideal}
V_g	VGLNT	v	Signal due to sunglint
V_{ideal}	VEFF	v	Voltage response before spatial effects are included
v_n	EFF	v	Voltage response from the electronics
$\hat{v}_n$	VNOISE	v	RMS level of system noise
v'_n	EFF	v	Voltage response from detector or from the electronics after random noise is added
v_s	VS	m/sec	Scan velocity in focal plane
W	BLKBDY	$w/cm^2/\mu m$	Blackbody emittance
y	Y	m	Vertical scene size in focal plane
y_i	YI	m	Center of i^{th} detector
δ	-	sr	Delta function or detector IFOV
$\Delta\lambda$	DV	μm	Integration interval for passband
$\Delta\nu$	CV	cm^{-1}	Integration intervals for passband
ϵ_B	EB	-	Background emissivity
ϵ_N	ETN	-	Emissivity of missile nose
ϵ_S	ETS	-	Emissivity of missile fuselage
θ	TH	rad	View angle of observer from cloud normal
θ'	TH	rad	Supplement view angle
θ_{ALT}	ALT	rad	Elevation angle of sun
θ_D	-	rad	Solar dispersion angle off of a glint point (= 9.3 mr)
θ_E	ELVS	rad	Zenith angle for the line-of-sight from the observer to the background cell
θ_L	THL	rad	Zenith angle of observer as seen from cloud

LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	Description
θ_0	THO	rad	Solar zenith angle measured wrt cloud normal
θ_n	THN	rad	Zenith angle of cloud normal
θ_s	-	rad	Solar zenith angle
θ_{TS}	THTATS	rad	Starting zenith angle of target
λ	XL	μm	Wavelength
$\overline{\lambda}$	-	μm	Mean wavelength for passband of interest
λ_L	XLAML	μm	Lower bound of passband
λ_u	XLAMU	μm	Upper bound of passband
ν_L	BL	cm^{-1}	Lower bound of passband
ν_u	BU	cm^{-1}	Upper bound of passband
ξ	ASPECT	degree	Aspect angle or view angle of missile
ρ	-	-	Direction vector in focal plane, $\hat{i}x + \hat{j}y$
ρ_D	RHO	-	Diffuse solar reflectivity
ρ_G	-	-	Specular reflectivity
σ	-	v or w/cm^2	Noise level standard deviation
τ_A	TAUA	-	Atmospheric transmission
τ_o	TAUO	-	Transmission of optics
τ_p	TGTAU	-	Plume transmission
ϕ	PH	rad	Azimuth angle between sun and observer in plane of cloud (the smaller angle measured from the reciprocal of the sun's projection in the cloud's plane)
ϕ_L	PHL	rad	True bearing of observer as seen from cloud
ϕ_n	PHN	rad	True bearing of cloud normal

LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	Description
ϕ_S	TRUEB	rad	True bearing of sun (TRUEB in SUNLOC)
ϕ_{TB}	PHL	rad	True bearing of background centroid
ϕ_{TS}	PHITS	rad	Starting azimuth angle of target
Ω_c	-	sr	Solid angle subtended by aperture, $\frac{\pi D^2}{4R^2}$
ω	-	-	Transform frequency

SECTION 1

INTRODUCTION

Wide field-of-view Infrared Search and Track (IRST) systems are designed to search the engagement space and detect incoming threats based on the IR signatures generated by the exhaust plume or aerodynamically heated structure (see Figure 1). These systems complement RF radar because they are passive and because they operate in a different portion of the electromagnetic spectrum which makes it difficult to jam both the radar and the surveillance sensor simultaneously. On the other hand, one of the primary limitations of the IR surveillance sensor is its ability to detect targets at long ranges without excessive false alarms due to background clutter. There are a variety of options available to minimize the false alarms and increase the probability of detection including judicious selection of the spectrum bands, focal plane arrays and signal processing. The large number of options make it impractical to experimentally determine the optimal design, but there has been a general lack of analysis tools available to complement the experimental programs.

The purpose of the IRST evaluation model (IRSTEM) is to provide the analyst with a flexible tool for determining the performance of wide field-of-view surveillance sensors under realistic battlefield conditions. Flexibility is provided by allowing the user to specify the sensor characteristics including both the hardware design and software logic. Realism is provided by allowing the user to input a spatially and spectrally varying background scene which can include clouds, sun glints and other potential false targets. The ability of the search set to to then detect the target can be analyzed using the user's specified hardware and signal processing since the code predicts the time-dependent signals from the individual detector preamplifiers.

IRST performance analyses generally are made assuming the background noise is Gaussian (in magnitude) and white (in frequency). These assumptions greatly simplify the computations and reduce the probability of detection (P_d) and false alarm rate (FAR) computations to analytical expressions:

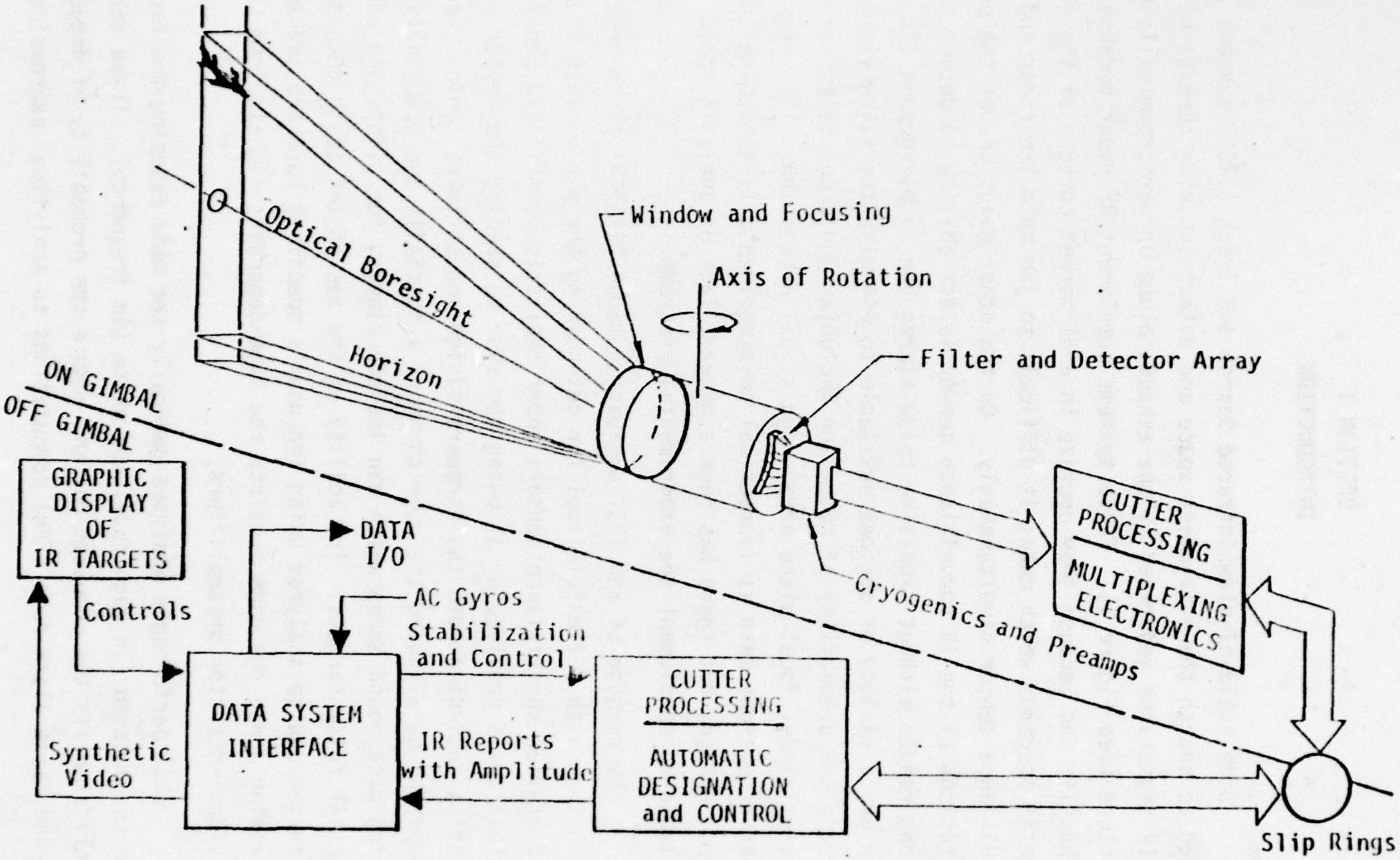


Figure 1. IRST Schematic.

$$P_d = \frac{1}{\sqrt{2\pi}\sigma_n} \int_T^{\infty} e^{\frac{-(H - H_T)^2}{2\sigma_n^2}} \, dH \qquad (1)$$

and

$$FAR = \frac{1}{\sqrt{3}} \left[\frac{f_2^3 - f_1^3}{f_2 - f_1} \right]^{1/2} e^{-T/2\sigma_n^2} \qquad (2)$$

where

H_T = irradiance of target at the aperture (w/cm^2)

T = threshold level for clutter rejection (w/cm^2)

= S/N · NEI

f_1, f_2 = lower and upper video cutoff frequencies, respectively (hz)

σ_n = standard deviation of background or system noise (w/cm^2)

If one wishes to incorporate the impact of spatial frequency variations on system performance without sacrificing mathematical simplicity, the power spectral density or Wiener spectrum, of the background scene can be used to establish the magnitude of σ_n. That is,

$$\sigma_n^2 = \delta^2 \int_{K_1}^{K_2} P(K) \, dk \qquad (3)$$

where

δ^2 = IFOV of the detector (sr)

K = spatial frequency

$P(K)$ = 1-D Wiener Spectrum

$\cong aK^b$

a,b = constants

Using such a formulation over the white noise approach does more realistically weight the average power in a typical background scene to the lower spatial frequencies but it inadequately models the high frequency spikes which tend to dominate the false alarm problems. Hence, the Wiener spectrum approach tends to underestimate the false alarm rate.

In addition to the basic accuracy problems, the statistical approach to IRST analyses also suffer from the problem of inflexibility. The formulations above are based on simple threshold crossing logic. And since the time-dependent signal response from each pixel is lost in the statistics, these formulations do not lend themselves to evaluations of various signal processing logics (e.g. multi-color discrimination, spatial discrimination, etc.). Therefore, it appeared reasonable to embark on a new methodology which is embodied in IRSTEM.

IRSTEM is structured such that the user can specify each background element or pixel (typically 4096 elements), each of which can differ from its neighboring elements. The target signature and potential false targets which can vary with time are added and computation of the signals arising from the detectors/preamplifiers is made based on the spectrally varying scene. These signals are modified to incorporate the spatially or temporarily varying effects (e.g. the optical transfer function and the electronic response function). These degradations are modelled by transforming the signal arrays into frequency space and then modifying the signals with the appropriate transfer functions before transforming the entire array back to the time/space domain. At this point, the signal is further degraded by random system noise which then results in a time-dependent signal from each detector/preamplifier which is used by the signal processing routine. The code discussed in this report does not include the signal processing options (e.g. spectral and spatial discrimination, signature growth and adaptive threshold), because the discrimination techniques and the order in which they are applied depend on the specific system design. To determine the range at which the sensor can discriminate the target from the background, the user simply manipulates the preamp signals in exactly the same manner in which the signals are processed by the hardware in the field.

This report summarizes the development of the initial IRSTEM code and includes information contained in the three quarterly reports submitted under this contract (refs. 1, 2 and 3). It should be noted, however, that some of the information included in those reports has not been duplicated here in the interest of brevity. The structure of the report includes a theoretical section immediately following this introduction. In that section two items not covered in previous reports (i.e., the background model and the sky/haze model) are discussed in addition to the logic flow and basic methodology for each of the major code elements. Whenever the terms are not defined for the equations within the theory section, the reader should refer to the List of Symbols at the front of this report. Section 3 is a concise summary of the codes and major subroutines. It is followed by a user's manual including input and output instructions and a list of major variables used in the code to facilitate code operation and troubleshooting. A sample program is provided to give the user a checkpoint to ensure the proper operation of the code, and a full code listing is included in Appendix A.

It should be noted that some of the features included in IRSTEM as documented here are the result of work done under other contracts. These items include the target signature and the target signature model which was done under SAI Contract N00039-77-C-0409 from the Naval Electronics Command. Three other features (the variable background array specification, input/output representation in wavelength instead of wave numbers, and modification of the integration routine) were funded under AF Contract No. F33615-78-C-1511. The code documented in this report is only the basic program which is expected to undergo extensive modification and expansion as analyses are conducted with it. A discussion of the basic features and limitations of the code as well as a list of recommendations for potential expansions are included in the final section of this report.

Section 2

IRSTEM LOGIC AND THEORETICAL BASIS

2.1 Logic Flow

The basic elements of IRSTEM are listed in Table 1 and graphically depicted in Figure 2. The engagement simulator consists of the user specified target dynamics and the specified location and time of day and year for the sensor. The latter specifications are used to determine the sun location for use in the glint and solar scattering computations. At present the target dynamics model is an extremely simple one which assumes that the target is always radially in-bound with no aspect or signature change during the engagement. The only trajectory inputs required are the starting position of the target (R_s), its velocity (V_T) and the maximum time at which the engagement is to cease (T_{max}). However, the engagement simulator is structured such that other modes of operation (e.g. crossing targets, targets with varying flight paths and targets with changing signatures) can be incorporated at a later time. The geometries associated with the engagement space are discussed in subsection 2.2 and followed by discussions of the background models and target signature models in the following subsections.

At present the false target information is assumed to be caused by sun glints, although the user could incorporate flares and other decoys, if desired. Sunglints are modelled in IRSTEM as randomly occurring events in specific cells whose location is specified by the user. The glint irradiance (or voltage response) is added to the aperture irradiance due to the diffuse solar scatter and thermal emission of the background. Even though the glint areas are small compared to an individual background pixel, the glint irradiance dominates the signal response because the energy propagates as a near-collimated beam, whereas the diffuse solar component spreads over a hemispherical solid angle.

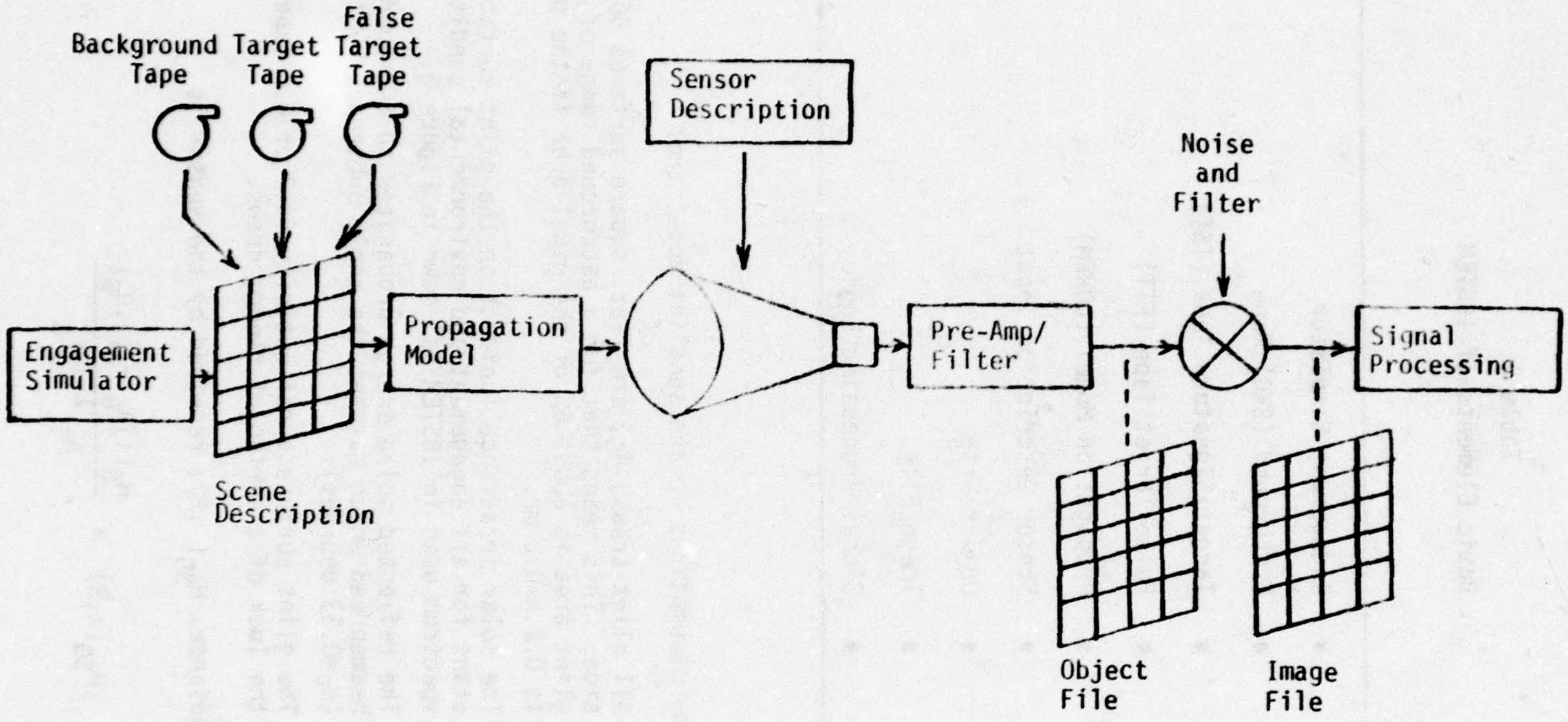


Figure 2. Functional Relationships of Primary Code Elements

Table 1

Basic Elements of IRSTEM

- Engagement Simulator
- Background (BKG) Tape
- Target Signature Tape (TST)
- False Target Tape (FTT)
- Propagation Model (LOWEM)
- Sensor Description Input
- Object File
- Image File
- Signal Processing Logic

The key assumptions in the sunglint model are:

(1) All glint areas, A_G, are flat, square surfaces 50 cm on a side. This means that for a background range of 10 km the glint area is about 6% of the pixel area if the pixel IFOV is 0.2 x 0.2 mr.

(2) The solar irradiance incident on the glint surface is constant for all engagement and environmental conditions. The spectrum used in IRSTEM is shown in Figure 3.

(3) The reflected solar energy propagates to the aperture with a beamspread which matches the angle subtended by the sun (θ_0=0.53 degrees)

(4) The glint surface's reflectivity is 0 or 0.8 depending on the luck of a series of random draws.

The flint irradiance, $H_{SG}(,R)$, received by the sensor is

$$H_{SG}(\lambda,R) = \frac{H_S(\lambda)A_G \, \tau_A(\lambda,R_G)}{A_G + \theta_D^2 R_G^2} \qquad (4)$$

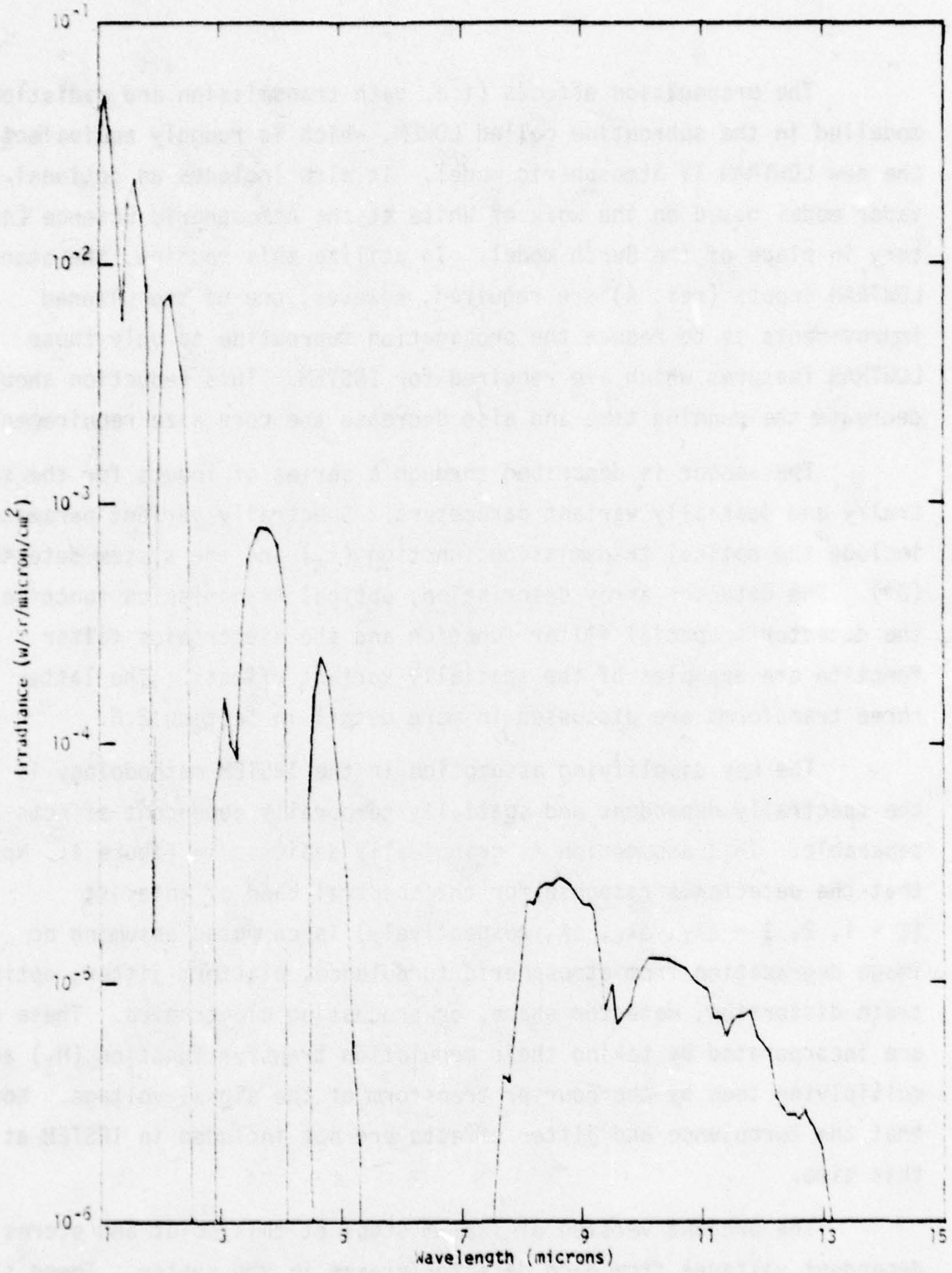


Figure 3. Solar Spectral Irradiance at the Earth's Surface

The propagation effects (i.e. path transmission and radiation) are modelled in the subroutine called LOWEM, which is roughly equivalent to the new LOWTRAN IV atmospheric model. It also includes an optional water vapor model based on the work of White at the Atmospheric Science Laboratory in place of the Burch model. To utilize this routine, the standard LOWTRAN inputs (ref. 4) are required, however, one of the planned improvements is to reduce the propagation subroutine to only those LOWTRAN features which are required for IRSTEM. This reduction should decrease the running time and also decrease the core size requirements.

The sensor is described through a series of inputs for the spectrally and spatially variant parameters. Spectrally variant parameters include the optical transmission function (τ_0) and the system detectivity (D^*). The detector array description, optical transmission function, the detector's spatial filter function and the electronics filter function are examples of the spatially variant effects. The latter three transforms are discussed in more detail in Section 2.6.

The key simplifying assumption in the IRSTEM methodology is that the spectrally dependent and spatially/temporally dependent effects are separable. This assumption is graphically depicted in Figure 4. Note that the detector's response for the spectral band of interest ($\xi = 1, 2, 3 \rightarrow \Delta\lambda_1, \Delta\lambda_2, \Delta\lambda_3$ respectively) is computed assuming no image degradation from atmospheric turbulence, platform jitter, optical train distortion, detector shape, or processing electronics. These effects are incorporated by taking their modulation transfer function (H_i) and multiplying them by the Fourier transform of the signal voltage. Note that the turbulence and jitter effects are not included in IRSTEM at this time.

The present version of IRSTEM stops at this point and stores the time-dependent voltages from each detector/preamp in the system. These signals are generated for each passband of interest as the detector array sweeps across the background scene in the neighborhood of the potential target. Each of these sweeps are updated at the frame time of the detector, which is typically of the order of 1 to 2 seconds. If (a) the proper background scene has been inputted, (b) the target signature is realistic, and (c) the atmospheric inputs and sensor inputs included in the transforms are

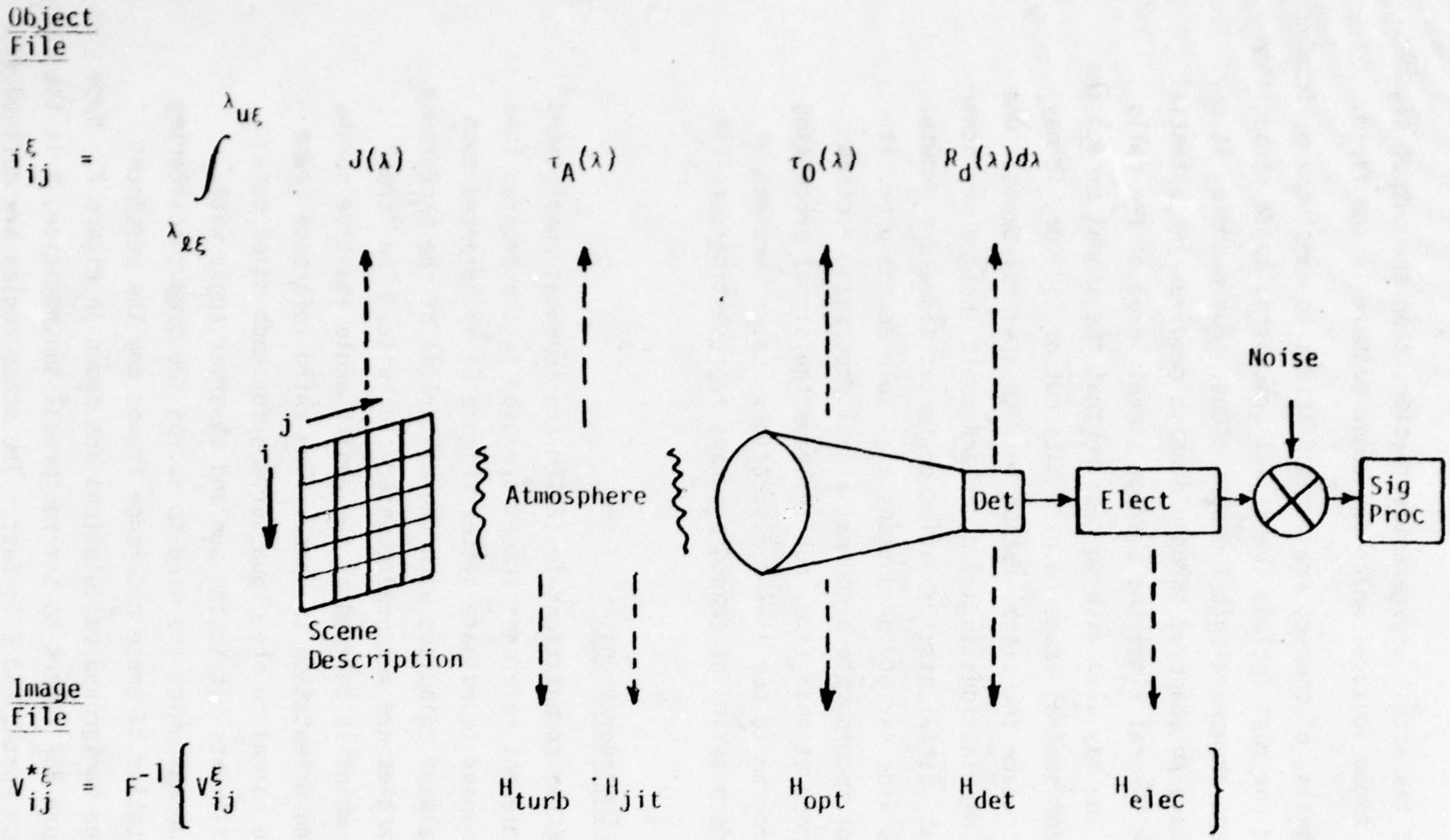


Figure 4. Separation of Spatial and Spectral Computations

characteristic of the actual engagement situation, then the output signals should duplicate those voltages which one could measure in the field.

These signals, of course, are not sufficient to model the performance of the sensor and one must include the signal processing logic in addition to the hardware and phenomenological descriptions. For example, it may be desirable to have an adaptive threshold which requires the potential target cell to be several times the average signal level of the cells surrounding it. One may also wish to require that the signal exceed the threshold level for several scans (e.g. 3 hits out of 5). Or, it may be desirable to compare the signal ratios between spectral bands. One could make these examinations in any order and could include any other techniques such as spatial discrimination or target signature growth. Since there are a wide variety of options available to the user, it was decided to not incorporate a nominal signal processing routine into the IRSTEM code at this time, but to leave the signal processing portion of the program to the user's discretion. Later versions of IRSTEM may include a series of canned programs representing specific hardware.

2.2 Geometry Considerations

The geometric computations in IRSTEM are somewhat complicated because three different reference frames are used in the program (see Figure 5). The sensor coordinate system (Figure 6) is oriented such that the y-axis always coincides with the centerline of the background and its azimuth angles are measured counter-clockwise. The "true" reference system which is defined by the zenith angle and true north, always has a fixed orientation in space. The third reference frame is defined by the normal to the cloud surface for each pixel containing a cloud element. It is the sun and observer angle with respect to this normal which are used to access the proper scattering data. The orientation of these reference frames and the pertinent angles used in the background calculations are shown in Figure 7. Note that in this figure RSP refers to the reciprocal sun position, N is the cloud normal, TN is true north, and E is East. The other angles are defined in the list of symbols.

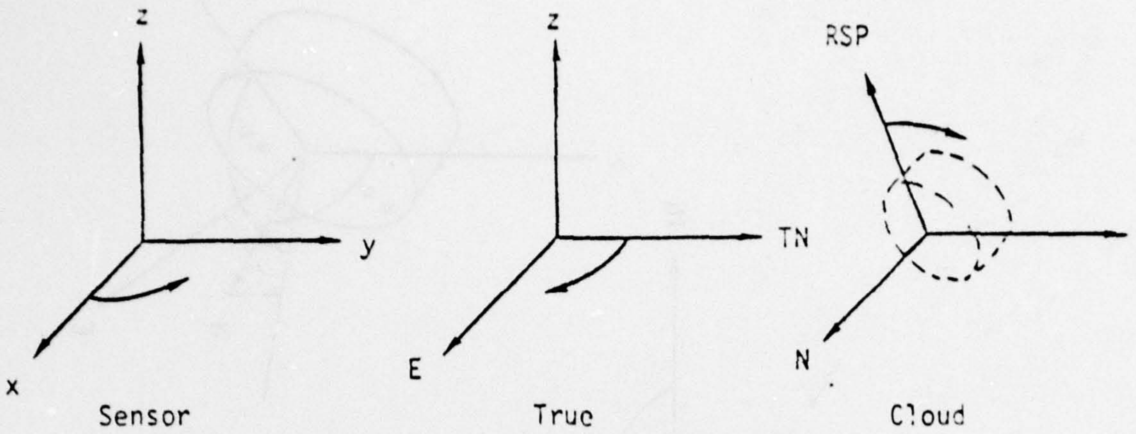


Figure 5. Coordinate Systems.

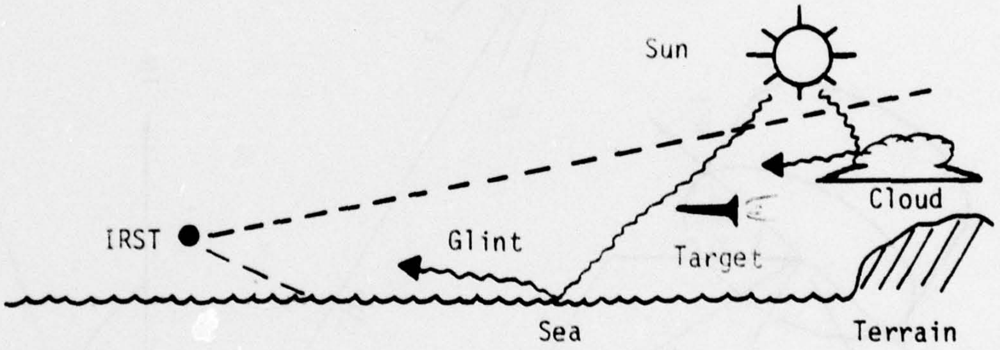


Figure 6a. Pictoral.

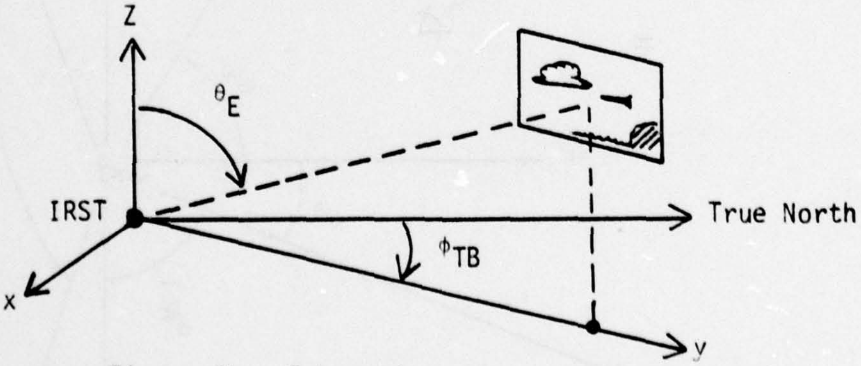


Figure 6b. Schematic

Figure 6. Geometry Sensor Coordinate System.

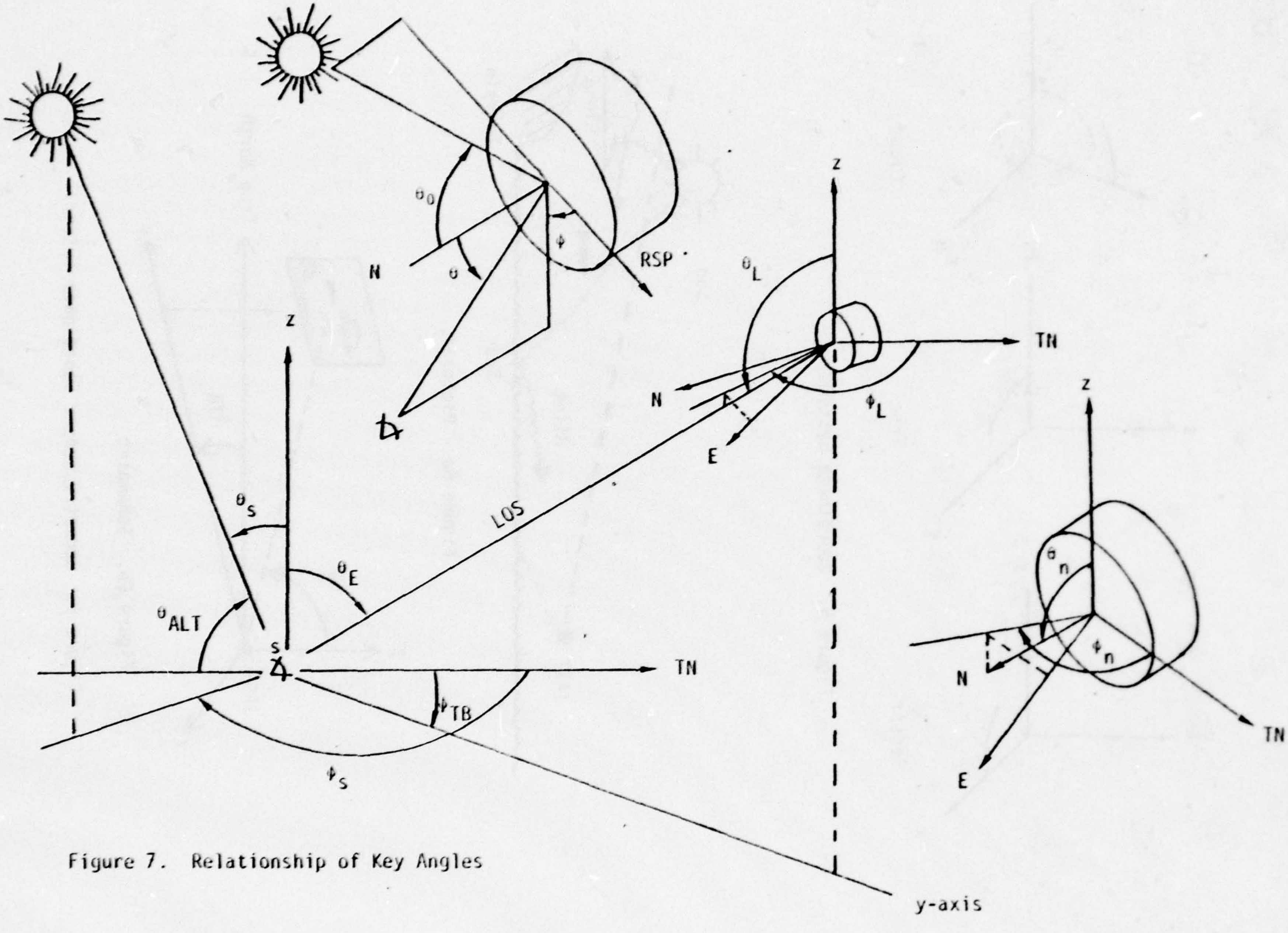


Figure 7. Relationship of Key Angles

Since the background scene is modelled as an array of discrete pixels I_{MAX} high by J_{MAX} across, the target's angular position (θ_T, ϕ_T) must be converted to scene coordinates (II, JJ) as follows. The target position is compared to the first pixel in the upper left-hand corner (θ_1, ϕ_1) which can be computed knowing the centroid of the scene (θ_E, ϕ = 1.5707 rad) and the pixel size (always assumed to be 0.2 by 0.2 mr). That is,

$$II = \frac{\theta_T - \theta_1}{2 \times 10^{-4}} + 1$$

$$= 5000(\theta_T - \theta_E + I_{MAX}*10^{-4}) + 1$$

and

$$JJ = \frac{\phi_T - \phi_1}{2 \times 10^{-4}} + 1$$

$$= 5000(\phi_T - 1.5707 + J_{MAX}*10^{-4}) + 1$$

Note that the angular coordinates correspond to the lower right-hand corner of the pixel (see Figure 8). Also note that the detector array is assumed to scan the scene from left to right with velocity, v_s.

2.3 Backgrounds Model

Five thermal backgrounds have been generated for IRSTEM. Each background file consists of coded data for a 64 x 64 grid of 0.2 x 0.2 mr pixels. This pixel size was selected to represent the minimum practical detector IFOV.

File 1 on the background tape consists of data for a partly cloudy sky with a 23 km haze. The field-of-view consists of 50% sky, and 50% cloud at a 10 km range (see Figure 9). The cloud is made up of a core with

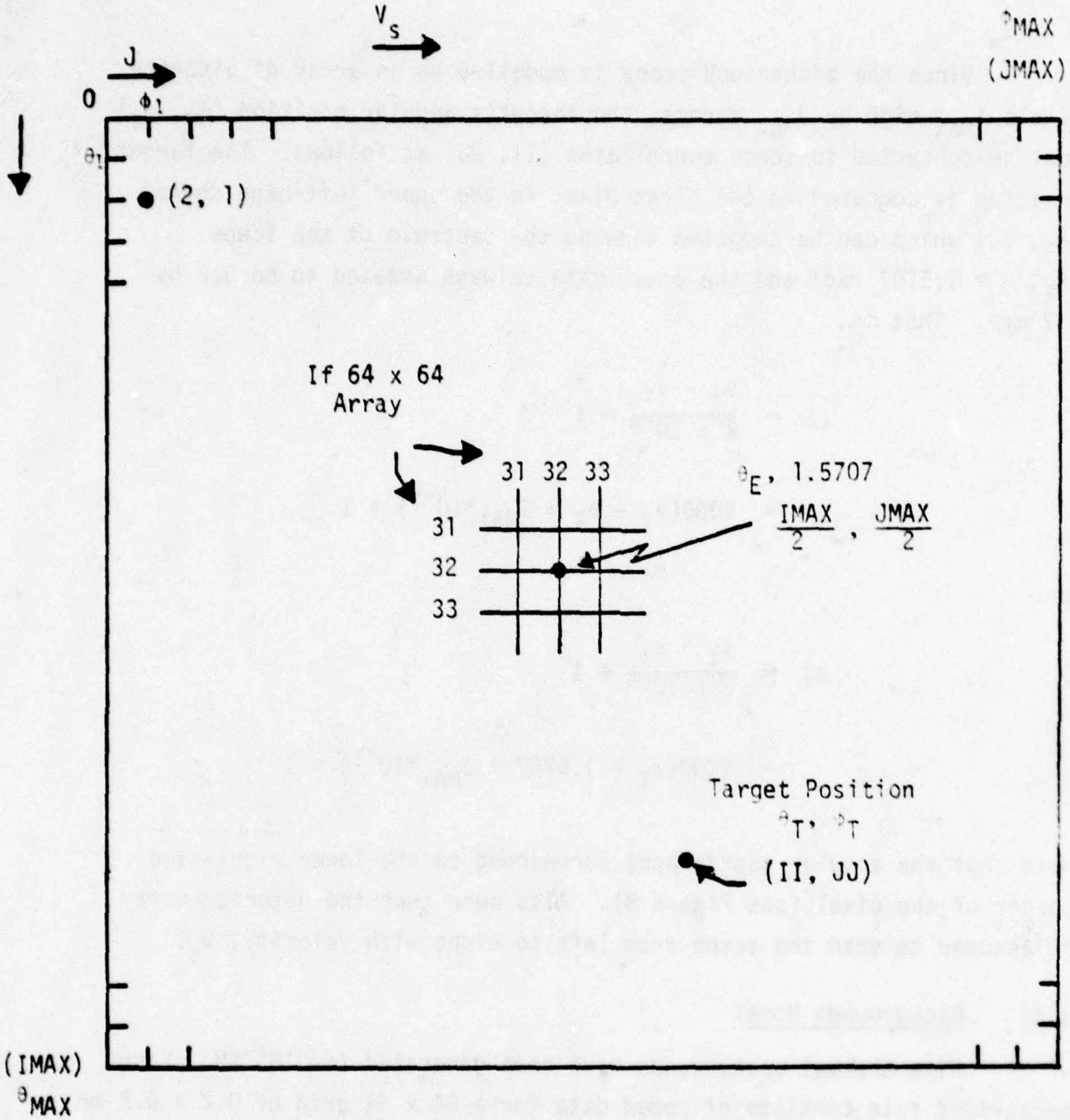
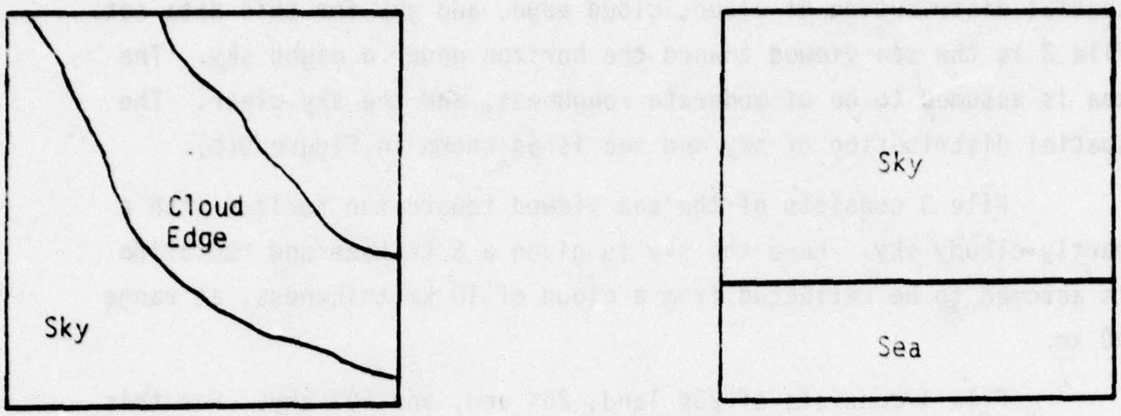
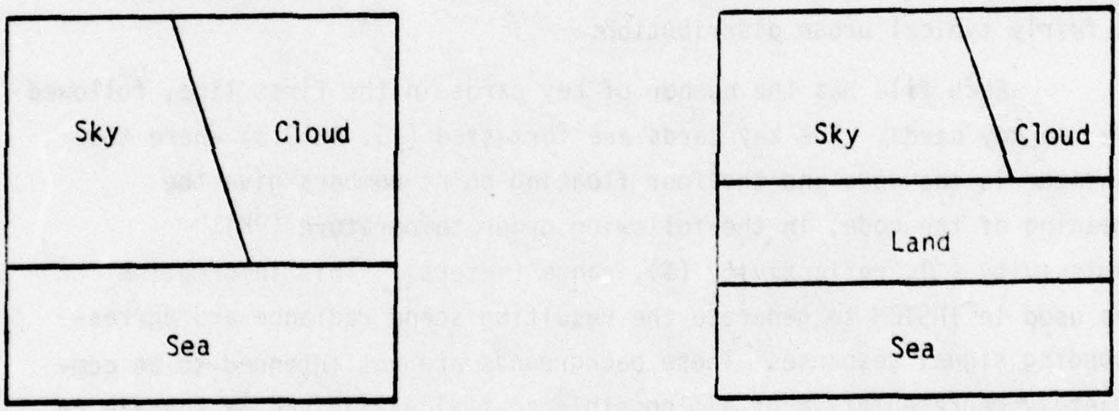


Figure 8. Computing Target Coordinates.



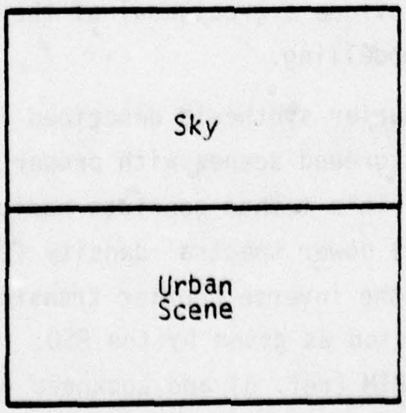
(a) Partly cloudy sky 23 km haze.

(b) Sea under night sky-clear sky, moderate sea



(c) Sea with partly cloudy sky-5 km haze, radiation reflected from cloud.

(d) Calm sea, terrain, and sky with 23 km haze and radiation reflected from cloud.



(e) Urban scene under sky with 23 km haze.

Figure 9. Five Nominal Backgrounds.

.5 km thickness and an edge with .1 km thickness; Figure 9(a) shows the spatial distribution of cloud, cloud edge, and sky for this data set. File 2 is the sea viewed toward the horizon under a night sky. The sea is assumed to be of moderate roughness, and the sky clear. The spatial distribution of sky and sea is as shown in Figure 9(b).

File 3 consists of the sea viewed toward the horizon with a partly cloudy sky. Here the sky is given a 5 km haze and radiation is assumed to be reflected from a cloud of 10 km thickness, at range 10 km.

File 4 consists of 25% land, 25% sea, and 50% sky. For this background a 23 km haze was assumed, with radiation reflected from a cloud of 10 km thickness at a range of 10 km.

File 5 is data for an urban scene viewed towards the horizon, with sky under a 23 km haze. Data used was for Flint, Michigan and represents a fairly typical urban distribution.

Each file has the number of key cards in the first line, followed by the key cards. The key cards are formatted (I5, 4E10.3) where the integer is the code and the four floating point numbers give the meaning of the code, in the following order temperature ($^{\circ}K$), emissivity (%), reflectivity (%), range (meters). This information is used in IRSTEM to generate the resulting scene radiance and corresponding signal response. These backgrounds are not intended to be completely representative of all possible spatial variations of terrain or sea background. However, the contrast provided by mixing scene types in a given background provides a great deal of the variability required for sensor performance modelling.

The method of Fourier synthesis described in Rusbridge (ref. 5) was used to generate background scenes with proper spatial correlation between scene elements. This method consists basically of multiplying a two-dimensional spatial power spectral density (PSD) by an uncorrelated random array and taking the inverse Fourier transform. The resulting array then has spatial correlation as given by the PSD. One-dimensional PDSs were obtained from the ERIM (ref. 6) and Lockheed (ref. 7) field measurements. An example temperature contour map is shown in Figure 10. In general, there are assumed to be 5 possible temperatures, 2 possible ranges, and 4 possible emissivities for a total of 40 different codes.

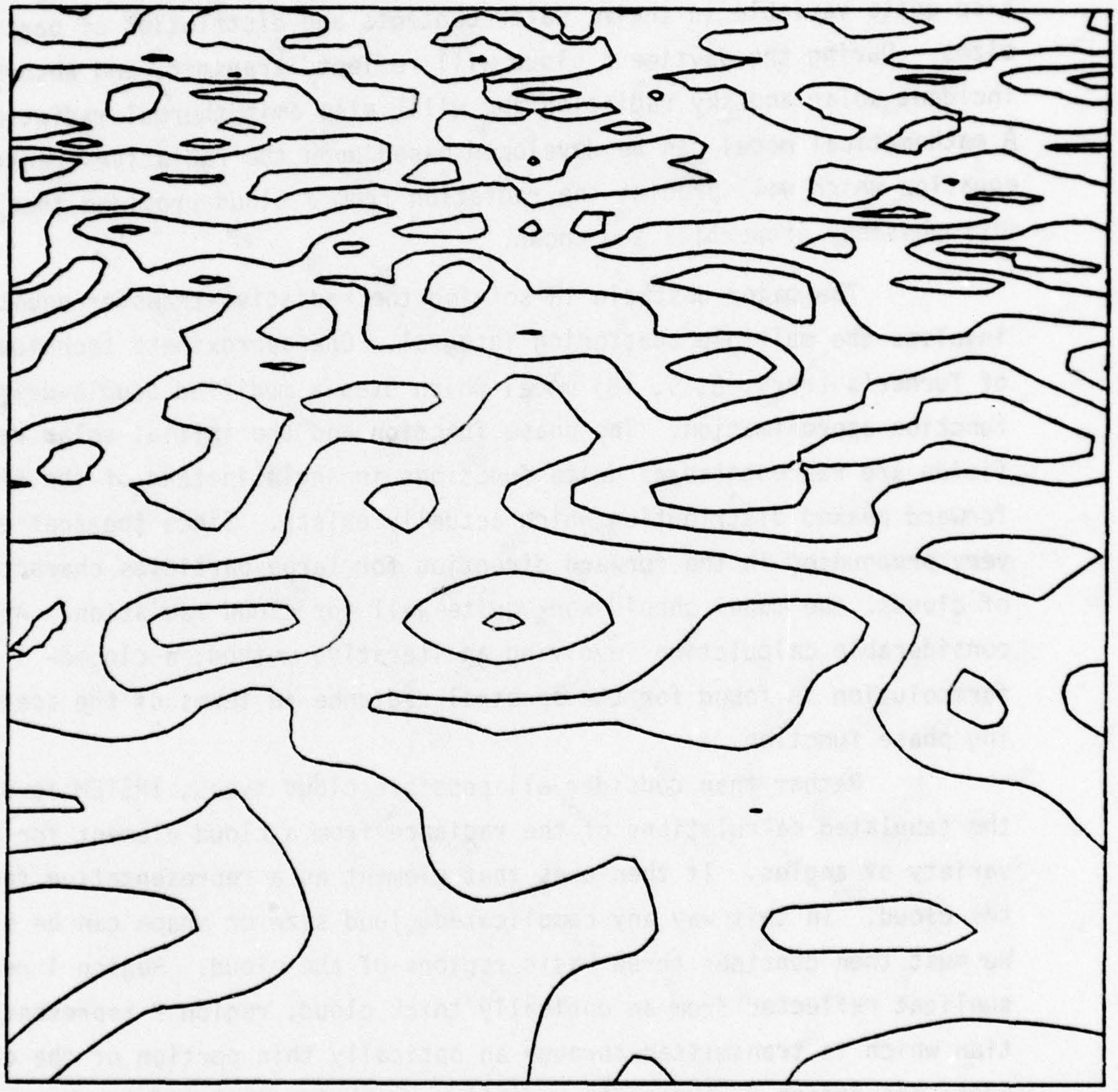


Figure 10 Moderate Sea Used for File 3 Ground Temperature
Mean 288.95°K Std. Dev. .73°K

Reflectivity is always assumed to be given by Kirchoff's law

$$\rho_\lambda = 1 - \varepsilon_\lambda$$

2.4 Cloud/Haze Model

Clouds appear in an infinite variety of sizes and shapes and are also quite variable in their water contents and distribtion of particle sizes. During the daytime a cloud will reflect, transmit, and absorb incident solar and sky radiation and will also emit thermal radiation. A mathematical model can be developed based upon the radiative-transfer equation which will predict the radiation from a cloud provided that the microphysical properties are known.

The major obstacle in solving the radiative-transfer equation involves the multiple scattering integral. One approximate technique is that of Turner's (refs. 8, 9, 10) model which uses a modified double-delta function approximation. The phase function and the initial solar radiation fields are represented as delta functions in angle instead of the highly forward peaked distribution which actually exists. Since the scattering is very pronounced in the forward direction for large particles characteristic of clouds, the model should work quite well for cloud radiation. After considerable calculation involving an iterative method, a closed-formsolution is found for the spectral radiance in terms of the scattering phase function.

Rather than consider all possible cloud types, IRSTEM is based on the tabulated calculations of the radiance from a cloud element for a large variety of angles. It then uses that element as a representative facet of the cloud. In this way any complicated cloud size or shape can be simulated. We must then consider three basic regions of the cloud. Region 1 represents sunlight reflected from an optically thick cloud; region 2 represents radiation which is transmitted through an optically thin portion of the cloud edge; and region 3 represents radiation which is emitted from the optically thick cloud. In addition, the radiance for a 5 Km. and a 23 Km. visual range hazes has been calculated and tabulated for IRSTEM by Turner. It was a maritime haze with a real particulate refractive index of 1.5.

To incorporate the cloud/haze radiance data, the user first identifies the background cells in which the cloud is located and specifies the direction of the normal to the cloud surface for that cell. The code then takes the appropriate radiance data from the cloud/haze data files, interpolating points if required, based on the relationship between the solar angles, viewing angle, and direction of the surface normal. Graphical representations of portions of the data base incorporated in IRSTEM are shown in Figures 11 and 12 for $\lambda=2$ μm. All units are given in mw/sr/cm^2/μm.

2.5 Target Signature Model

A detailed target signature model has been incorporated into the program based on recent SAI work under NAVELEX Contract No. N00039-77-C-0409. The various signature components are treated separately to give a physically more realistic model. The radiant intensity from the rocket's plume, tailpipe, and aerodynamically heated skin are combined to give the overall spectral radiant intensity as a function of aspect angle θ, as shown in equation 5.

$$\begin{aligned} J_T(\lambda,\xi) &= J_p(\lambda,20^0)f_p(\xi) \\ &+ N^*(T_E,\lambda)\tau_p(\lambda,160^0)A_E(\xi) \\ &+ \varepsilon_N A_N(\xi)N^*(T_N,\lambda) + \varepsilon_S A_S(\xi)N^*(T_S,\lambda) \end{aligned} \qquad (5)$$

where

$J(\lambda,\xi)$ - Spectral radiant intensity (w/sr-μm)

$\tau_p(\lambda,\xi)$ - Plume transmission

$N^*(\lambda)$ - Blackbody spectral radiance (w/cm^2-sr-μm)

$A(\xi)$ - Projected area viewed from aspect angle ξ (cm^2)

$f_p(\xi)$ - Aspect dependence of the plume emission

T - Temperature (^{0}K)

ε - Emissivity

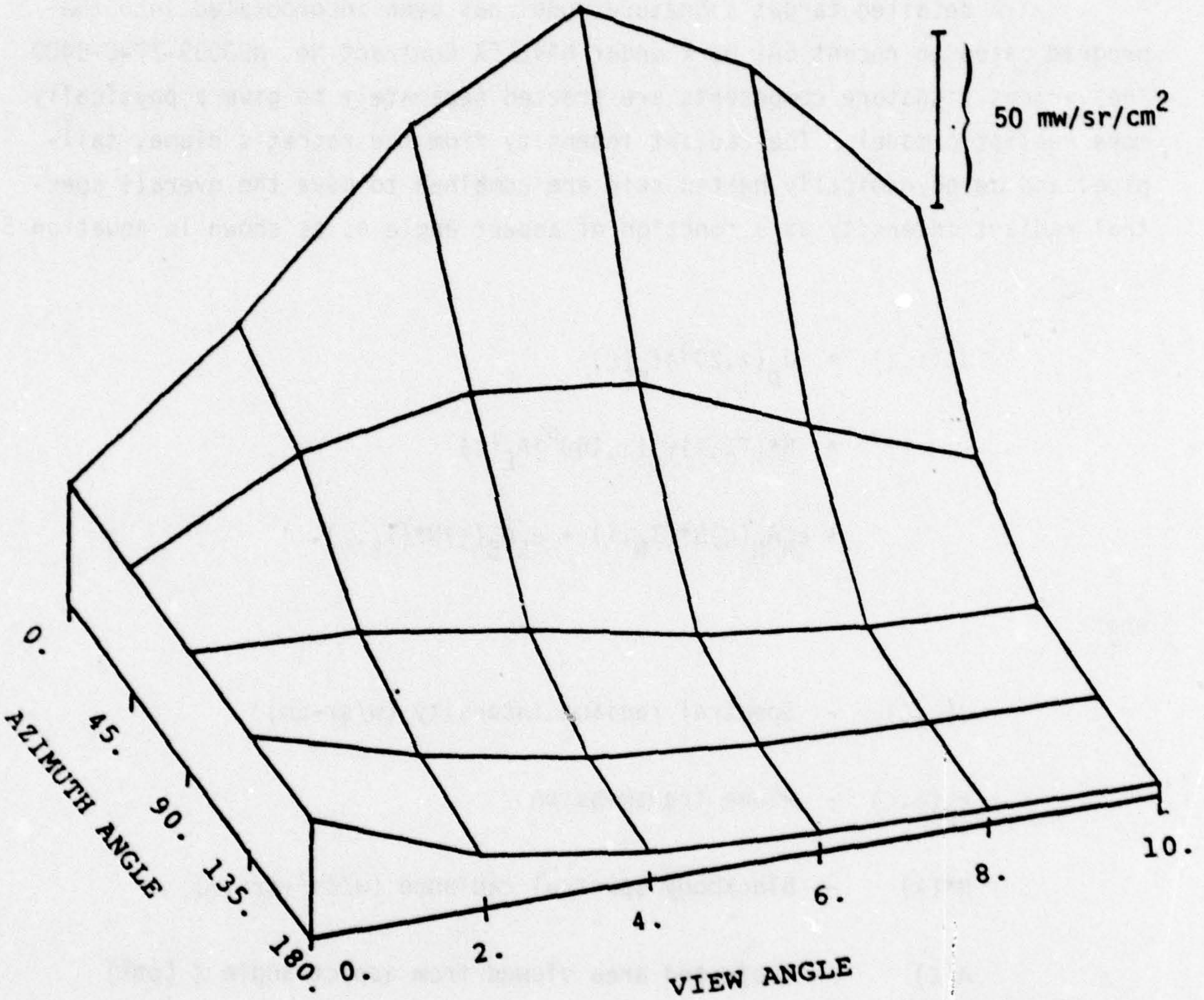


Figure 11. Downward Directed Radiance, 0.1 KM Cloud Thickness Solar Zenith Angle is 6°.

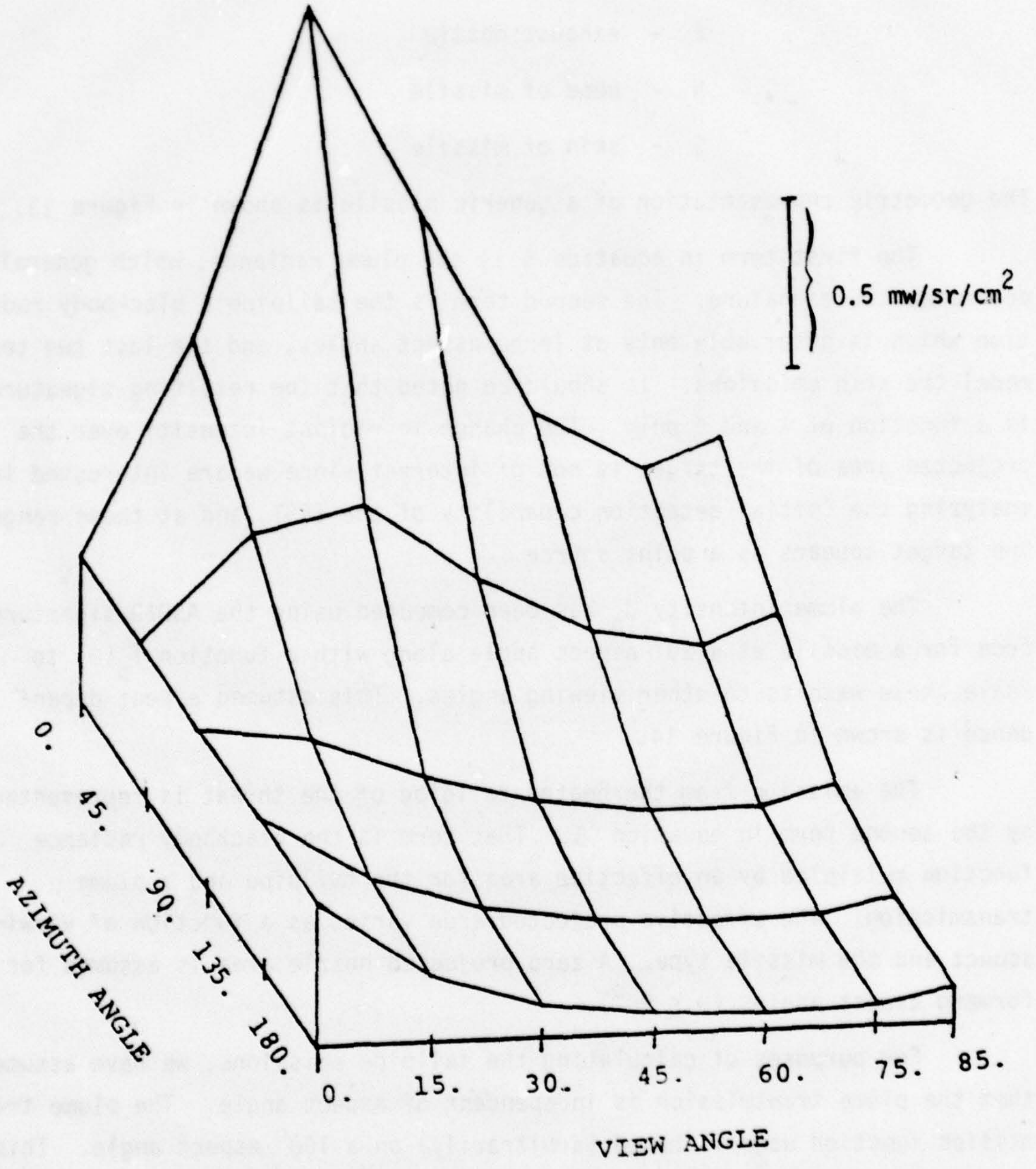


Figure 12. Downward Directed Radiance through Haze 23 KM Visual Range Solar Zenith Angle is 30°.

T - total

p - plume

E - exhaust nozzle

N - nose of missile

S - skin of missile

The geometric representation of a generic missile is shown in Figure 13.

The first term in equation 5 is the plume radiance, which generally dominates the signature. The second term is the tailpipe's blackbody radiation which is observable only at large aspect angles, and the last two terms model the skin emissions. It should be noted that the resulting signature is a function of λ and θ only. The change in radiant intensity over the projected area of the target is not of interest since we are interested in analyzing the initial detection capability of the IRST, and at these ranges the target appears as a point source.

The plume intensity J_p has been computed using the ASDIR signature code for a missile at a 20^o aspect angle along with a function $f_p(\theta)$ to scale these results to other viewing angles. This assumed aspect dependence is shown in Figure 14.

The emission from the heated tailpipe of the threat is represented by the second term in equation 5. That term is the blackbody radiance function multipled by an effective area for the tailpipe and a plume transmission. The effective projected area varies as a function of viewing aspect and the missile type. A zero projected nozzle area is assumed for forward aspect angles ($\theta \leq 90^o$).

For purposes of calculating the tailpipe emissions, we have assumed that the plume transmission is independent of aspect angle. The plume transmission function used is based (arbitrarily) on a 160^o aspect angle. This function is shown in Figure 15 along with a 110^o curve for comparison which shows that the assumption to not vary the plume transmission as a function of aspect angle is a reasonable one.

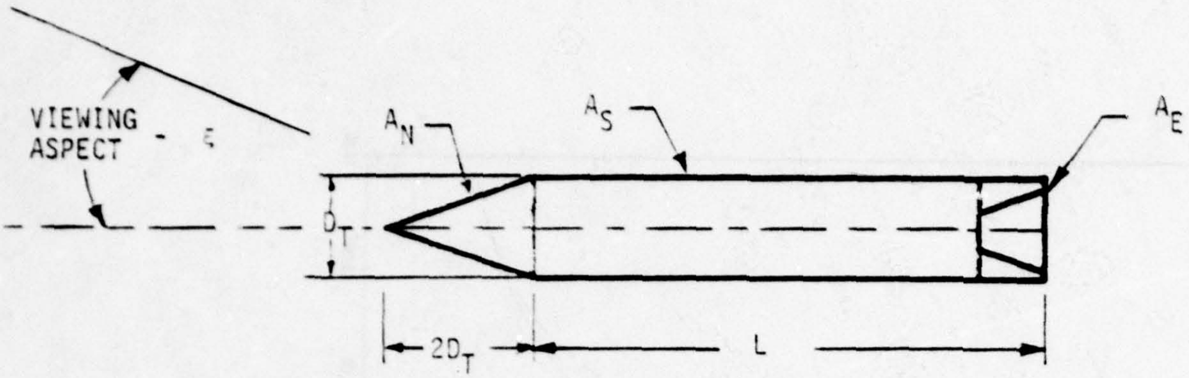


Figure 13. Assumed Missile Geometry.

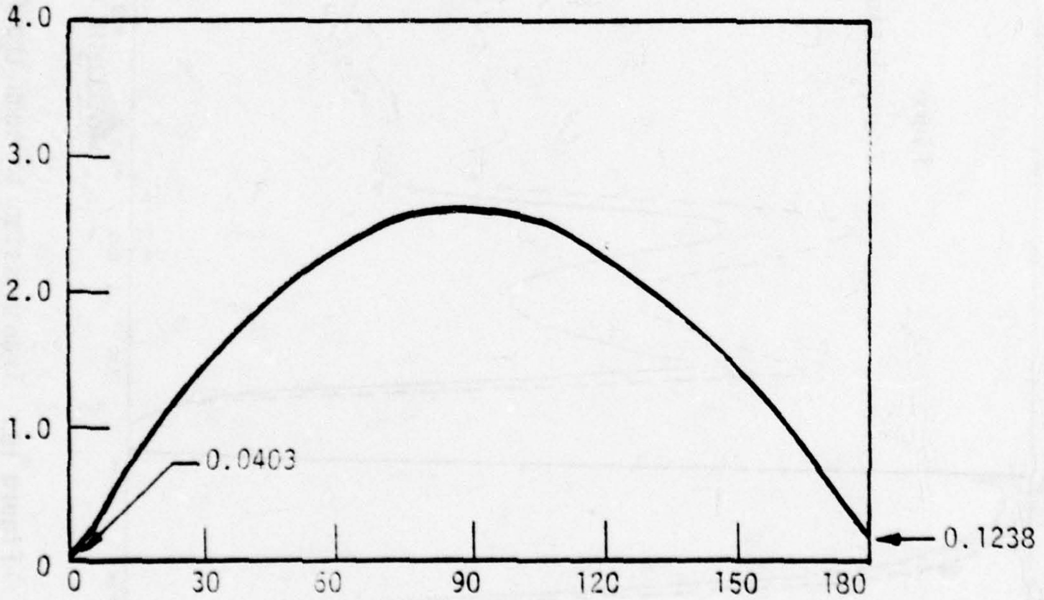


Figure 14. Aspect Angle Dependence of Plume Emission.

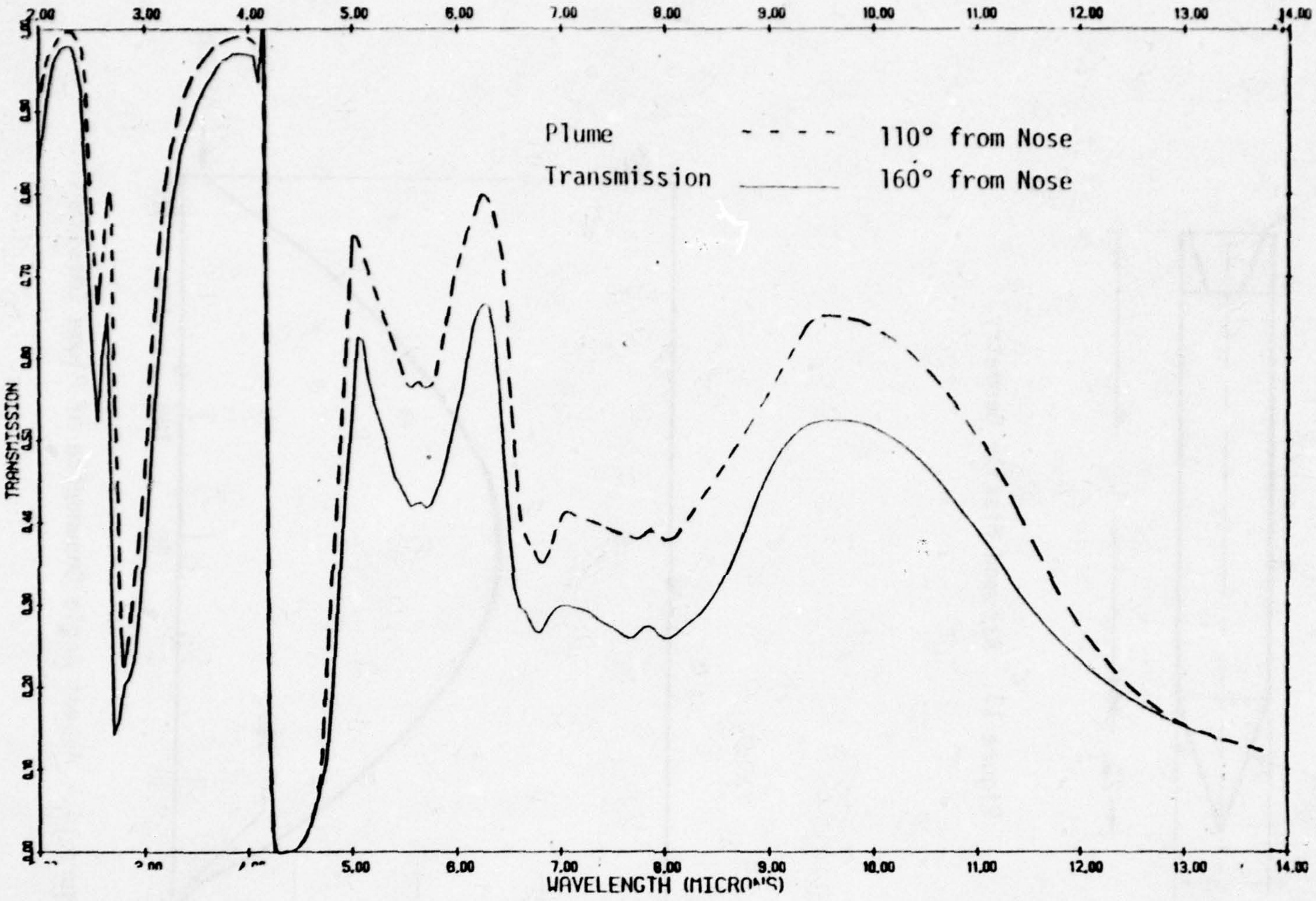


Figure 15. Transmission through the Plume for a 110° and 160° Viewing Geometry to the Exhaust Nozzzle.

The missile nose and skin emissions are computed based simply on the product of the blackbody function and a projected area. The radiance from aerodynamic heating is divided into two terms so that higher temperature (at or near the stagnation temperature) can be assumed for the nose of the missile and more moderate temperature assumed for the rest of the skin.

The various portions of a typical missile signature and the resultant total signature are shown in Figures 16, 17, 18 and 19. Note that these example plots are based on viewing the missile from the rear, which is not consistent with the present trajectory mode of only radially in-bound targets (ref. Section 2.1). This generalized signature model which includes the tailpipe emissions has been developed in anticipation of a more general trajectory model in later versions of IRSTEM which will model crossing targets.

2.6 Sensor Model

2.6.1 Methodology.

If we assume the projection of the detector array moves across the background scene as shown in Figure 20, the ideal voltage generated at the output of the detector due to any given pixel is

$$v_{\text{ideal}}(\bar{\rho}) = \int_{\Delta\lambda} N(\lambda,\bar{\rho})\, A_{BKG}\,\tau_A(\lambda)\tau_o(\lambda)\;\Omega_c R_d(\lambda)\,d\lambda$$

$$= \pi D^2 10^{-8} \int_{\Delta\lambda} N(\lambda,\bar{\rho})\;\tau_A(\lambda)\tau_o(\lambda)\;R_d(\lambda) \qquad (6)$$

assuming 0.2 x 0.2 mr pixels.

Equation (6) is a manifestation of one of the key simplifying assumptions used in IRSTEM; namely, the separability of the spectrally and spatially dependent effects.

To compute the spatially-dependent effects (or temporally dependent effects since $x = v_s t$), we consider 3 distortions: the sensor optics, the finite detector size, and the electronics response. The optical distortions are incorporated by convolving the ideal voltage with the optical point spread function (PSF) to produce an effective signal response, V_{eff}.

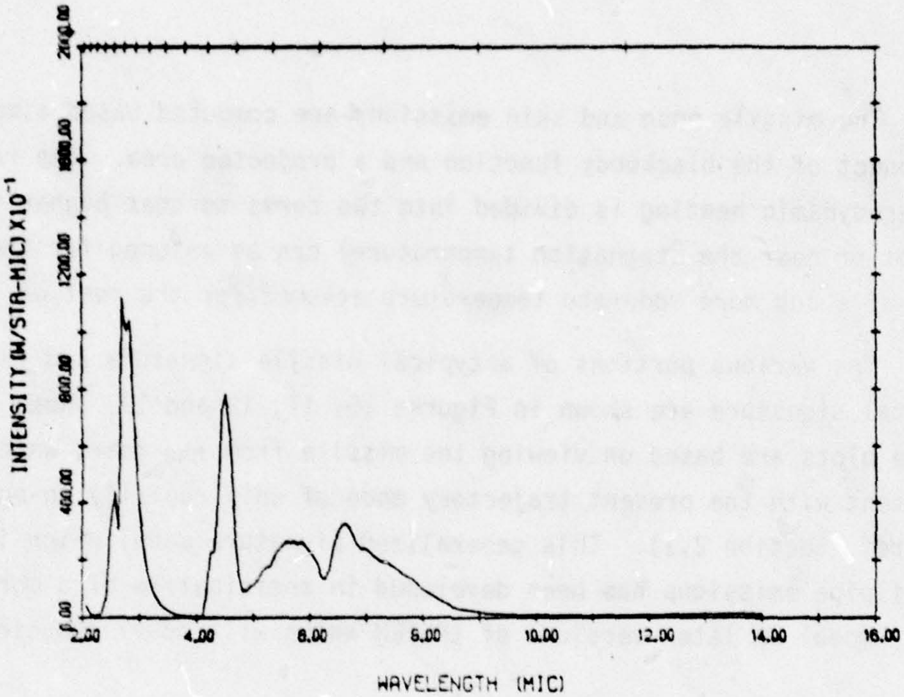


Figure 16. Typical Plume Signature.

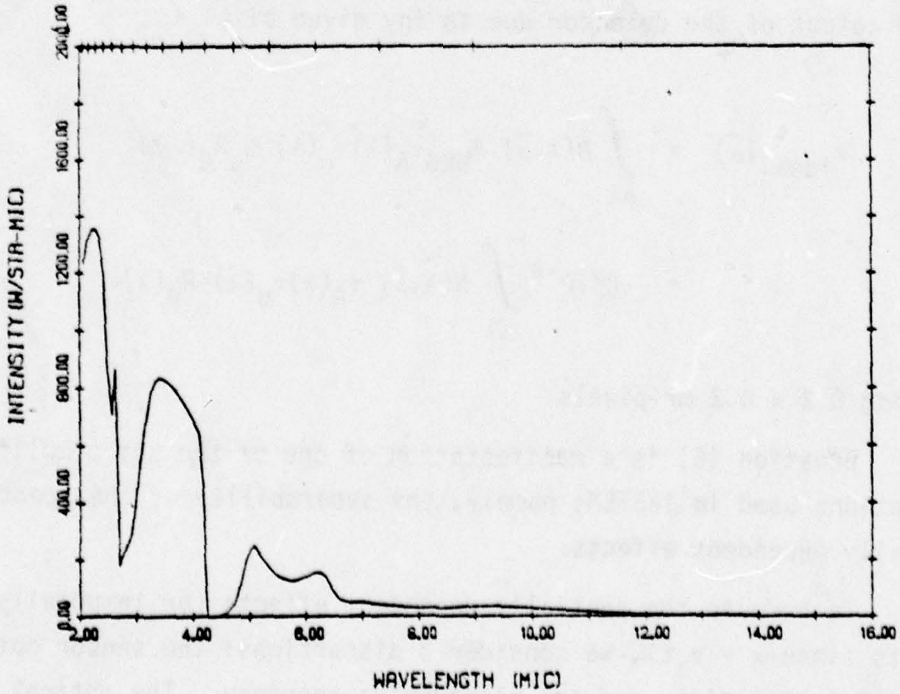


Figure 17. Typical Exhaust Nozzle Signature.

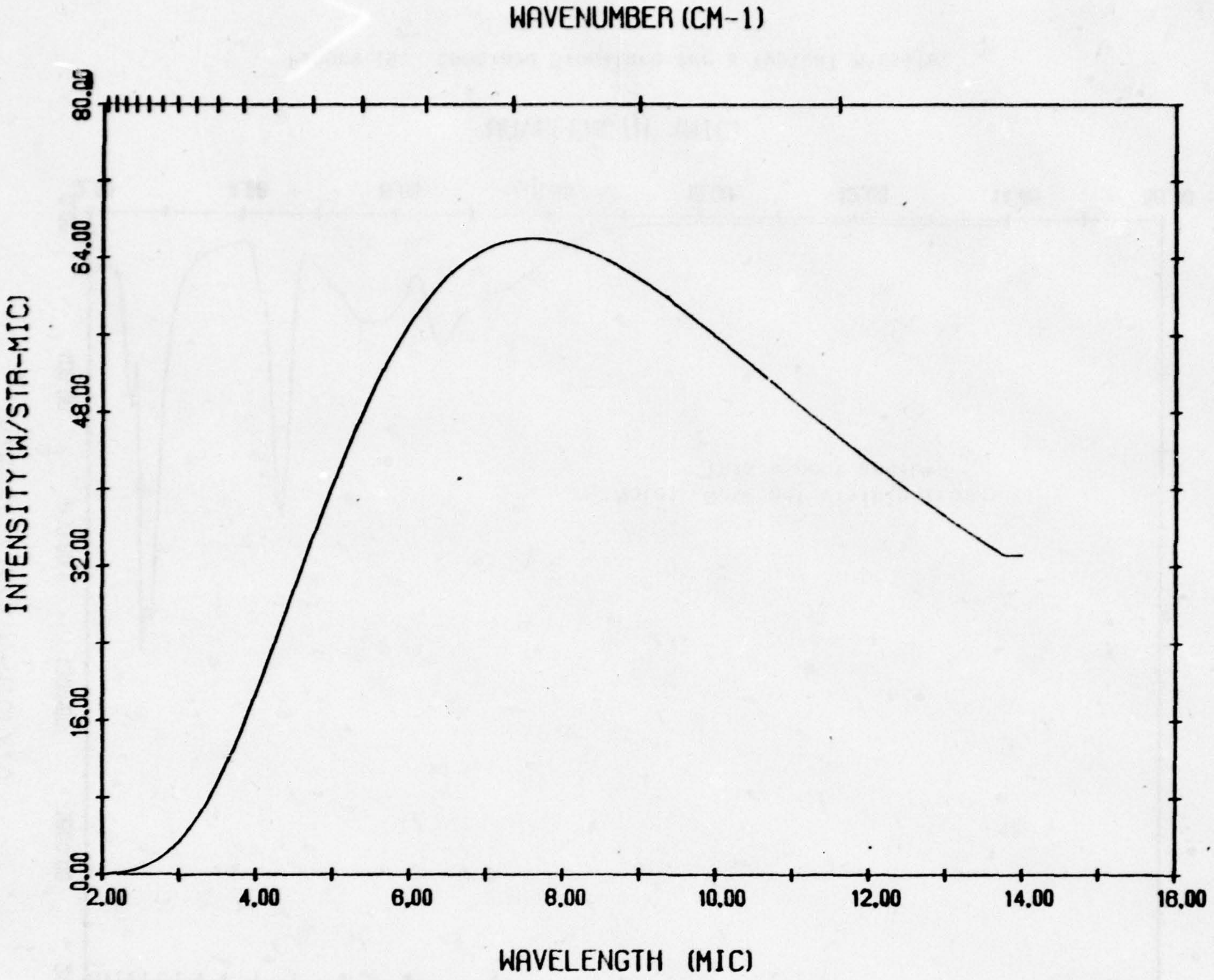


Figure 18. Typical Skin Signature.

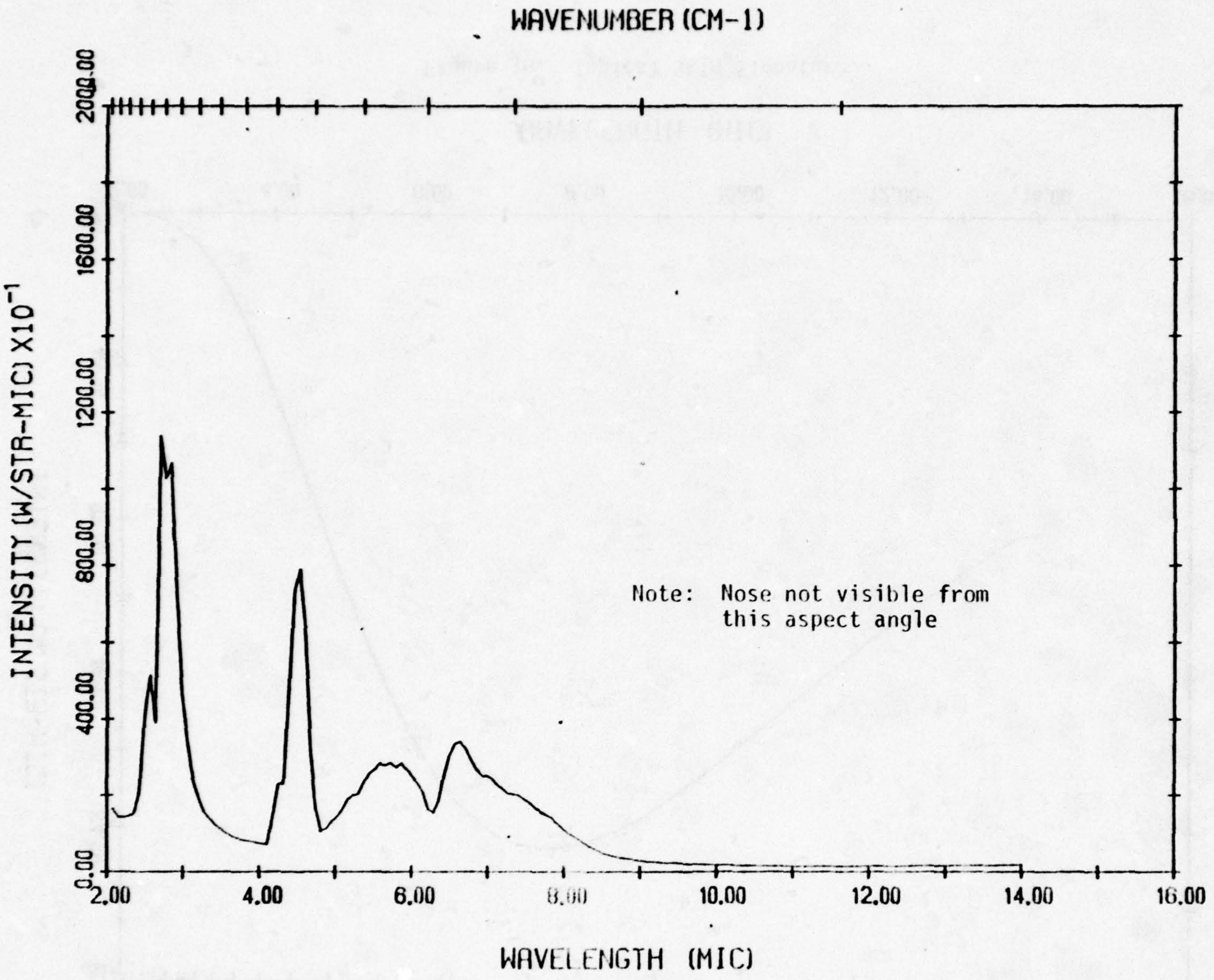


Figure 19. Combined Signature for a Typical Missile.

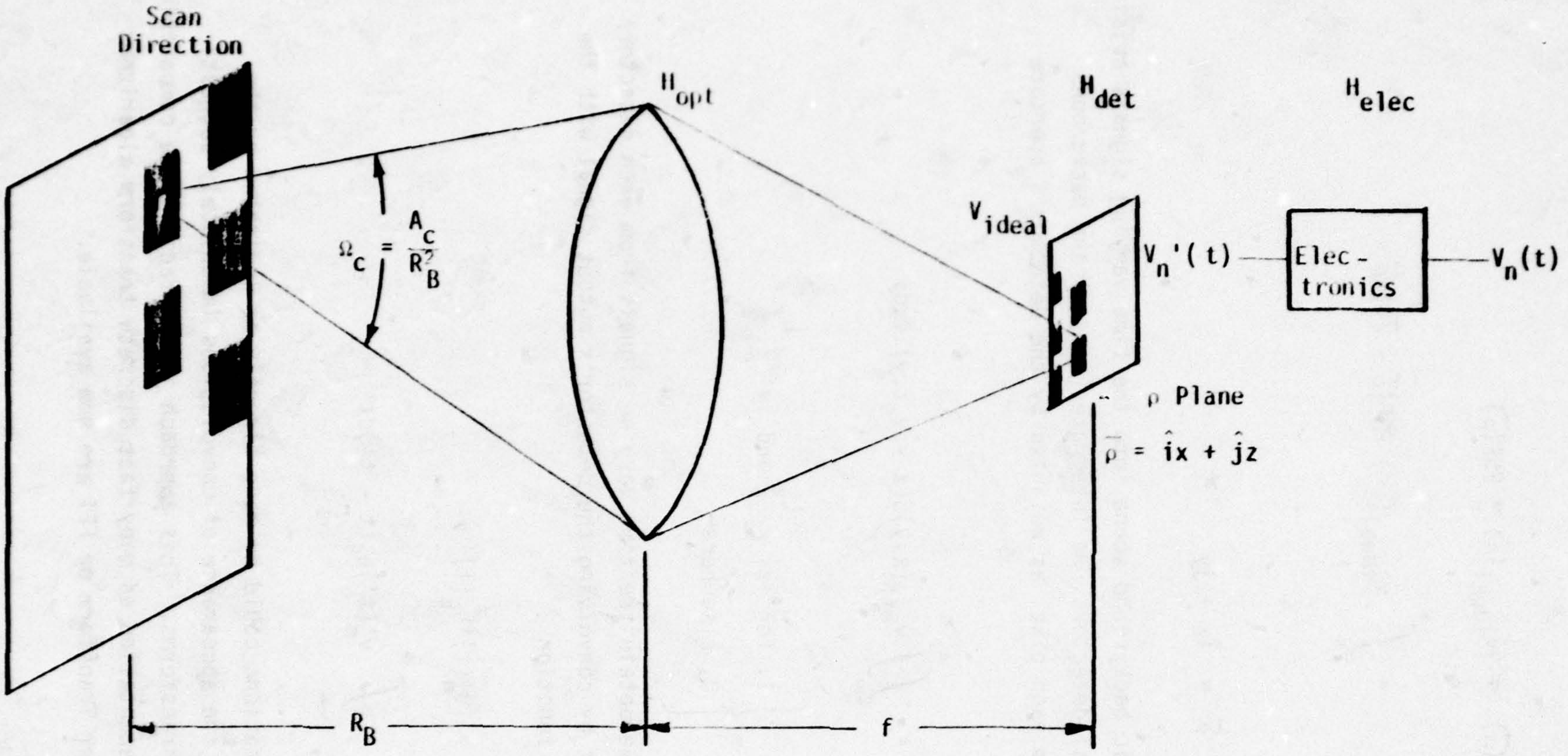


Figure 20. Projection of Array on Background.

$$v_{eff}(\bar{\rho}) = v_{ideal}(\bar{\rho}) * PSF(\bar{\rho})$$

$$= \int_{-\infty}^{\infty} v_{ideal}(\bar{\rho}') \, PSF(\bar{\rho} - \bar{\rho}') d\bar{\rho}' \qquad (7)$$

where

$$\bar{\rho} = \hat{i}x + \hat{j}y$$

To convert the static background scene into the time varying signals arising from the n individual detectors, we integrate (or sum) the background signals arising from each pixel as weighted by the detector's aperture function.

$$v_n'(t) = \iint_{-\infty}^{\infty} v_{eff}(x,y) d(x - v_s t, y) \, dxdy \qquad (8)$$

where

$$d(x,y) = \begin{cases} 1, \text{ for } |x| \leq \frac{L_x}{2} \text{ and } |y| \leq \frac{L_y}{2} \\ 0, \text{ elsewhere} \end{cases}$$

Finally, we obtain the time varying signals from each detector/preamplifier circuit by convolving the detector's output signal with the electronic response function

$$v_n(t) = v_n'(t) * h_E(t)$$

$$= \int_{-\infty}^{\infty} v_n'(t') h_E(t - t') dt' \qquad (9)$$

The computations could be made directly as indicated by the equations; however, the appearance of convolutions immediately suggests the use of Fourier transforms. This approach is, in fact, quite compatible with a digital implementation as many fast discrete transform algorithms like the Fast Fourier Transform or FFT are now available.

Defining the one- and two-dimensional transform pairs as

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega) e^{i\omega t} d\omega$$

where

$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt$$

and

$$f(\overline{\rho}) = f(x,y) = \frac{1}{4\pi^2} \iint_{-\infty}^{\infty} F(k_x, k_y) e^{i(k_x x + k_y y)} dk_x dk_y$$

where

$$F(k_x,k_y) = \iint_{-\infty}^{\infty} f(x,y) e^{-i(k_x x + k_y y)} d_x d_y \ ,$$

we can rewrite equations 7, 8 and 9.

$$V_{eff}(\vec{k}) = V_{ideal}(\vec{k}) H_{opt}(\vec{k}) \qquad (10)$$

Since, $v_n'(t) = \iint_{-\infty}^{\infty} V_{eff}(k_x,k_y) H_{det}(k_x,k_y) e^{ik_x v_s t} dk_x dk_y$,

$$V_n'(\omega) = \iint_{-\infty}^{\infty} V_{eff}(\vec{k}) H_{det}(\vec{k}) \left[\int_{-\infty}^{\infty} e^{i(k_x v_s t - \omega t)} dt \right] dk_x dk_y$$

$$= \iint_{-\infty}^{\infty} V_{eff}(\vec{k}) H_{det}(\vec{k}) \delta(v_s k_x - \omega) dk_x dk_y$$

$$= \frac{1}{v_s} \int_{\infty}^{\infty} V_{eff}(\frac{\omega}{v_s}, k_y) H_{det}(\frac{\omega}{v_s}, k_y) dk_y \quad (11)$$

and

$$V_n(\omega) = H_E(\omega) V'_n(\omega) \quad (12)$$

Therefore we can combine equations 10, 11, and 12 and compute $v_n(t)$ as

$$v_n(t) = \frac{1}{2\pi} \iint_{-\infty}^{\infty} V_{ideal}(k_x, k_y) H_{opt}(k_x, k_y) H_{det}(k_x, k_y) H_{elec}(v_s k_x) \cdot e^{ik_x v_s t} dk_x dk_y$$

In other words, the transformed ideal voltage array is modified by the appropriate transform for the optics, detectors and electronics to create a new array which is inverse transformed to generate the resultant time-dependent signal response from each detector.

2.6.2 Sensor Transforms.

The transfer functions which are currently built into IRSTEM are summarized as follows:

Optics - Circular Clear Aperture

$$H_{opt}(k) = \frac{2}{\pi} [\cos^{-1} A - A\sqrt{1-A^2}]$$

where

$A = \frac{\lambda F \bar{k}}{2\pi D}$

F = Focal length

D = Aperture diameter

Note also that $k_x = 2\pi/X$, X = 0 to X_{max} where X_{max} is the linear extent of the background image in the focal plane.

Detectors - Rectangular

$$H_{Det}(k) = A_d \left(\text{sinc}\ \frac{k_x L_x}{2}\right) \left(\text{sinc}\ \frac{k_y L_y}{2}\right)$$

where

H_{Det} = Detector response

A_d = Detector area = $L_x L_y$

$\overline{k}$ = Spatial frequency vector, $\hat{i}k_x + \hat{j}k_y$

$\text{sinc}(x) = \sin(x)/x$

Electronics - Low-Pass Filter

$$H_{Elec}(k_x v_s) = \frac{1}{\sqrt{1 + \left(\frac{k_x v_s}{2\pi f_0}\right)^2}}$$

where

v_s = Image scan rate across the detectors = $\frac{2\pi F}{T_s}$

f_0 = Filter cutoff frequency

F = Focal length

T_s = Scan time

Even though these transforms are currently hardwired into IRSTEM, the user can replace them with alternative expressions. With some slight code modification, the user can even specify the physical characteristics of the hardware (e.g. aperture shape, obscurations, and distortions) and then use the Fast-Fourier Transform to compute the frequency response function when an analytical expression is not readily available.

2.6.3 Other Sensor Considerations

Selecting Appropriate Detector Response

The image array which results from the inverse transform operation discussed above is based on the full number of pixels in the background scene. Since the instantaneous field-of-view (IFOV) of the detectors are generally larger than 0.2 x 0.2 mr pixels, the rows corresponding to the center of the detector are selected to represent the output signals and the rest of the array is discarded. The determination of which rows correspond to detector centers proceed as shown in Figure 21. The number of detectors falling fully within the vertical scene dimension is computed using the detector length and degree of overlap with the next detector.

$$N = \frac{Y - L_y}{L_y - OVL} + 1$$

The detector centers are at

$$y_i = \frac{L_y}{2} + (i-1)(L_y - OVL)$$

or pixel numbers

$$II = y_i/(2 \times 10^{-4} F) + 1$$

since the top edge of the first detector always coincides with the top edge of the scene. In the example shown in Figure 21, all dimensions are normalized to the pixel size as follows.

$$Y = 18.5 \qquad OVL = 1$$

$$L_y = 5$$

which implies N = 4 with detector centers at 3, 7, 11 and 15.

System Noise.

Random system noise (e.g. thermal, shot, or 1/f noise) is modelled in IRSTEM by modifying the image file voltages by a random number, $\overline{v}_n$,

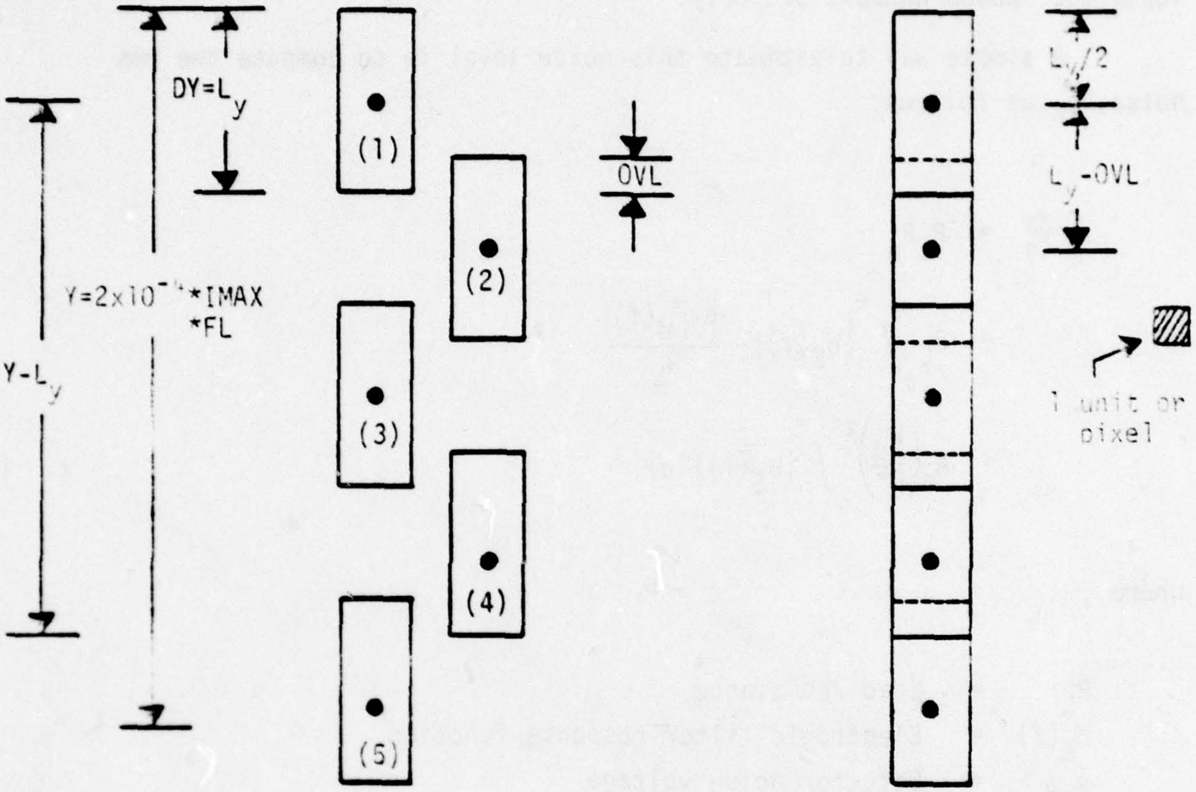


Figure 21. Determination of Detector Centers.

which is uncorrelated from cell to cell (see Figure 22). A random number sequence of 299 numbers with zero mean and unity standard deviation is built into the code. The user must input the rms noise level (or standard deviation since we are assuming Gaussian statistics) to allow the program to scale the random numbers properly.

A simple way to estimate this noise level is to compute the rms noise, $\overline{v}_n$ as follows:

$$\overline{v_n^2} = R_L P_n$$

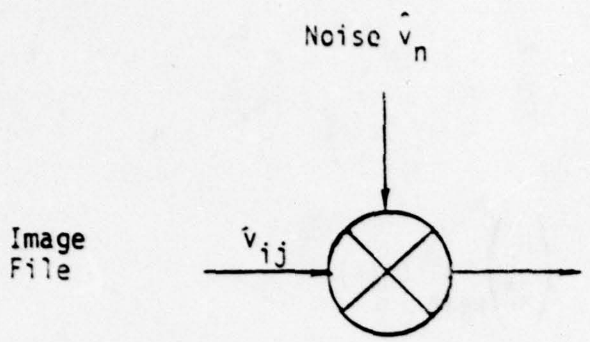
$$= R_L \int_0^\infty |H_E(f)|^2 \frac{dv_{nd}^2(f)}{R_L}$$

$$= A_d \left(\frac{R_d}{D^*}\right)^2 \int_0^\infty |H_E(f)|^2 df \qquad (13)$$

where

R_L = Load resistance
$H_E(f)$ = Electronic filter response function
v_{nd} = Detector noise voltage
= $\frac{R_d}{D^*} \sqrt{A_d \Delta f}$
R_d = Responsivity
D^* = Detectivity
A_d = Detector area

Note that the system noise is simply the detector noise modified by the filter response function. This response function must be integrated over the frequency interval of interest to properly account for the additional noise input due to the filter's limited bandpass since the filter response function already has been convolved with the object file, the optical point-spread function, and the detector response. If we have an ideal low-



$$v'_{ij} = v_{ij} + \hat{v}_n$$

$$\hat{v}_n = RN * \overline{v}_n$$

RN → Random Number

Figure 22. Random Noise Input to IRSTEM

pass filter with cutoff f_0 , the integral in equation (13) is simply f_0; if the response function is $1/(1+f/f_0)$, the result is $\pi f_0/2$. This implies the rms noise input can be given by

$$\overline{v}_n = K\left(\frac{R_d}{D^*}\right)_{peak} \sqrt{A_d f_0}$$

where K = 1 for an ideal low-pass filter
= $\sqrt{\pi/2}$ for a more realistic low-pass filter

The peak values for R_d and D* are shown because they are readily available from the detector manufacturers. These values are also required inputs along with $D^*(\lambda)$ to compute the spectral responsivity. That is, the code computes

$$R_d(\lambda) = \left(\frac{R_d}{D^*}\right)_{peak} D^*(\lambda)$$

We do not require $R_d(\lambda)$ to be user specified since this information is not as readily available as $R_{d\,peak}$, D^*_{peak}, and $D^*(\lambda)$.

2.7 Summary of Equations

The basic equations used in IRSTEM are summarized below in approximate order of appearance. The list of symbols at the front of this report defines each parameter.

Responsivity

$$R_d(\lambda) = \left(\frac{R_d}{D^*}\right)_{peak} D^*(\lambda)$$

Passband in Wavenumbers

$$\nu_L = 5\left\{\frac{10^4}{5\lambda_u}\right\} , \quad \left\{\;\right\} \text{implies integer value}$$

$$\nu_u = 5\left\{\frac{10^4}{5\lambda_L}\right\} + 1$$

$$\Delta\nu = 5\left\{\frac{10^4 \Delta\lambda}{5\lambda^2_L}\right\}$$

Blackbody Function

$$W(\lambda) = \frac{c_1}{\lambda^5 \left(\exp(c_2/\lambda T) - 1\right)}$$

Static Background

$$V_{ideal} = \pi D^2 10^{-8} \left[10\int_{\Delta\lambda} N_A \tau_o R_d d\lambda + \frac{\rho_D 10^4}{\pi} \int_{\Delta\lambda} H_s \tau_A \tau_o R_d d\lambda \right.$$

$$\left. + \frac{10^4 \varepsilon_B}{\pi} \int_{\Delta\lambda} W \tau_A \tau_o R_d d\lambda \right]$$

Cloud/Sky Background

$$V_{ideal} = \pi D^2 10^{-8} \left[10\int N_A \tau_o R_d d\lambda + 10\int N_c \tau_o \tau_A R_d d\lambda \right]$$

Sunglints

$$V_{ideal} = V_{ideal\ (before\ glint)} + V_G$$

$$V = \frac{RN\pi D^2 \rho_g K 10^4}{4} \int H_S \tau_A \tau_o R_d d\lambda$$

where

$$K = \frac{2500}{0.25 + 8.7 \times 10^{-5} R_G^2}$$

Target Cell

$$V_{ideal} = V_{ideal}\ (\text{before target}) \left(1 - \frac{A_T 10^8}{4R^2}\right)$$

$$+ \ \pi D^2 10^{-8} \left[10^4 \int J_T \tau_A \tau_o R_d d\lambda + 10 \int N_A \tau_o R_d d\lambda\right]$$

where

$$J_T = J_T(\lambda, 20^\circ) f_p(\xi) + N^*(T_E, \lambda) \tau_p(\lambda, 160^\circ) A_E(\xi)$$

$$+ \ \varepsilon_N A_N(\xi) N^*(T_N, \lambda) + \varepsilon_S A_S(\xi) N^*(T_S, \lambda)$$

Optical Transfer Function

$$H_{Opt}(\vec{k}) = \frac{2}{\pi} \left[\cos^{-1} A - A\sqrt{1 - A^2}\right]$$

where $A = \frac{\lambda F \vec{k}}{2\pi D}$

Detector Transfer Function

$$H_{Det}(\vec{k}) = A_d \left(\text{sinc}\ \frac{k_x L_x}{2}\right) \left(\text{sinc}\ \frac{k_y L_y}{2}\right)$$

Electronics Transfer Function

$$H_{Elec}(k_x v_s) = \frac{1}{\sqrt{1 + \left(\frac{k_x v_s}{2\pi f_o}\right)^2}}$$

Interpolation

$$Y_{new} = Y_{j-1} + \left(\frac{\lambda_{new} - \lambda_{j-1}}{\lambda_j - \lambda_{j-1}}\right)\left(Y_j - Y_{j-1}\right)$$

Target Cell Location

$$II = 5000(\theta_{TS} - \theta_E + I_{max}/10^4) + 1$$

$$JJ = 5000(\phi_{TS} - 1.5707 + J_{max}/10^4) + 1$$

Sun Location

$$\theta_{ALT} = \sin^{-1}\left[\sin(Lat)\sin(Dec) + \cos(Lat)\cos(Dec)\cos(Lha)\right]$$

$$\phi_S = \cos^{-1}\left\{\left[\sin(Dec) - \sin\theta_{ALT}\sin(Lat)\right] / \left[\cos\theta_{ALT}\cos(Lat)\right]\right\}$$

Cloud Coordinate Transformation

$$\theta_0 = \cos^{-1}[\sin\theta_n \sin\theta_s \cos(\phi_n - \phi_s) + \cos\theta_n \cos\theta_s]$$

$$\theta = \cos^{-1}[\sin\theta_n \sin\theta_L \cos(\phi_n - \phi_L) + \cos\theta_n \cos\theta_L]$$

$$\phi = 180^{\circ} - \cos^{-1}\left[\frac{\cos\theta_d - \cos\theta\,\cos\theta_0}{\sin\theta\,\sin\theta_0}\right]$$

where

$$\theta_d = \cos^{-1}[\sin\theta_L\,\sin\theta_S\,\cos(\phi_L - \phi_S) + \cos\theta_L\,\cos\theta_S]$$

Section 3
PROGRAM SUMMARY

In this section the IRSTEM code is reviewed to identify its major elements and the methodology for combining these elements. The subroutines are listed along with a functional description and the inputs and the outputs associated with each subroutine. Specific instructions for operating the code are discussed in Section 4.

3.1 Overall Program Flow.

The top level flow diagram for IRSTEM is shown in Figure 23. The program begins by reading the background codes associated with each pixel. Then the code keys are read to specify the temperature emissivity, reflectivity and range associated with each unique background code. Since these codes may not be numbered consecutively, the codes are reordered to make them sequential reserving codes 1 through 6 for sky and cloud data.

After the background information has been fixed, the scene is scanned to identify duplicate ranges to minimize calls to LOWEM later in the program. Also at this time, the minimum and the maximum ranges for the entire background scene are identified although they are not used in this version of IRSTEM. Anticipated modifications to minimize the computational time probably will use this minimum/maximum range.

Since LOWTRAN (i.e. Subroutine LOWEM) requires regular wavenumber spacings ($\Delta\nu$ or CV) that are multiples of 5 cm^{-1}, the integrations to form the V_{ideal} arrays must be done in terms of λ spacings which correspond to equal ν intervals. These spacings are fixed in the early part of the program as follows:

$$(1) \quad \Delta\nu = \left\{ \frac{10^4}{5\lambda_L^2} \Delta\lambda \right\} 5$$

$$(2) \quad \nu_L = \left\{ \frac{10^4}{5\lambda_u} \right\}$$

$$(3) \quad \nu_u . = \left\{ \frac{10^4}{5\lambda_L} + 1 \right\} 5$$

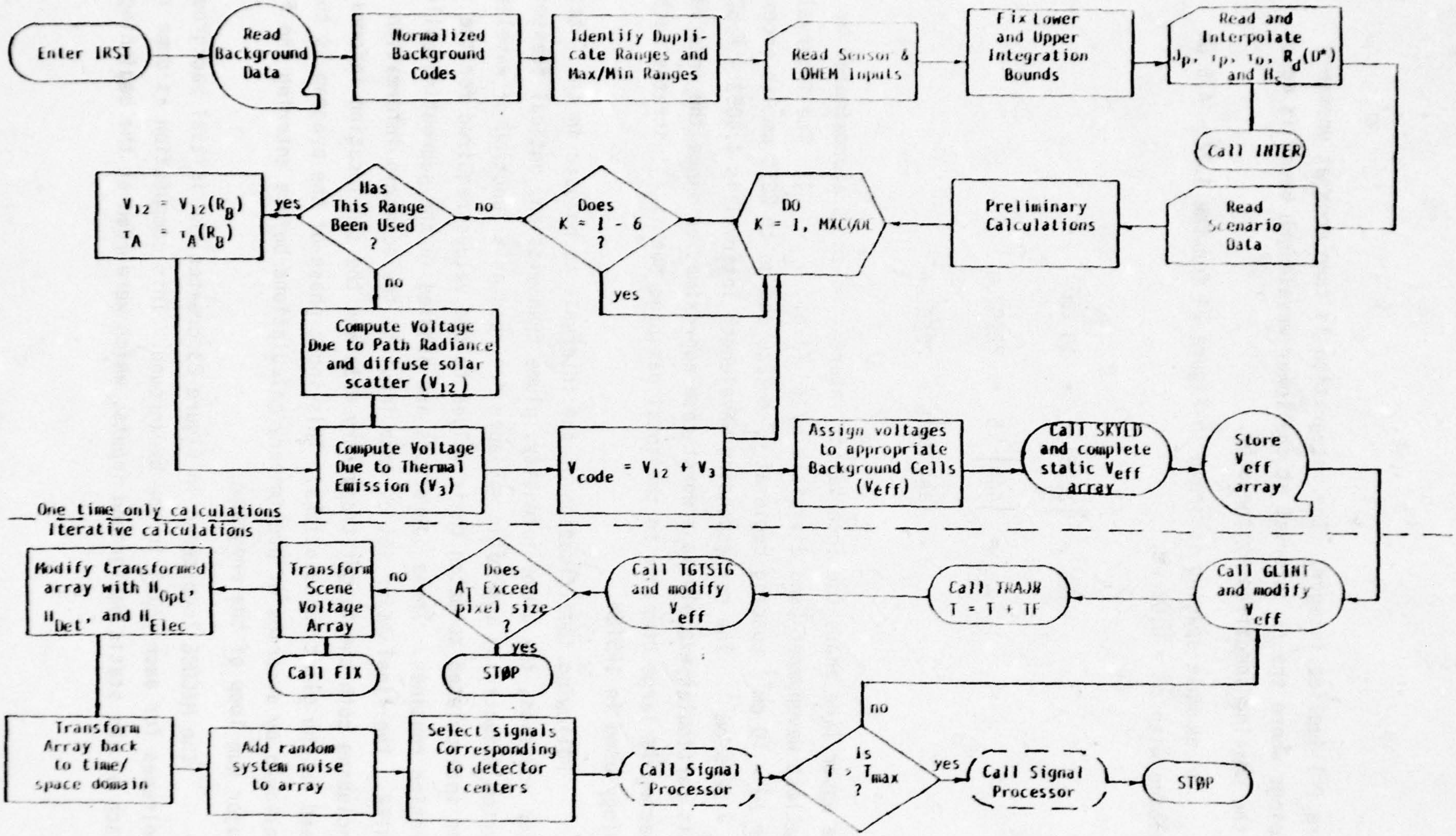


Figure 23. IRSTEM Flow Chart.

where { } implies integer. The integration is then done at uneven λ spacings where the $\Delta\lambda$ interval at the lower wavelength bound is equal to the spacing specified by the user.

An example spacing is shown in Figure 24 for the 4.42 - 4.5 μm passband with $\Delta\lambda = 0.02$ μm.

$$\Delta\nu = \left|2.05\right| 5 = 10 \text{ cm}^{-1}$$

$$\nu_L = \left|444\right| 5 = 2220 \text{ cm}^{-1}$$

$$\nu_u = \left|453.49\right| 5 = 2265 \text{ cm}^{-1}$$

The upper line shows the interval of interest which is approximated by the smallest wavenumber band divisible by $\Delta\nu$ (i.e., $\nu_L - \nu_u$). The intervals for $\Delta\nu = 10$ cm^{-1} spacing begin at $\nu_L \approx 2220$ and go to 2270 cm^{-1} to encompass $\nu_u = 2265$ cm^{-1}. The corresponding wavelength interval is 4.4053 - 4.505 μm. This particular example is a worst case approximation since the interval spacing is large compared to the total passband but it illustrates methodology used in IRSTEM.

Following specification of the intervals to be used in the integration routines, the plume intensity, plume transmission, optical transmission system detectivity and solar radiance are read as a function of wavelength and interpolated to match their values to the values required for the integration routines. These operations are handled in the subroutine called INTER. The final major set of data input is the scenario information including both the target trajectory data and the sun location information used in the glint calculations. This input phase of the program is then followed by a series of preliminary calculations before entering the first major due loop of the program.

The MXCODE loop shown in Figure 23 creates the initial background voltages for each pixel in the background. This computation is done for each of the static background inputs, which were read at the beginning

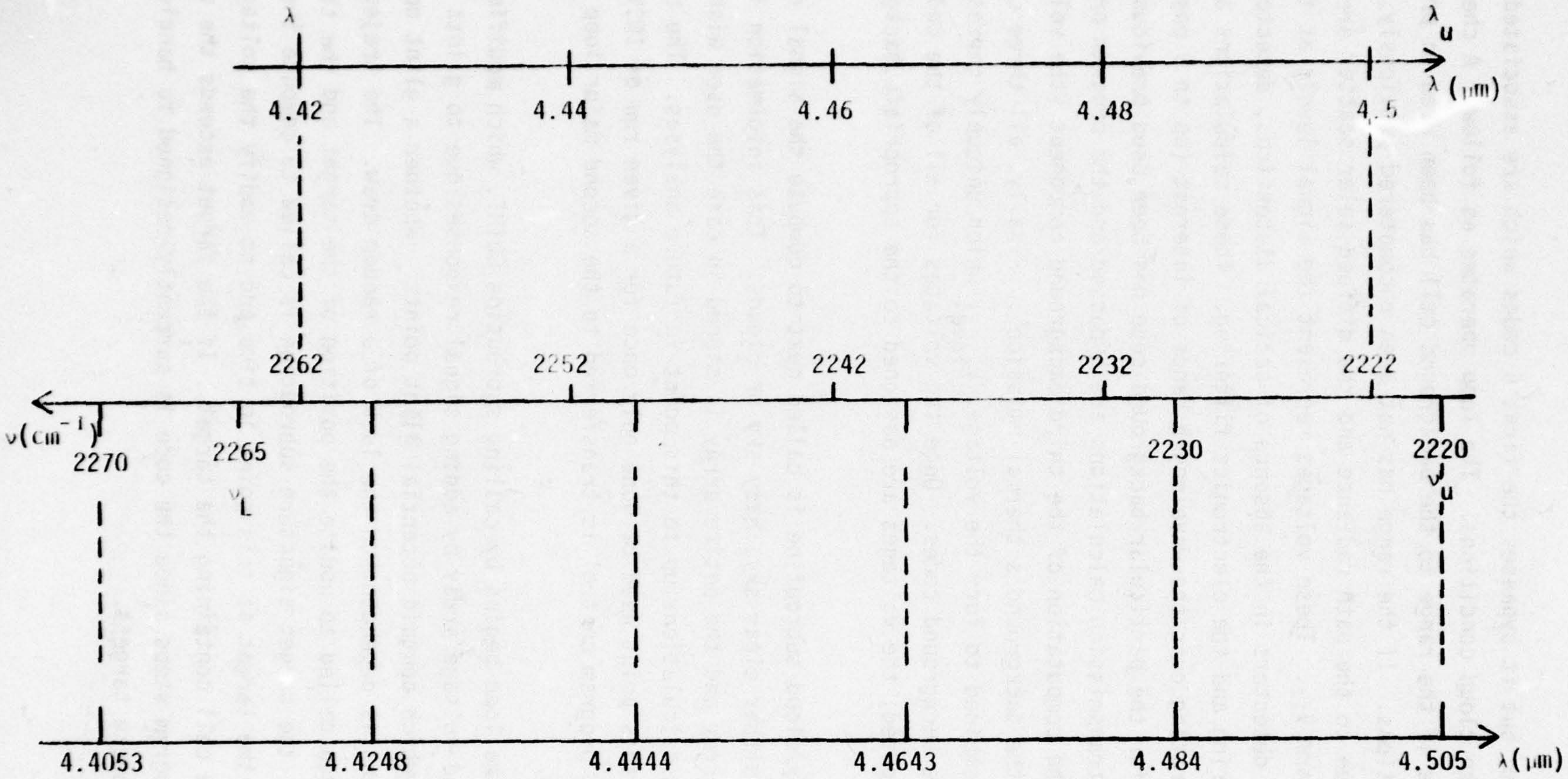


Figure 24. Example Interval Specification.

of the program, but it bypasses the first 6 codes which are associated with the sky and the cloud conditions. The loop operates as follows: A check is made to see if the range to the background cell has been used in previous calculations. If the range has not been encountered previously, the voltage due to the path radiance and the diffuse solar scatter are combined to form V_{12}. These voltages represent the signal levels at the output of the detectors in the absence of optical distortions, detector spatial filtering and the electronics filtering. These calculations are made by integrating over the wavelength bands of interest (up to 3 passbands) If the range for the particular background code has been used previously, the V_{12} and path transmission calculations are bypassed and the program proceeds directly to the computation of the third background component (the voltage array due to the background's thermal emission). Finally, all three components are combined to form the voltage, V_{ideal} which uniquely corresponds to each of the background codes. Once the voltages for all of the codes have been computed, the voltages are assigned to the appropriate background cells (V_{eff}).

The sky/cloud subroutine is called next to compute the signal responses arising from either clear sky, hazy sky or clouds. This information is added to the V_{eff} array and the entire array is stored in case the user wishes to bypass the calculations up to this point in future analyses. The calculations to this point need be done only once for a given run of IRSTEM. At this point program control is transferred to the second major loop - the time loop.

The time loop begins by calling subroutine GLINT, which modifies the background voltage array by adding signal responses due to glints to the cells which contain potential glint points. Whether a glint occurs on a given scan is dependent on the luck of a random draw. The trajectory routine is then called to update the position of the target and the time clock. Next, the target signature subroutine is called to compute the signature of the target at this point in time and to modify the voltage array for the cell containing the target. If the target exceeds the pixel size, the program stops since the code is currently designed to handle only point-source targets.

Now the scene array is ready for transformation to the frequency domain so that the array can be modified by the sensor induced distortions. This transformation is accomplished by calling subroutine FIX which controls the calls to the fast-Fourier transform subroutine (FOURT). Once the transformation is complete, the transformed array is modified by the optical transmission function, the detector transmission function and the electronics transmission function to create a new array which is transformed back to the time/space domain. Next, random noise is then added to each of the scene cells based on the normalized rms noise input specified by the user and the result of a random number draw. Finally, those rows corresponding to the sensor specified by the detector geometry are selected for manipulation by the signal processing routine. The rest of the information is dropped from the file.

At this point, the signal processing subroutine could be called by the user to analyze the performance of the search set. As noted earlier, this routine is not included at this time because of its unique relationship to each specific hardware design. The data presently is stored on a file in anticipation that a signal processing routine will be called after the time loop is completed; perhaps the signal processor will even be written as a separate program. It is anticipated that the signal processing routine will analyze the raw video signals generated by IRSTEM to determine at what point the target can be detected based on the discrimination techniques employed.

3.2 Subroutines and Functions

The subroutines and functions called by the main program are listed alphabetically in Table 2. Most of these routines are discussed further in the paragraphs below. Some of the more simple routines (e.g., DUMR and INTEG) are not reviewed; the LOWEM subroutines (HNO3, POINT and ANGL) are also not reviewed since they are described in reference 4. Summary tables, for each subroutine except those associated with LOWEM, are provided at the end of this subsection to delineate input/output variables.

Table 2.

IRSTEM Subroutines and Functions

Subroutine	Purpose
ANGL	LOWEM subroutine to compute zenith angle.
DUMR	Dummy read routine.
FIND	Selects data sets for sky/cloud radiance interpolations.
FIX	Calls Fast Fourier Transform and reorders the result of the transformation.
FOURT	Fast Fourier Transform.
GETANG	Calculates sun and observer angles with respect to the cloud normal.
GLINT	Calculates signal response due to solar glints.
HNO3	LOWEM Subroutine for HNO_3 extinction coefficients.
INTEG	Integration routine (trapezoidal rule).
INTER	Reads J_p, τ_p, τ_o, R_d and H_s as a function of λ and interpolates values needed for integration. Also interpolates cloud radiance.
LOWEM	Path transmission and radiance model (LOWTRAN IV).
POINT	LOWEM subroutine to interpolate absorber concentrations as a function of altitude.
SCALR	Scales array for printing.
SKYCLD	Calculates voltage response for sky and cloud background elements.

Table 2. (Continued)

Subroutine	Purpose
SUNLOC	Calculates sun location.
TGTSIG	Calculates target signature.
TRAJR	Calculates target position as a function of time.
Function	
BLKBDY	Computes the blackbody emittance for a specified wavelength and temperature.
INTERP	Interpolates plume signature angular dependence.
NODD	Generates +1 or -1 depending on whether the function is even or odd.

Subroutine FIND. The sky/cloud spectral radiance data is stored in 5 files (see discussion of Subroutine SKYCLD and the model methodology in Section 2.4) as a function of the solar and view angles. The angles for the reflected solar and haze situations are:

solar angle (θ_0)	:	0, 15, 30, 45, 60, 75, 85
relative azimuth angle (ϕ)	:	0, 45, 90, 135, 180
view angle (θ), or supplement view angle (θ')	:	0, 15, 30, 45, 60, 75, 85

If we designate each spectral radiance data file (λ = 2, 3, 4, 5, 6, 8 10 and 14 μm) with a 3 parameter code corresponding to (θ_0, ϕ, θ), the data set (1, 3, 2) implies $\theta_0 = 0^0$, $\phi = 90^0$ and $\theta = 15^0$. If $\theta_0 = 15^0$ and $\phi = 150^0$ and $\theta = 50^0$, the desired data would lie somewhere between the (1, 4, 4) and (1, 5, 5) curves. This subroutine calculates the ratios between the two bounding curves through three successive calls from SKYCLD.

The angles for files 2 and 3 (transmission through 0.1 and 0.5 km thick clouds respectively) are:

azimuth angle (ϕ)	:	0, 45, 90, 135, 180
view angle (θ')	:	0, 2, 4, 6, 8, 10

Here the solar angle (θ_0) is not explicitly used since the line-of-sight between the observer and the sun is the reference angle (see discussion of subroutine SKYCLD).

Subroutine FIX. This routine calls the fast Fourier transform and then reorders the transformed array. This re-ordering is necessary as the transform has been formulated for values on the interval (0, N-1) which yield 2 half periods back to back. It is necessary to move the origin to N/2 as shown in Figure 25 to ensure the peak of the transformed spectrum corresponds with the d.c. component of the transfer functions.

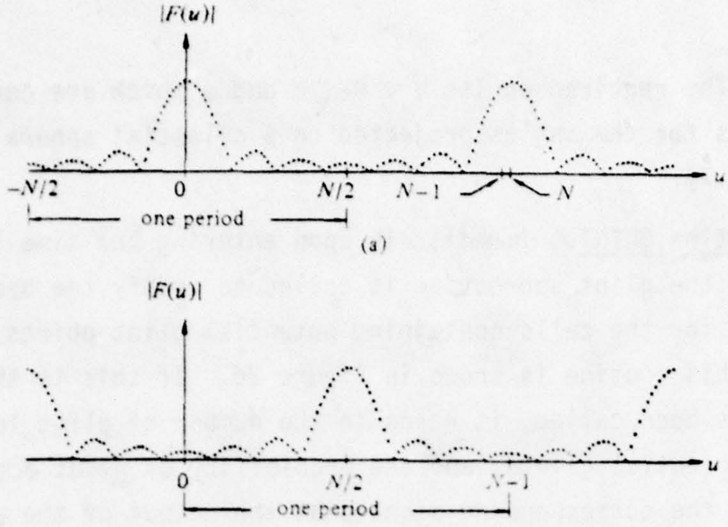


Figure 25. Shifting the Transformed Signal.

Subroutine FOURT. This subroutine performs the fast Fourier transform. The subroutine is being used with no modification. FOURT performs an n-dimensional fast Fourier transform on an n-dimensional array of complex data. The transform performed may be expressed as follows: TRANSFORM (J1, J2, ...) = SUM (DATA (I1, I2, ...)*W1**((I1-1)*(J1-1))*W2**((I2-1)*(J2-1))*...) where I1 and J1 run from 1 to the maximum of the first dimension, I2 and J2 run from 1 to the maximum of the second dimension. The basis of the routine was developed by Cooly and Tukey. The FORTRAN code being used was developed in 1965 at Sandia Corporation. The input data for the transform is assumed to be in the time domain and equally spaced at intervals of DT. The transformed values are considered to be in frequency space. The frequency intervals are equally spaced from 0 to 2 (N(I)-1)/(N(I)+DT) where N(I) is the dimension of the data (64) in each of the I dimensions (2). FOURT does not require the array to be a multiple of 2, but the computations are faster if this criteria is met. This routine was chosen because of its flexibility and computational speed. A two-dimensional transform of a 64 x 64 array requires less than one second on the CDC 6600.

Subroutine GETANG. Once the sun's location has been established, subroutine GETANG then converts this information along with the observer's position into the cloud reference frame before calling the solar scatter data table. The required angles are θ_0, θ and ϕ which are computed using the law of cosines for the angles projected on a celestial sphere (see Ref. 3 and Section 2.7).

Subroutine GLINT. Immediately upon entering the time loop in the main program, the glint subroutine is called to modify the background voltage array for the cells containing potential glint points. The flow diagram for this routine is shown in Figure 26. If this is the first time the subroutine has been called, it reads in the number of glint locations, the location of potential glints, and the probability of glint occurrence and then computes the corresponding signals at the output of the pre-amps due to each glint. If this is not the first time that the subroutine has been called, the signal levels computations are not repeated, and program control is transferred directly to the loop which calculates the random number for each glint point. If this random number exceeds the probability of glint occurrence the voltage for the cell under examination is modified by the precalculated glint voltage before program control is transferred back to the main program.

Subroutine INTER. This subroutine serves a dual purpose of reading the wavelength dependent data inputs and interpolating the data for the wavelength intervals required by the integration subroutine. IFLAG can take on values between 0 and 4 which in turn keys the routine to read the plume intensity, plume transmission, optical transmission, detectivity and solar irradiance inputs, respectively. Once this data has been read, the routine checks to see whether the specified wavelength interval for the passband of interest lies outside the minimum or maximum values specified by the inputs. If the wavelength of interest lies within the data bounds (as it should) YNEW is determined using a linear interpolation routine. IFLAG ≥ 5 allows for interpolation of the cloud/sky radiance tables. Figure 27 shows a logic flow for this subroutine.

Subroutine LOWEM. This subroutine is essentially LOWTRAN 3B with path emissions added. This program calculates the transmittance and irradiance of the atmosphere from 350 inverse centimeters to 40,000 inverse centimeters (0.25 to 28,5 microns) at 30 inverse centimeters spectral

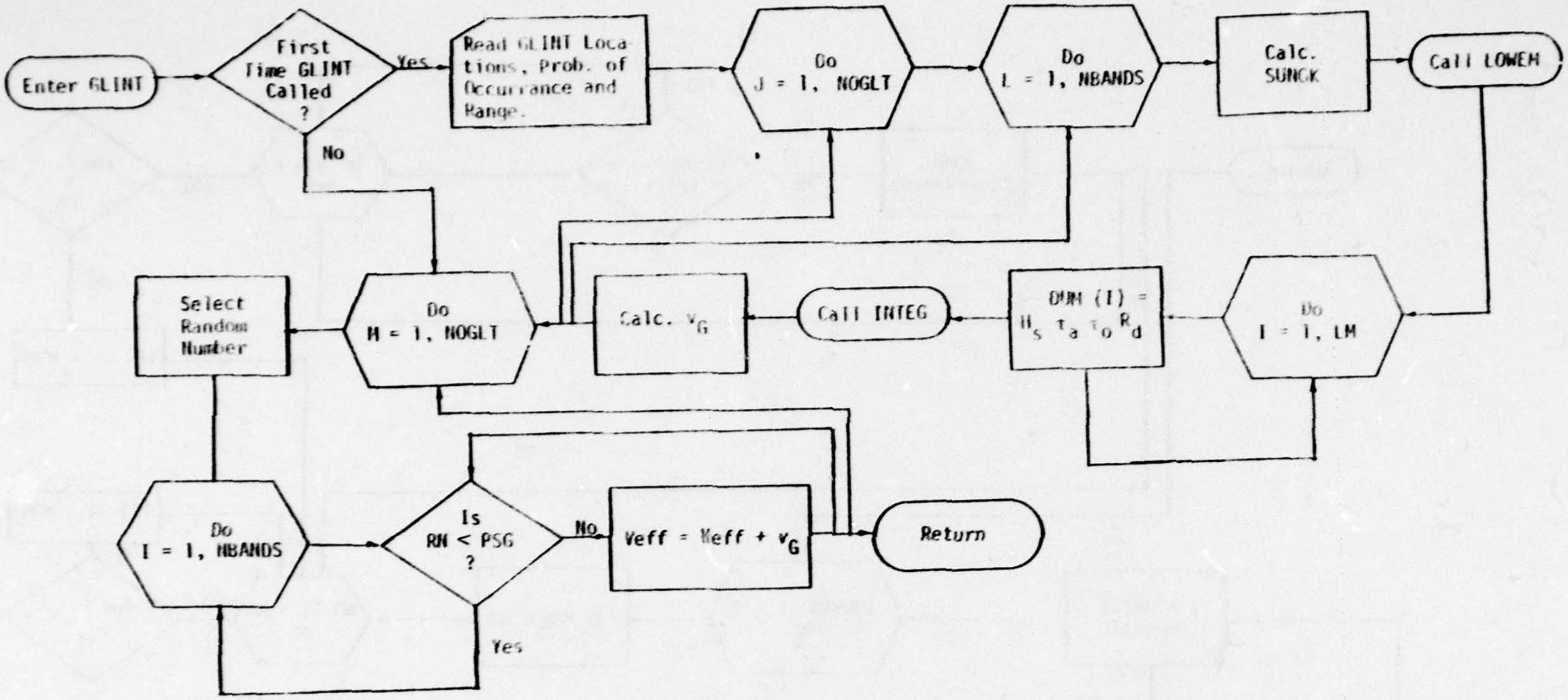


Figure 26. Flow Diagram for Subroutine GLINT.

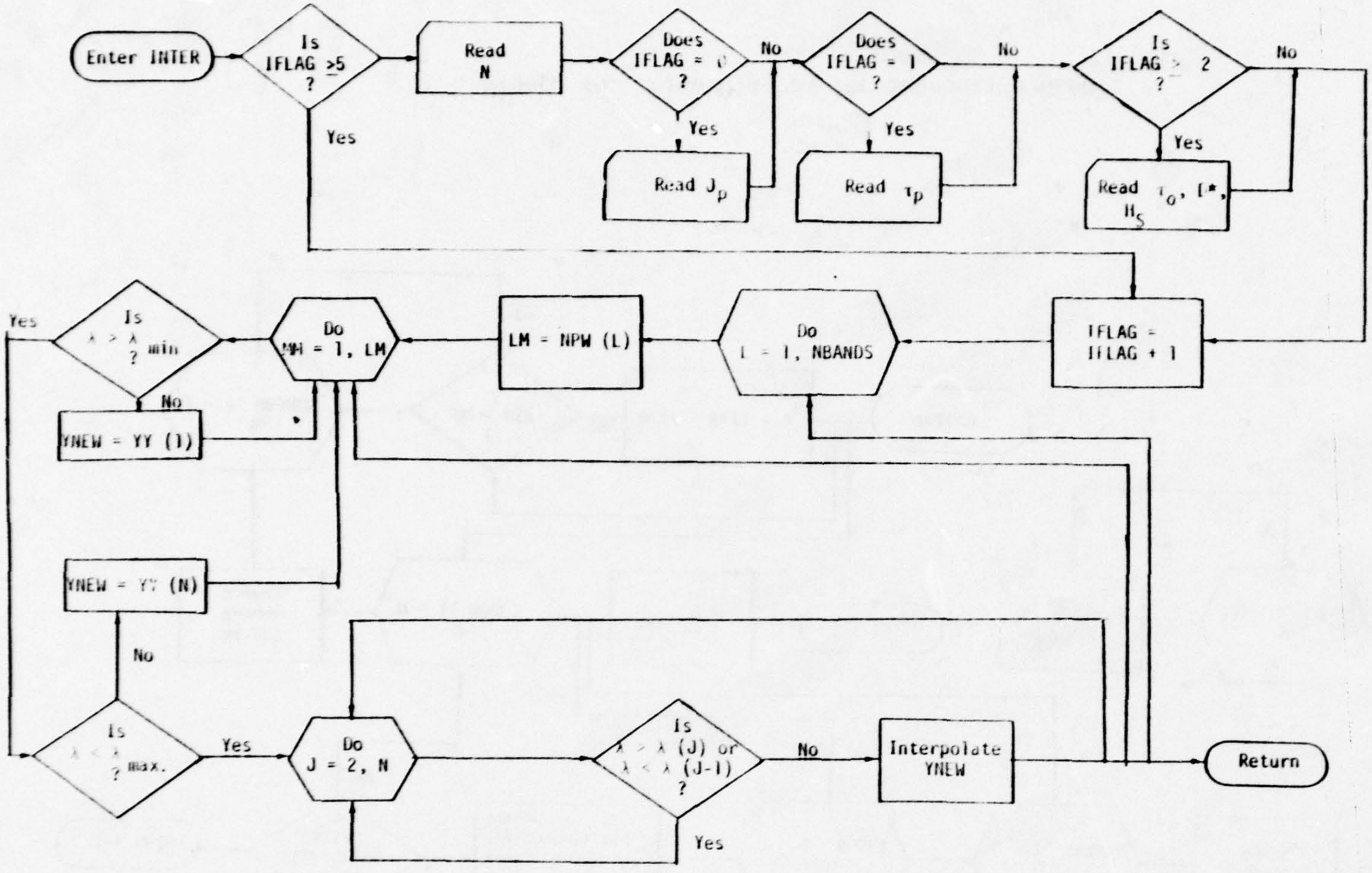


Figure 27. Flow Diagram for Subroutine INTER.

resolution on a linear wavenumber scale. Refraction and earth curvature effects are included. The atmosphere is layered in 1 kilometer intervals between 0 and 25 kilometers, 5 kilometer intervals to 50 kilometers, a 20 kilometer interval to 70 kilometers and a 30 kilometer interval to 100 kilometers. There are six model atmospheres available: tropical, mid-latitude summer, mid-latitude winter, sub-arctic summer, sub-arctic winter, and the 1962 U.S. Standard. The type of path is input using a code from 1 to 6 to select one of these atmospheres. It is also possible to input a new atmosphere such as radiosonde data in which case a seventh option would be indicated. Aerosol scattering can be computed and there is a haze model available.

There are three types of atmopsheric paths - vertical or slant paths to space, vertical or slant paths between two altitudes, and a constant pressure path. The output of this subroutine is the path radiance and atmospheric transmission. Subroutine LOWEM requires Subroutine POINT which calculates the mean refractive index above and below a given altitude and interpolates exponentially to determine the equivalent absorber amount at that altitude. Also required for LOWEM is Subroutine ANGL which calculates the initial zenith angle, taking into account refraction effects.

Subroutine SCALR. This subroutine adjusts the magnitude of the voltage array to facilitate the evaluation of the computer printout. The minimum and maximum signal levels are first found. If the data is complex, the amplitude is used for finding the minimum and maximum. The minimum is then used to scale the data. A multiple of 10 is calculated such that when the data is multiplied/divided by this factor, the minimum does not exceed 100. Using the factor based on the minimum, the voltages are displayed.

Since the minimum is used, it is conceivable that the maximum value will exceed two digits, and the signal level will be displayed with an asterisk (*). If this is the case, a new scale factor, based on the maximum, is used to scale the voltage array again. Glint points are ignored during these scaling calculations and are always displayed with asterisks.

Subroutine SKYCLD. Subroutine SKYCLD is one of the more complicated routines within IRSTEM. It is here that the signal response due to background sky and clouds are computed and substituted into the V_{eff} array (see Fig. 28). There are six types of sky conditions as indicated on Table 3. IC1 indicates a clear sky; this parameter keys the program to compute the path radiance only. IC2 and IC3 represent hazy conditions with 23 and 5 km visibility, respectively. These conditions vary from the clear sky computations in that solar scattering is added to path radiance. The last three types of sky conditions are clouds. The first two (100 m and 500 m clouds) represent the case when the observer is on the opposite side of the cloud from the sun and sees partial transmission as well as scattering and thermal radiation from the cloud. The last case (10 km cloud) models the back reflection from an optically thick cloud. Table 3 indicates the dimensions of the solar zenith angle (SZA) solar azimuth angle (AZA) and view angle (VA) which must be known to properly read the cloud radiance data that is on TAPE 8. The specific order of the data files is shown in the right hand column of Table 3.

The SKYCLD computations begin by calling the sun location subroutine to compute the azimuth and elevation angles of the sun. A series of angles are calculated next which are valid for all of the sky and cloud options except 10 km (reflective) cloud. It should be noted that the cloud normal is forced to coincide with the sun angle for all cases except the 10 km cloud to simplify the calculation of relative angles (see Figure 7). A series of flags are set before preceding into the signal response calculations to insure the proper sky and cloud radiance values are used. A detail flow diagram of the flag-setting algorithm is shown in Figure 29.

The initial step in setting the flags is to check to see if the clear sky conditions prevail; if so, the next few steps are bypassed and the calculations proceed as shown in Figure 28. Next a check is made to see if the 10 km thick cloud is specified; if so, the number of unique normals describing the cloud are read followed by the flags and data limits for TAPE 8. If neither IC1 nor IC6 are applicable, the subroutine DUMR is called to skip over the 10 km cloud file, and a check is made to see if the 100 m cloud is

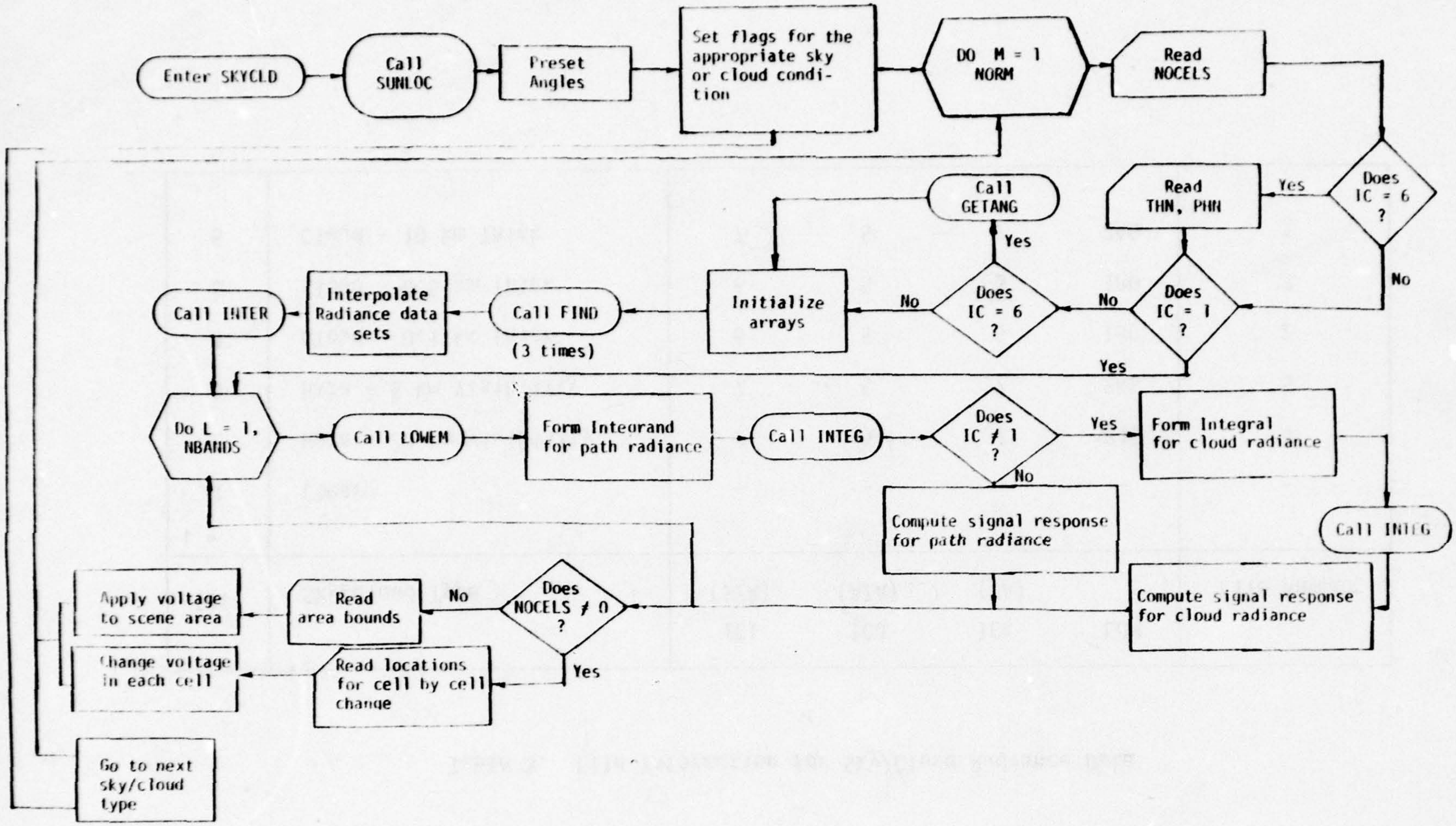


Figure 28. SKYCLD Flow Diagram.

Table 3. File Information for Sky/Cloud Radiance Data

ICi	Sky/Cloud Type	ICI (SZA)	ICJ (AZA)	ICK (VA)	LJM	File Number
i =						
1	Clear	-	-	-	-	-
2	Haze - 23 km Visibility	7	5	7	245	4
3	Haze - 5 km Visibility	7	5	7	245	5
4	Cloud - 0.1 km Thick	6	5	6	180	2
5	Cloud - 0.5 km Thick	6	5	6	180	3
6	Cloud - 10 km Thick	7	5	7	245	1

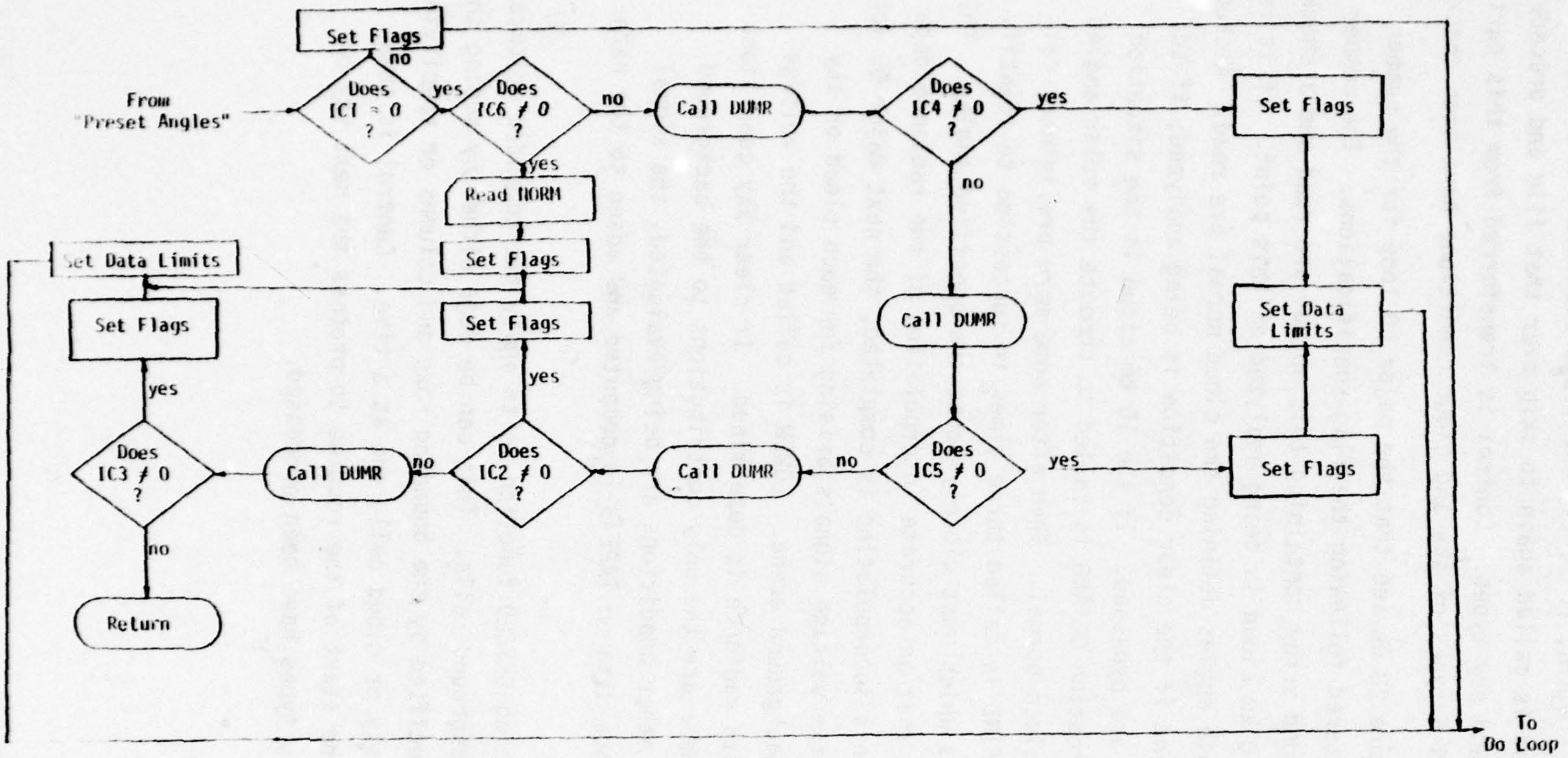


Figure 29. Flow Diagram for Setting Flags in SKYCLD.

now under consideration. Again, if it is, the flags and data limits are set; otherwise, the dummy read is called again to skip over that file and precede to the remaining cloud and sky types. Control is transferred from this part of the subroutine after all 6 types of sky and cloud conditions have been checked.

Returning to Figure 28 we see that the major DO loop for the number of unique normals is entered following the flag specifications. The number of cells of the background array containing this normal are read and a check is made to see if the 10 km cloud is being analyzed at this point. If it is, the elevation and azimuth angles defining the cloud normal are read. A check is then made to determine if the clear condition is being analyzed; if so, the next several steps are bypassed. If the 10 km cloud is the situation under examination, Subroutine GETANG is called to compute the solar angles in terms of the local cloud normal. Then after some more preliminary calculations, Subroutine FIND is called three times in succession to identify the radiance data files which most closely bound the specified angles. This is necessary to insure that an accurate interpolation of the radiance data tape is made. After this interpolation is completed, the next major DO loop is entered to compute the voltage signals arising for each cloud or sky condition within the background scene. LOWEM is called and the voltage contribution due to path radiance is determined. If clear sky conditions are being analyzed, these are the only contributions to the background signal level. If any other conditions are being evaluated, the signal response to the radiance data on TAPE 8 is computed and added to the path radiance.

The only remaining SKYCLD function is to apply the computed voltages to the appropriate background cells. This can be done either by adding the signals to an area specified by the bounding rows and columns or specifying the location of each sky or cloud cell, one at a time. Control is then transferred back to the start of the routine to process the next sky or cloud type until all 6 types have been processed.

The sequence of READ statements within SKYCLD are summarized in Table 4. The first time through the subroutine, checks are made for clear sky. If present, the number of cells which are clear and the minimum and maximum boundaries or the individual cell locations are read. On the next pass through the subroutine, a check is made to see if the 10 km cloud is present. If it is present, the number of cells with those normals, the defining angles for the cloud normal, and the cell locations are read. All of the rest of haze and thin cloud conditions are read in a manner similar to clear sky, in the sequence shown by the table.

Subroutine SUNLOC. The objective of SUNLOC is to calculate the altitude (vertical angle measured above the horizon) and true bearing (azimuth angle measured clockwise from true north) of the sun as a function of the geographical position of the observer (latitude and longitude), date (month, day), and time of day (Greenwich Mean Time). To develop a solution, one utilizes the celestial triangle as reviewed in references 1 and 3. The pertinent equations are specified in Section 2.7.

Subroutine TGTSIG. The target signature subroutine computes the total integrated intensity for each passband of interest and sums the projected areas of the overall missile. It begins by computing the projected areas of the tailpipe, nose and missile body. Then for each of the passbands, the tailpipe, missile nose, and missile body signatures are computed using the blackbody. The plume signature then is computed and all four terms are combined to give the overall radiant intensity. The equations used in this routine are summarized in Section 2.7.

Subroutine TRAJR. This subroutine locates the position of the target on the background with respect to an I, J index as well as the range from the sensor. Currently, this trajectory routine assumes that the target is a point source flying radially inbound with an aspect angle which does not change with time. Since these computations are in a separate subroutine, the trajectory information can be fed from an engagement simulator if desired.

Table 4. Read Sequence for SKYCLD*

NOCELS ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)	Clear Sky
NORM NOCELS THN, PHN ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)	10 km Cloud
NOCELS ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)	0.1 km cloud, 0.5 km cloud, 23 km haze and 5 km haze (in turn)

* Assuming all sky and cloud types are present in background scene

3.3 Subroutine Summary Tables

This subsection consists of tables summarizing the inputs and outputs of each subroutine. The first table (Table 5) is the cross-reference map of calls to each subroutine. Note that most of the calls come from either the main program, IRSTEM, or the SKYCLD subroutine. Tables 6 - 20 summarize the key parameters within each subroutine. Note that the column marked "location" identifies how the parameter is transferred to and from the subroutine. If a common block is used, its name appears in capital letters.

Table 5. Subroutine Call Reference Map

Calling Program/Routine	ANGL	DUMR	FIND	FIX	FOURT	GETANG	GLINT	HNO3	INTEG	INTER	LOWEM	NODD	POINT	SCALR	SKYCLD	SUNLOC	TGTSIG	TRAJR	BLKBDY	INTERP
IRSTEM				X			X		X	X	X			X	X	X	X		X	
ANGL	—												X							
DUMR		—																		
FIND			—																	
FIX				—	X							X								
FOURT					—															
GETANG						—														
GLINT							—		X		X									
HNO3								—												
INTEG									—											
INTER										—										
LOWEM	X							X			—		X							
NODD												—								
POINT													—							
SCALR														—						
SKYCLD		X	X			X			X	X	X				—	X				
SUNLOC																—				
TGTSIG																	—		X	X
TRAJR																		—		
BLXBDY																			—	
INTERP																				—

Table 6
Subroutine FIND Parameters

Input Parameter	Location	Description
THO	Call Statement	Desired θ_0, ϕ or θ on successive calls from SKYCLD (degrees).
ICI	Call Statement	Number of data entries.
SZA	Call Statement	Value of θ_0, ϕ or θ for which radiance data exists (degrees).

Output Parameter	Location	Description
J1	Call Statement	Data entry index for SZA immediately below THO.
J2	Call Statement	Data entry index for SZA immediately above THO.
D	Call Statement	Relative position of THO between SZA entries.

Table 7

Subroutine FIX Parameters

Input Parameter	Location	Description
ISIGN	Call Statement	ISIGN equals 1 for an inverse transform ISIGN equals -1 for a forward transform
NUMBER	Call Statement	NUMBER equals 1 for a complex data; 0 for real data
U	Call Statement	Data to be transformed

Output Parameter	Location	Description
U	Call Statement	Transformed data

Table 8

Subroutine FOURT Parameters

Input Parameter	Location	Description
DATA	Call Statement	Data to be transformed, corresponds to VARRY
NN	Call Statement	Dimension array describing the data dimensions, i.e., NN(1) = 64, NN(2) = 64, sets up a two-dimensional transform of 64 x 64 array
NDIM	Call Statement	The dimensionality of the transform, in this case, 2
ISIGN	Call Statement	Integer giving direction of transform to be done corresponds to ISIGN of Subroutine FIX
IFORM	Call Statement	Integer parameter describing the form of the data which corresponds to NUMBER of Subroutine FIX
WORK	Call Statement	Dummy variable or working array for the fast Fourier transform

Output Parameter	Location	Description
DATA	Formal Parameter	Transformed data is put back into the input data array

Table 9
Subrcutine GETANG

Input Parameter	Location	Description
ALT	ANG	Elevation angle of sun (rad).
PHL	GLT	True bearing of observer as seen from the cloud (rad).
PHN	ANG	True bearing of cloud normal (rad).
THL	GLT	Zenith angle of observer as seen from cloud (rad).
THN	ANG	Zenith angle of cloud normal (rad).
TRUEB	ANG	True bearing of sun (rad).

Output Parameter	Location	Description
TH	ANG	Angle of observer from cloud normal (rad).
THO	ANG	Angle of sun from cloud normal (rad).
PH	ANG	Angle between sun and observer in plane of cloud measured from reciprocal of the sun direction (rad).

Table 10
Subroutine GLINT Parameters

Input Parameter	Location	Description
INIT	GLT	Flag = 0 until GLINT is called then = 1.
NOGLT	Card Read	Number of GLINT points.
PSG	Card Read	Probability that glint does not appear in a designated cell on the scan.
NG(I,1)	Card Read	Row number for glint I.
NG(I,2)	Card Read	Column number for glint I.
RGLINT(I)	Card Read	Range to glint I (m).
VEFF	GLT	Static voltage array (v).

Output Parameter	Location	Description
VEFF	GLT	Voltage array after glint is superimposed on a specified cell (v).

Table 11
Subroutine INTEG Parameters

Input Parameter	Type/Location	Description
N	INTP	number of discrete points of the function
Y(300)	INTP	discrete points of the function to be integrated
WAVEL (100,3)	CONST	wavelength integration points

Output Parameter	Type/Location	Description
Y(1)	INTP	result of the integration.

Table 12
Subroutine INTER Parameters

Input Parameter	Location	Description
IFLAG	INTP	flag specifying which spectral curve is being read and interpolated.
N	INTP	number of points to be read defining spectral curve.
NPW(3)	INTG	number of integration points in each curve for each given waveband.
WAVEL (100,3)	CONST	wavelength integration points.
XX (200)	Card Read	wavelengths defining the spectral curve.
YY (200)	Card Read	functional values at given wavelength values.

Output Parameter	Location	Description
YNEW (100,3)	INTP	interpolated values as a function of even inverse centimeter spacing

Table 13

Subroutine LOWEM Parameters

Input Parameter	Type/Location	Description
MODEL	Call Statement	integer to select the model atmosphere: model 1 - tropical model 2 - mid-latitude summer model 3 - mid-latitude winter model 4 - sub-arctic summer model 5 - sub-arctic winter model 6 - 1962 U.S. Standard model 0 - horizontal path when meteorological data are used model 7 - new model atmosphere
IHAZE	Call Statement	integer to indicate aerosol attenuation IHAZE 0 - no aerosol attenuation IHAZE 1 - aerosol attenuation calculated.
ITYPE	Call Statement	integer to indicate the type of atmospheric path: ITYPE 3 - vertical or slant path to space ITYPE 2 - vertical or slant path between two altitudes ITYPE 1 - horizontal (constant pressure) path
LEN	Call Statement	LEN 1 - for a downward looking when two paths are possible (normally set to 0)
JP	Call Statement	print option
IM	Call Statement	IM 1 - for radiosonde data (normally set to 0)
M1, M2, M3	Call Statement	these integer values are used to change the temperature, the water and the ozone altitude profiles (normally set to 0)
ML	Call Statement	ML 1 - for radiosonde (normally set to 0)
IEMIS	Call Statement	integer to indicate mode of calculations: IEMIS 0 - transmission mode IEMIS 1 - radiance mode. (Always in IRSTEM.)

Table 13 (continued)

Subroutine LOWEM Parameters

Input Parameter	Type/Location	Description
RO	Call Statement	range (km)
H1	Call Statement	height of observer in kilometers
H2	Call Statement	source altitude in kilometers
ANGLE	Call Statement	zenith angle at H1 in degrees
RANGE	Call Statement	pathlength in kilometers
BETA	Call Statement	earth center angle
VIS	Call Statement	visual range at sea-level in kilometers
WAVE1	Call Statement	lower bound of calculations in microns
WAVE2	Call Statement	upper bound of calculations in microns
DELAM	Call Statement	increment of calculations in microns
IXY	Call Statement	
ISP	Call Statement	integer to indicate previous calculations have been done: ISP 0 - indicates first call to Subroutine LOWEM ISP 1 - indicates more than one call to LOWEM
IWRITE	Call Statement	print FLAG
IJK	Call Statement	not used
ISTATE	Call Statement	not used
IAFLG	Call Statement	not used
TOTRAN	Call Statement	array names for transmission values
LW	Call Statement	dimension counter
NSAI	Call Statement	0 - Burch H_2O model, 1 - White model

Output Parameter	Type/Location	Description
TAUA	LOW	transmissivity
APRA	LOW	path radiance

Table 14
Subroutine SCALR

Input Parameter	Location	Description
EFF (64, 64, 1)	Call Statement	Signal response array (v)
IMAX	PRT	Number of rows in scene.
JMAX	PRT	Number of columns in scene
L	Call Statement	Waveband
LAVEL	Call Statement	Label for array printout
NG (40, 2)	PRT1	Location of glint points
NOGLT	PRT1	Number of glints

Output Parameter	Location	Description
IBK6 (64, 64)	PRT	Scaled background array.

Table 15

Subroutine SKYCLD

Input Parameter	Location	Description
ALT	ANG	Elevation angle of sun (rad).
APR	LOW	Path radiance (mw/sr/cm^2/μm).
AZA	Data Statement	Azimuth angle between sun and observer in cloud plane for which radiance values exist (rad).
D	MISC	Optics diameter (m)
DI, DJ, DK	Subroutine FIND	Relative position of THO, PH and TH between the bounding data entries.
DUM (300) or YNEW (300	INTP	Interpolated integrands for signal response calculations.
DV(3)	INTG	Wavelength interval (μm)
ELVS	ITRAJ	Zenith angle of sensor (rad).
I1, I2	Subroutine FIND	Data entry indices for SZA immediately below and above THO.
IC1-IC6	GLT	Flags indicating the sky or cloud condition.
ICMIN, ICMAX	Card read	Rows bounding a given sky or cloud condition.
J1, J2	Subroutine FIND	Data entry indices for AZA immediately below and above PH.
JCMIN, JCMAX	Card read	Columns bounding a given sky or cloud condition.
K1, K2	Subroutine FIND	Data entry indices for VA immediately below and above TH.
NBANDS	INTG	Number of passbands.
NI(K), NJ(K)	Card Read	Row and column location of the Kth cell of a given sky or cloud condition.
NOCELS	Card read	Number of background cells with a given normal.

Table 15 (Continued)

Input Parameter	Location	Description
NORM	Card Read	Number of unique normals for a given sky condition (set to 1 internally except for 10 km clouds).
PH	Internal calculation	Azimuth angle between sun and observer in cloud plane (rad) - from ANG only for 10 km cloud.
PHL	GLT	True bearing of line-of-sight (rad).
PHN	Card read	Azimuth angle of cloud normal (rad).
RB(40)	IMPT	Range to cloud (m)
RD		Responsivity (v/w)
SZA	Data statement	Solar zenith angle wrt cloud normal for which radiance data exists (rad).
TAUA	LOW	Atmospheric transmissivity.
TAUO	GLT	Optical Train Transmissivity.
TH	Internal calculation or ANG	View angle of observer wrt cloud normal (rad) from ANG only for 10 km cloud.
THN	Card read	Zenith angle of cloud normal (rad).
THO	Internal calculation or ANG	Solar zenith angle wrt cloud normal (rad) from ANG only for 10 km cloud.
TRUEB	ANG	True bearing of sun (rad).
VA	Data statement	Azimuth angle between sun and observer in cloud plane for which radiance values exist (rad).
XLAML(L),XLAM(U)	GLT	Upper and lower wavelengths for each waveband (μm).
YR	Data statement or TAPE 8	Wavelengths for which radiance data exists on TAPE 8 (μm) or the radiance values from the tape (mw/sr/cm^2/μm)

Table 16
Subroutine SUNLOC

Input Parameter	Location	Description
MON	GLT	Month of year (1 - 12)
DAY	GLT	Day of month (1 - 31)
HR	GLT	Time of day (GMT).
RLAT	GLT	Latitude of interest (degrees) - North is +, South is - .
RLONG	GLT	Longitude of interest (degrees)

Output Parameter	Location	Description
ALT	ANG	Altitude of sun from horizon (rad)
TRUEB	ANG	True bearing of sun clockwise from True North (rad).

Table 17
Subroutine TGTSIG

Input Parameter	Location	Description
ASPECT	ITRAJ	View angle of target wrt its centerline (degrees)
DP	MISS	Tailpipe diameter (m).
DT	ITRAJ	Target diameter (m).
ETE	MISS	Tailpipe emissivity.
ETN	MISS	Nose emissivity.
ETS	MISS	Skin emissivity.
TE	MISS	Tailpipe temperature (^{O}K)
TL	ITRAJ	Target length (m).
TN	MISS	Nose temperature (^{O}K).
TS	MISS	Skin temperature.
TJP (100, 3)	IMPT	Plume spectral intensity (w/m/μm)
TNL	MISS	Length of missile nose (m)
TGTAU (100, 3)	IMPT	Plume spectral transmissivity.
WAVEL (100, 3)	CONST	Wavelength of interest (μm)

Ouptut Parameter	Location	Description
TJ	ITRAJ	Total target intensity (w/sr/μm)
AT	ITRAJ	Total target cross-section (m^2)

Table 18
Subroutine TRAJR Parameters

Input Parameter	Type/Location	Description
ELVS	ITRAJ	theta position of the sensor (rad)
IMAX	PRT	number of rows.
JMAX	PRT	number of columns.
PHITS	ITRAJ	azimuth position of the target (rad)
RS	ITRAJ	initial range of the target (m)
T	ITRAJ	engagement clock time (sec)
TF	ITRAJ	frame time (sec)
THTATS	ITRAJ	theta position of the target (rad).
VT	ITRAJ	velocity of the target (m/sec).

Output Parameter	Type/Location	Description
II	ITRAJ	I index position of target.
JJ	ITRAJ	J index position of the target
R	ITRAJ	range of the target.

Table 19
Function BLKBDY

Input Parameter	Location	Description
C1	Call Statement	Constant = 3.713×10^4 ($w\ u^4 cm^{-2}$)
C2	Call Statement	Constant = $1.4388 \times 10^4 (\mu^O K)$
TT	Call Statement	Temperature (^{O}K)
XL	Call Statement	Wavelength (μ)

Output Parameter	Location	Description
BLKBDY	Call Statement	Blackbody emittance ($w\ cm^{-2}\ \mu^{-1}$)

AD-A060 174 SCIENCE APPLICATIONS INC ALBUQUERQUE N MEX F/G 17/5
INFRARED SEARCH AND TRACK EVALUATION MODEL (IRSTEM).(U)
AUG 78 L N PECKHAM, L L DORAN N00173-77-C-0236
UNCLASSIFIED SAI-A64-995-199 NL

2 OF 3
AD
A060 174

Table 20
Function INTERP

Input Parameter	Location	Description
ARG	Call Statement	Aspect angle (degrees).
N	Call Statement	Number of points defining plume intensity curve (nominally - 12)
X	Call Statement	Function describing the curve.

Output Parameter	Location	Description
Y	Call Statement	Function's value at the aspect angle of interest.

Section 4

USER'S INSTRUCTIONS

In this section code design information is provided to assist the IRSTEM user. The first part of this section reviews the input requirements and the output options. The key parameters used in the code are summarized on a table which includes the parameter, its symbol in the text and where it is defined, stored and used. This table combined with the List of Symbols and Subroutine Tables in Section 3 give a complete cross-reference for each of the major parameters. Finally, the section is completed with a sample program and test case.

4.1 Inputs/Outputs

There are 36 sets of inputs required to operate IRSTEM, 33 formal inputs and three namelists. These inputs include a combination of tapes, formal input cards and namelists structured to provide maximum flexibility for the user. Some of the inputs are simply a single parameter while others are full arrays of many thousands of elements. There are no default options in IRSTEM; so the user must provide data for each of these inputs whenever the program is exercised.

Table 21 summarizes the input stream. All of the inputs are assumed to be cards or files of data in card image format unless otherwise noted as tapes or namelists. Each entry shows the requisite format, the calling routine (if other than the main program), the parameter's units and a description of each parameter including the flag options. The paragraphs below discuss these inputs, in turn, and provide additional information for the user beyond what is in the table.

Program operation begins by specifying the background array size and whether the debug option for additional printout is desired. It should be noted that in addition to specifying IMAX and JMAX, arrays other than 64 by 64 require the user to alter several dimension statements and common blocks. The required modifications are shown in Table 22. Most of the changes occur within the main program; however, five of the subroutines do require array

Table 21

IRSTEM Inputs

<u>Input 1 - 3I5</u>

IMAX	-	Number of rows in background array.
JMAX	-	Number of columns in background array.
NBUG	-	0 → standard output 1 → expanded output

<u>Input 2</u> - 5A6,I5 (Tape 1)

HOL	-	Title
MXCODE	-	Maximum number of different codes on the background tape.

<u>Input 3</u> - 15I5 (Tape 1)

IBKG(I,J)	-	Array of background codes from 1 to IMAX and 1 to JMAX.

<u>Input 4</u> - I5,4F10.3

KEY(I)	-	Integer value corresponding to background code.
TB(I)	°K	Temperature for I^{th} background code.
EB(I)	-	Emissivity for I^{th} background code.
RHO(I)	-	Diffuse reflectivity for I^{th} background code.
RB(I)	m	Range to I^{th} background code.

<u>Namelist SENSOR</u>

XLAML(I)	μm	Lower bound of the wavebands of interest	I = 2,3
XLAMU(I)	μm	Upper bound of the wavebands of interest	
TF	sec	Scan time	
D	m	Diameter of the optics	
DX	m	Width of the detector	
DY	m	Length of the detector	
OVL	m	Amount of overlap between detectors.	
FL	m	Focal length	
FO	hz	Cutoff frequency	
ELVS	degrees	Elevation angle of the background	
VNOISE	v	RMS noise level	
RDPK	v/w	Peak responsivity	
DSTRPK	$cm\ hz^{1/2}\ w^{-1}$	D* or detectivity	

Table 21 (Continued)

IRSTEM Inputs

Input 5 - 2I5, 2E10.3, A8

MODET	-	Type of trajectory, trajectory mode (not used)
NBANDS	-	Number of wavebands to be considered (1, 2 or 3)
XLAML(1)	μm	Lower bound of first waveband
XLAMU(1)	μm	Upper bound of first waveband
NAMET	-	Name of the target.

Input 6 - 4I5, 4F10.3, I5

MODEL	–	Integer code for type of atmosphere (see Table 13)
IHAZE	-	Integer to indicate if aerosol scattering is to be used (0→no aerosol, 1→aerosols included)
ITYPE	-	Type of atmospheric path (see Table 13)
IEMIS	-	Mode code to indicate transmittance or radiance (must be 1 if path radiance is to be included)
HS	m	Observer altitude
DV(I)	μm	Integration intervals (I=1,NBANDS)
NSAI	-	NSAI=1 indicates that White water vapor continuum is to be used in place of the Burch model.

Input 7 - I5 from INTER

N	-	Number of (λ, J_p) pairs

Input 8 - 4(F12.3,E8.2) from INTER

λ(I)	μm	Wavelength	I = 1,N
TJP(I)	w/sr/μm	Target plume intensity	

Input 9 - I5 from INTER

N	-	Number of (λ, τ_p) pairs

Input 10 - 9XF7.4, 52XF6.4 from INTER

λ(I)	μm	Wavelength	I=1,N
TGTAU(I)	-	Plume transmission	

Input 11 - I5 from INTER

N	-	Number of (λ, τ_0) pairs)

Table 21 (Continued)

IRSTEM Inputs

Input 12 - 8F10.3 from INTER

$\lambda(I)$	μm	Wavelength	I = 1,N
TAUO(I)	-	Optical Transmission	

Input 13 - I5 from INTER

N	-	Number of (λ, D*) pairs

Input 14 - 8F10.3 from INTER

$\lambda(I)$	μm	Wavelength	I = 1,N
D*(I)	cm $hz^{1/2}w^{-1}$	Detectivity	

Input 15 - I5 from INTER

N	-	Number of (λ, H_s) pairs

Input 16 - 8F10.3 from INTER

$\lambda(I)$	μm	Wavelength	I = 1,N
SR(I)	w/cm^2	Solar irradiance at earth's surface	

Namelist TRAJ

RS	m	Initial range of target
TV	m/sec	Velocity of target
DT	m	Diameter of target
TL	m	Length of target body
THTATS	degrees	Elevation of target
PHITS	degrees	Azimuth of target
TNL	m	Length of Nose
TPL	m	Plume Length (not used at this time)
DP	m	Diameter of the exhaust pipe
TE	^oK	Temperature of exhaust
TN	^oK	Temperature of the nose
TS	^oK	Temperature of the body of the missile

Table 21 (Continued)
IRSTEM Inputs

Namelist TRAJ (Continued)

ETN	-	Emissivity of the nose
ETS	-	Emissivity of the body of the target
ETE	-	Emissivity of the exhaust
ASPECT	degrees	Aspect angle of the target relative to the line of sight
TMAX	sec	Maximum time of the encounter

Namelist SUN

RLAT	degrees	Latitude of the observer
RLONG	degrees	Longitude of the observer
MON	-	Month (1-12)
DAY	-	Day (1-31)
HR	-	Hour of the day (GMT)
PHL	degrees	Locates the observer with respect to true North in a counterclockwise direction as seen from the target

Input 17 - I5 from SKYCLD

NOCELS	-	Number of cells with clear sky (Flag for Input 18. If NOCELS=0, block data is read)

Input 18 - 16I5 from SKYCLD

ICMIN	-	Row limits for clear sky
ICMAX	-	
JCMIN	-	Column limits for clear sky
JCMAX	-	

or

Input 18 - 16I5 from SKYCLD

NI(K)	K = 1, NOCELS	Cell by cell specification of clear sky positions
NJ(K)		

Input 19 - I5 from SKYCLD

NORM	-	Number of unique normals for 10 km thick cloud.

Table 21 (Continued)

IRSTEM Inputs

Input 20 - I5 from SKYCLD

NOCELS	-	Number of cells with 10 km thick cloud.

Input 21 - 2E10.3 from SKYCLD

THN	degrees	Zenith angle of cloud normal
PHN	degrees	Azimuth angle of cloud normal

Input 22 - 16I5 from SKYCLD

Same as Input 18 for 10 km thick cloud

Input 23 Input 24	Same as Inputs 17 and 18 for 0.1 km thick cloud
Input 25 Input 26	Same as Inputs 17 and 18 for 0.5 km thick cloud
Input 27 Input 28	Same as Inputs 17 and 18 for 23 km haze
Input 29 Input 30	Same as Inputs 17 and 18 for 5 km haze

Input 31 - I5, E10.3 from GLINT

NOGLT	-	Number of cells with potential glints
PSG	-	Probability that a glint will not occur on any given scan.

Input 32 - 16I5 from GLINT

NG(I,1	I = 1, NOGLT	Row position of I^{th} glint
NG(I,2)		Column position of I^{th} glint

Input 33 - 8E10.3 from GLINT

RGLNT(I) I=1, NOGLT	m	Range to each glint point

Table 22

Changes Required if IMAX or JMAX Do Not Equal 64

Dimension Statements	Dimension	IRSTEM	Subroutines					
			FIX	GETANG	GLINT	SCALR	SKYCLD	SUNLOC
VARRAY	64,64,6	X						
IBKG	64,64	X				X		
TVEFF	64,64,3	X						
H	64,64,3	X						
V	64,64,6	X						
EFF	64,64,3	X						
U	64,64		X			X		
Common Blocks								
GLT (VEFF)	64,64,3	X		X	X		X	X
PRT (IBKG)	64,64		X					

modifications before the program will function properly. To make the modifications, the user changes the array dimension from 64 to the appropriate number. It is not required that this number be a multiple of 2, but the Fast Fourier Transform will operate more efficiently if it is a multiple of 2.

Inputs 2, 3 and 4 define the background. After the header information is provided, the background codes (one for each cell) are read as Input 3. Then key cards are read (one for each background type) to associate each code with the desired temperature, emissivity, reflectivity and range.

The next 3 sets of inputs provide information about the sensor and the atmospheric conditions desired for the engagement. These inputs are fixed parameters that do not vary with wavelength. Namelist Sensor provides information on the hardware design and Input 6 is a shortened LOWTRAN input list required by LOWEM. The rest of the LOWEM parameters are shown in the subroutine table (Table 13). These parameters are set to default values internally in the program.

Inputs 7 through 16 are the spectrally dependent parameters which must be read in the order shown. Two sets of inputs are needed for each parameter. The first card specifies the number of data points and the remaining cards give the wavelength and corresponding value of the functional for each data point. These inputs are called from Subroutine INTER which then interpolates the function as required for the integration subroutine. Two additional namelists follow Input 16. The first is used to describe the engagement dynamics and inputs required for the target signature calculation (Namelist TRAJ). The second specifies the location of the engagement with parameters necessary to compute the sun's location (Namelist SUN).

Inputs 17 through 30 are associated with the cloud radiance model. The cloud inputs must, of course, be correlated with the background data read at the start of the program; however, these cards give the user the flexibility of creating any type of cloud or clear/haze air conditions he wishes. The required read sequence is clear sky, 10 km thick clouds, 0.1 km thick clouds, 0.5 km thick clouds, 23 km haze and finally 5 km haze if present in the background description. In general, there are two inputs required for each sky/cloud condition. The first is the number of cells whose location will be individually specified as containing this sky or cloud condition. The next input then specifies the location of these cells. If the sky/cloud condition can be conveniently described as a rectangular section, the user has the option of specifying the bounds of the rectangle instead of specifying the location of individual cells. However, the user cannot specify a combination of area and individual cell locations. The above read sequences are valid for all the sky and cloud conditions with the exception of the 10 km, reflective cloud. Here, the first input is the number of unique cloud normals used to describe the cloud. Then the number of cells with those normals are given and defined by their zenith and azimuth angles. Finally, the location of these cells are read in the same manner as before (i.e., by block areas or individual cell locations). Inputs 20 through 22 are repeated then for each of the normals specified in Input 19.

The final three inputs are associated with the sun glint computations. Input 31 identifies the number of cells containing potential sun glints and the probability with which the sun glints will occur. Note that this probability is applied equally to all glints. Next, each glint location must be specified on a cell-by-cell basis (there is no option for specifying sun glint areas at this time). Finally the range associated with each of the sun glints is specified. Normally this range will correspond to the background range given in Input 4.

The IRSTEM outputs are summarized in Table 23 which shows the parameter in the order of its appearance. Parameters which are preceded with an asterisk indicate debug options which are printed only if NBUG > 0.

The output sequence generally follows the input sequence with the background conditions specified first followed by descriptions of the sensor, target and environmental conditions. Note that when Namelist SENSOR is printed, the wavelength values for the primary band are not repeated since they are shown at the beginning of the output listing. The outputs which are printed on each iteration of the time loop are (1) the total projected area at that time, (2) the target's range and (3) the response voltage of the target cell for each waveband. The signal response from each detector, $V_n(t)$, is recorded on Tape 12 for later signal processing analysis but is not printed. To more fully understand the output sequence and format, the reader should examine the sample output given at the end of this section.

Table 23

IRSTEM Outputs

Parameter	Units	Description
IMAX, JMAX	-	Number of rows and columns in background array.
HOL		Title
KEY(I)		Descriptors for each background code.
TB(I)	°K	
EB(I)		
RHO(I)		
RB(I)	m	
*IBKG(I,J)	-	Input background array
Input 5		Target information and passbands
XLAML(J) J=2, NBANDS	µm	
XLAMU(J)	µm	
Input 6		LOWEM inputs
Namelist SENSOR		
$\tau_o(\lambda)$	-	
$D^*(\lambda)$	cm $hz^{1/2}$ w^{-1}	Spectrally dependent inputs.
$R_d(\lambda)$	v/w	
$H_s(\lambda)$	w/cm^2	
Namelist TRAJ	-	
Namelist SUN		
*IBKG(I,J)	-	Background array with sequenced numbers.
*VEFF(I,J,L)	v	Signal response to static scene and sunglints.
$*J_{TP}(\lambda)$		
$J_N(\lambda)$	w/sr/µm	Target signature including component parts
$J_S(\lambda)$		
$J_P(\lambda)$		
$J_T(\lambda)$		

Table 23 (Continued)
IRSTEM Outputs

Parameters	Units	Description
* A_N	m^2	Projected target areas.
A_S		
A_E		
A_T		
T	sec	
A_T	m^2	
*VEFF(I,J,L)	v	Scaled scene response.
*TVEFF		Scaled transformed array.
R	m	Target status presented for each iteration of the time loop.
VEFF(L)	v	
*EFF	v	Scaled scene array after the sensor distortions are added.
V_n	v	Final signal response for each of the detectors is written on TAPE 12.

4.2 Parameter List

A List of Symbols is given in the front of this report identifying the symbols used in the theory section. In Section 3.2 a series of tables (Tables 6 through 20) are provided summarizing the inputs and outputs associated with each of the subroutines and in Section 4.1 above, the inputs and outputs required to operate the code are identified. In this subsection the cross-references for the key parameters is completed by identifying each of the important code symbols as they appear in IRSTEM in alphabetical order.

Each of these key parameters are listed on Table 24 which includes the corresponding report symbol, its units, where the symbol is defined, its common block, and which are the primary routines in IRSTEM in which it is used. Under the "Defined" column there are four options. Words which appear in all caps (such as SUNLOC) indicate the parameter is defined in a subroutine. If the word begins with a capital letter (such as Sensor), this indicates a namelist read. Formal read inputs are indicated as Input x and are based on the read sequence shown in Table 21. Finally, some of the parameters are defined in data blocks. The dimensions of the variables are given in the "Description" column where applicable, and if the array is a complex one, this also is noted.

Table 24
Parameter List

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
AE	AE	m^2	TGTSIG	-	TGTSIG	Projected area of tailpipe.
ALT	θ_{ALT}	rad	SUNLOC	ANG	FIND	Elevation of sun above horizon.
AN	A_N	m^2	TGTSIG	-	TGTSIG	Projected area of missile nose.
ANGLE	ξ	degrees	Data Block	POST	IRSTEM TRAJR	(12) Angles defining relative plume strength.
APR	N_A	mw/str-cm^2	LOWEM	LOW	IRSTEM LOWEM TRAJR SKYCLD	(100) Path radiance
ARG	ASPECT	degrees	TGTSIG	-	INTERP	Aspect angle of missile.
AS	A_S	m^2	TGTSIG	-	TGTSIG	Projected area of missile fuselage.
ASPECT	ξ		Traj	ITRAJ	TRAJR	Angle between target centerline and sensor line-of-sight.
AT	_	m^2	TGTSIG	ITRAJ	TRAJR	Total projected target area.
AZA	ϕ	degrees	Data Block	-	SKYCLD	(2,7) Solar azimuth angle wrt cloud normal defining sky/cloud radiance data.
BL	ν_L	cm^{-1}	IRSTEM	INTG	IRSTEM	(3) Lower bound of passband.
BLKBDY	W	w/cm^2/μm	BLKBDY	-	IRSTEM TGTSIG	Blackbody emittance.
BU	ν_u	cm^{-1}	IRSTEM	INTG	IRSTEM INTEG	(3) Upper bound of passband.
CV	$\Delta\nu$	cm^{-1}	IRSTEM	INTG	IRSTEM	Wavenumber increment size.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
D	D	m	Sensor	MISC	IRSTEM	Optics diameter.
DAY	-	-	Sun	GLT	SUNLOC	Day of the month (1-31)
DEGRAD	-	-	IRSTEM	MISC	Most Routines	$\pi/180$
DP	-	m	Traj	MISS	TGTSIG	Tailpipe diameter.
DSTRPK	D^*_{peak}	cm $hz^{1/2}w^{-1}$	Sensor	-	IRSTEM	Peak detectivity.
DT	D_T	m	Traj	ITRAJ	TGTSIG	Target diameter.
DUM	-	-	IRSTEM	INTP	IRSTEM	(300) Dummy array for spectral integrations.
DV	$\Delta\lambda$	µm	Input	INTG	IRSTEM SKYCLD	Wavelength increment for LOWEM
DX	L_x	m	Sensor	-	IRSTEM	Detector dimension in scan direction.
DY	L_y	m	Sensor	-	IRSTEM	Detector dimension orthogonal to scan.
EG	ϵ_B	-	Input	IMPT	IRSTEM	(40) Background emissivity.
EFF	V_{eff}	v	IRSTEM	-	IRSTEM SCALR	(64, 64, 3) Complex voltage array after transfer functions are added.
ELVS	θ_E	degrees	Sensor	ITRAJ	TGTSIG	Elevation of scene centroid measured from zenith (converted to radians internally).
ETE	-	-	Traj	MISS	TGTSIG	Tailpipe emissivity.
ETN	ϵ_N	-	Traj	MISS	TGTSIG	Missile nose emissivity.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
ETS	E_S	-	Traj	MISS	TGTSIG	Missile skin emissivity.
FL	F	m	Sensor	-	IRSTEM	Focal length.
FO	f_o	hz	Sensor	-	IRSTEM	Electronics cutoff frequency.
FUNC	f_ρ	-	Data Block	-	INTERP	(12) Plume strength as a function of aspect angle.
H	-	-	IRSTEM	GLT	IRSTEM	(64, 64, 3) Complex-Modified transform array.
HR	-	-	Sun	GLT	SUNLOC	Greenwich mean time (1-24)
HS	-	m	Input 6	CONST	LOWEM	IRST Altitude.
H1	-	km	IRSTEM	MISC	LOWEM	Height of observer (IRST).
H2	-	km	IRSTEM	MISC	LOWEM	Height of target.
I1,I2	-	-	FIND	-	SKYCLD	Data entry indices for SZA immediately below and above THO.
IBKG	-	-	Input 3	PRT	IRSTEM SCALR	(64, 64) Initial background code and normalized code; also used an output array for SCALR.
IC	-	-	SKYCLD	-	SKYCLD	Flag set to 1,2...to represent IC1, IC2...IC6.
ICI	-	-	SKYCLD	-	FIND	Flag indicating number of solar zenith angle points in cloud radiance data (see Table 3).
ICJ	-	-	SKYCLD	-	FIND	Flag indicating number of solar azimuth angle points (see Table 3)

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
ICK	-	-	SKYCLD	-	FIND	Flag indicating number of view angle points (see Table 3).
ICMIN, ICMAX	-	-	Input 18	-	SKYCLD	Rows bounding a given sky or cloud condition.
IC1	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating clear sky.
IC2	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating 23 km visibility.
IC3	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating 5 km visibility.
IC4	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating 0.1 km cloud transmission.
IC5	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating 0.5 km cloud transmission.
IC6	-	-	IRSTEM	GLT	IRSTEM SKYCLD	Flag indicating 10 km cloud reflection.
IEMIS	-	-	Input 6	CONST	LOWEM	Mode code to indicate transmittance or radiance (must = 1).
IERROR	-	-	TRAJR	ITRAJR	IRSTEM TRAJR	Flag indicating target is outside bounds of the scene.
IFLAG	-	-	INTER	INTP	INTER	Flag specifying which spectral curve is being read and interpolated.
IHAZE	-	-	Input 6	CONST	LOWEM	Flat to indicate if aerosol scattering is to be used.
II	-	-	TRAJR	ITRAJ	IRSTEM	Row in which target is located.

Table 24 (Continued)

Parameter						
Code	Report	Units	Defined	Common Block	Primary Routines	Description
IMAX	-	-	Input 1	PRT	IRSTEM TRAJR	Number of rows.
INIT	-	-	GLINT	GLT	GLINT	INIT = 0 until GLINT is called the first time.
ITYPE	-	-	Input 6	CONST	LOWEM	Type of atmospheric path
IZ1-IZ2	-	-	Data Block	REST	LOWEM	LOWEM call parameter (= 0)
J1,J2	-	-	FIND	-	SKYCLD	Data entry indices for AZA immediately below and above PH.
JCMIN, JCMAX	-	-	Input 18	-	SKYCLD	Columns bounding a given sky or cloud condition.
JJ	-	-	TRAJR	ITRAJ	IRSTEM	Column in which target is located.
JMAX	-	-	Input 1	PRT	IRSTEM	Number of columns.
K1, K2	-	-	FIND	-	SKYCLD	Data entry indices for VA immediately below and above TH.
KEY	-	-	Input 4	IMPT	IRSTEM	(40) Background key index.
KK	-	-	SKYCLD	-	SKYCLD	Set to IC1-IC6 respectively.
L	-	-	Most routines	-	Most routines	Waveband flag (= 1,2,3)
LAVEL	-	-	SCALR	-	SCALR	(16) Label for array printout.
LJM	-	-	SKYCLD	-	SKYCLD	Product of ICI, ICJ and ICK.
LM	-	-	IRSTEM	INTP	INTER	Number of points to be interpolated.

Table 24 (Continued)

Parameter						
Code	Report	Units	Defined	Common Block	Primary Routines	Description
MODEL	-	-	Input 6	CONST	LOWEM	Integer to select model atmosphere.
MODET	-	-	Input 5	ITRAJ	-	Type of trajectory (not used currently).
MON	-	-	Sun	GLT	SUNLOC	Month (1-12).
N	-	-	Input 7	-	INTER	Number of spectral curve points to be read.
NBANDS	-	-	Input 5 .	INTG	Most routines	Number of passbands.
NBUG	-	-	Input 1	GLT	IRSTEM SKYCLD	Debug flag for extra printouts.
NG	-	-	Input 32	-	GLINT	(40,2) Glint position: NG(#,1) - row NG(#,2) - column
NI(K)	-	-	Input 18	-	SKYCLD	(8) Row location of the K^{th} cell of a given sky or cloud condition.
NJ(K)	-	-	Input 18	-	SKYCLD	(8) Column location of the K^{th} cell of a given sky or cloud condition.
NOCELS	-	-	Input 17	-	SKYCLD	Number of background cells with a given normal.
NOGLT	-	-	Input 31	-	GLINT SCALR	Number of glint points.
NORM	-	-	Input 19	-	SKYCLD	Number of unique normals for 10 km thick cloud.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
NPW	-	-	IRSTEM	INTG	INTER	(3) Number of intergration points to be interpolated for each waveband.
NSAI	-	-	Input 6	CONST	LOWEM	Flag indicating use of Burch (NSAI=0) or White (NSAI=1) water vapor model.
OVL	OVL	m	Sensor	-	IRSTEM	Amount of overlap between detectors.
PH	ϕ	rad	GETANG	ANG	FIND SKYCLD	Azimuth angle between sun and observer in plane of cloud wrt reciprocal of sun direction.
PHITS	ϕ_{TS}	degrees	Traj	ITRAJ	TRAJR	Azimuth position of target (converted to radians internally).
PHL	ϕ_{TB}	degrees	Sun	GLT	GETANG SKYCLD	True bearing of observer.
PHN	ϕ_N	rad	Input 21	ANG	GETANG SKYCLD	True bearing of cloud normal.
PI	π	-	IRSTEM	MISC	Many	3.14159265
PSG	-	-	Input 31	-	GLINT	Probability of no sunglint on any given scan.
R	R	m	TRAJR	ITRAJ	IRSTEM	Target's instantaneous range.
RB	R_B	m	Input 4	IMPT	IRSTEM SKYCLD	(40) Range to background.
RD	R_d	v/w/µm	IRSTEM	GLT	GLINT IRSTEM SKYCLD	(100,3) Spectral responsivity

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
RDPK	$(R_d)_{peak}$	v/w	Sensor	-	IRSTEM	Peak responsivity.
RGLNT	R_g	m	Input 33	-	GLINT	(40,2) Range to glint.
RHO	ρ	-	Input 4	IMPT	IRSTEM	(40) Background diffuse reflectivity.
RLAT	Lat	degrees	Sun	GLT	SUNLOC	Latitude (North is +, South is -).
RLONG	-	degrees	Sun	GLT	SUNLOC	Longitude.
RN	RN	-	Data Block	-	IRSTEM	(299) Random numbers.
RS	-	m	Traj	ITRAJ	TRAJR	Starting range of target.
RZ1-RZ4	-	m	Data Block	REST	LOWEM	Lowtran parameters (=0).
SR	H_S	w/cm^2	Input 16	IMPT	GLINT IRSTEM	(100,3) Solar irradiance at earth's surface.
SZA	θ_0	degrees	Data Block	-	FIND SKYCLD	(2,7) Solar zenith angle wrt cloud normal defining sky/cloud radiance data.
T	t	sec	TRAJR	ITRAJ	IRSTEM TRAJR	Current time (t=0 at program start)
TAPE1	-	-	Input 3	-	IRSTEM	Background code input.
TAPE3	-	-	Input 3	-	LOWEM	LOWEM Input (=Tape 5)
TAPE5	-	-	-	-	IRSTEM	Input
TAPE6	-	-	-	-	IRSTEM	Output
TAPE8	-	-	-	-	SKYCLD	Cloud radiance data.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
TAPE11	-	v	IRSTEM	-	IRSTEM	Voltage response to background.
TAPE12	-	v	IRSTEM	-	-	Final image file wrt detector description.
TAUA	τ_A	-	LOWEM	LOW	GLINT IRSTEM SKYCLD	(100)Atmospheric transmissivity.
TAUO	τ_o	-	Input 12	GLT	GLINT IRSTEM SKYCLD	(100,3) Optical train transmissivity.
TB	T	°K	Input 4	IMPT	IRSTEM	(40) Background temperature.
TE	T_E	°K	Traj	MISS	TGTSIG	Tailpipe temperature.
TF	T_f	sec	Sensor	ITRAJ	IRSTEM TRAJR	Frame time.
TGTAU	τ_p	-	Input 10	IMPT	TGTSIG	(100,3) Plume spectral transmission.
TH	θ	rad	GETANG	ANG	FIND SKYCLD	Angle of observer wrt cloud normal.
THL	θ_L	rad	SKYCLD	GLT	GETANG	Zenith angle of observer (IRST) as seen from cloud.
THN	θ_N	rad	Input 21	ANG	GETANG SKYCLD.	Zenith angle of cloud normal.
THO	θ_0	rad	GETANG	ANG	FIND SKYCLD	Angle of sun wrt cloud normal.
THTATS	θ_s	degrees	Traj	ITRAJ	TRAJR	Elevation angle of target wrt zenith (converted to radians internally).

Table 24 (continued)

Parameter						
Code	Report	Units	Defined	Common Block	Primary Routines	Description
VARRAY	-	-	IRSTEM	GLT	IRSTEM	(64, 64, 6) Real array equivalenced to real voltage and complex transform arrays, also used for temporary storage during background calculations.
VCODE	-	v	IRSTEM	-	IRSTEM	(40, 3) Voltage response for each unique background.
VE	-	v	IRSTEM	-	IRSTEM	(3) Path emission voltage response
VEFF	V_{ideal}	v	IRSTEM	GLT	GLT/IRSTEM	(64, 64, 3) - Complex - Voltage array before and after glints and clouds
VGLNT	V_g	v	GLINT	-	GLINT	(40, 3) Voltage response due to glint.
VNOISE	v_n	v	Sensor	-	IRSTEM	RMS noise level.
VT	V_{ideal}	v	IRSTEM	—	IRSTEM	(3) Target voltage.
VV	-	-	IRSTEM	INTP	INTER	Interpolation increment size.
V12	-	v	IRSTEM	-	IRSTEM	(40, 3) Response to background diffuse scatter and path radiance.
WAVEL	-	-	IRSTEM	CONST	INTER	(100, 3) Wavelength integration points.
X	f_p	-	Data Block	-	INTERP TGTSIG	Plume strength curve wrt aspect angle. Equivalent to FUNC.
XL	λ	μm	IRSTEM/BLKBDY TGTSIG	-	BLKBDY	Wavelength.

Table 24 (continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
XLAML	λ_L	µm	Sensor	GLT	IRSTEM/SKYCLD	(3) Lower bound of passband.
XLAMU	λ_u	µm	Sensor	GLT	FASTEM/SKYCLD	(3) Upper bound of passband.
XX	-	µm	Input 8, 10, 12, 14 or 16	CLDS	INTER	(200) Wavelength defining the spectral curve.
YY	-	-	Input 8, 10, 12, 14 or 16	CLDS	INTER	(200) Functional at given wavelength.
YNEW	-	-	INTER	INTP	INTER	(100,3) Interpolated values of function.

4.3 Sample Program

In this section, a sample program is presented including the computer-generated list of the input and output stream. The selected test case is designed to illustrate the use of the parameters contained in the input/output tables (Tables 21 and 23) and is not designed to test all of the code's features.

Table 25 shows the input stream associated with this sample program. The target is flying radially inbound toward a single-color sensor. The background is characterized by three unique elements: a thick cloud, a 295°K graybody at 50 km, and a 300°K graybody at 20 km. It should be noted that the allocation of these background elements to the 4096 element array is not shown on this input list since it is read from a separate source (Tape 1). It also should be noted that the standard plume transmission tabulated input (see Figure 15) of 172 points is not shown here. Instead, a few of the beginning and end points are shown along with the τ_A values which bound the 3.8 - 4.2μm passband selected for this test case. Similarly, only the first few lines of the solar irradiance spectrum (Figure 3) are shown in the interest of brevity. Also not shown are a large number of inputs required by the propagation model. These inputs are the standard LOWTRAN inputs covered in reference 4. The last few lines of the input stream define the cloud angles, position, and the two glint points.

In Table 26 the corresponding outputs for this test case are shown as they appear for the NBUG=0 with two exceptions. First, the time loop is truncated after three iterations (t=0, 1 and 2 seconds) even though TMAX=10 seconds. Second, several array printouts are included which normally are printed only if NBUG>0. These additional array plots are (1) the background inputs after index normalization, (2 and 3) the signal response after the target has been added, for the minimum and maximum array normalization but before the glint and system noise are included and (4) one of the transformed arrays. Many more arrays are printed if NBUG>0 but are not shown here. Of course, these arrays contain more information than is required since only those rows corresponding to detector centers are stored on Tape 12 and subsequently used in the signal processing analyses. With respect to the standard time-loop printouts, it should be noted that the target's projected area and its spectral intensity are repeated even though they do not change for this radially-inbound trajectory. These printouts have been included in anticipation of time-varying signatures and trajectories to be incorporated in later versions of IRSTEM.

Table 25

Sample Input Stream

```
  64   64     1
   6 260.          .75        .9         20000.                          ____________ Input 1
   8 295.          .6         .001        50000.                         ____________ Input 4
   7 300.          .75        .1          20000.
$SENSOR XLAML(2)=0.,XLAML(3)=0.,XLAMU(2)=0.,XLAMU(3)=0.,TF=1.,D=.1,      ____________ Namelist SENSOR
DX=4.E-05,DY=4.E-04,OVL=4.E-05,FL=.15,F0=1.E+04,ELVS=80.,VNOISE=1.E-04,
RDPK=1.E+08,DSTRPK=1.E+11$
   1     1 3.8           4.2      DUMMYTGT                               ____________ Input 5
   2     1    2    1  15.          .04          .04          .04          1          ____________ Input 6
  64
 2.000     3.72E+02  2.190    3.72E+02  2.381    3.72E+02  2.571    5.00E+02       ____________ Input 7
 2.762     8.41E+02  2.952    3.90E+03  3.143    7.34E+02  3.333    4.90E+02       ____________ Input 8
 3.524     4.97E+02  3.714    4.98E+02  3.905    4.71E+02  4.095    4.82E+02
 4.286     1.59E+04  4.476    1.69E+04  4.667    1.60E+04  4.857    5.77E+03
 5.048     2.12E+03  5.238    4.38E+02  5.429    1.04E+03  5.619    1.39E+03
 5.810     3.17E+03  6.000    2.34E+03  6.190    9.98E+02  6.381    6.69E+03
 6.571     7.65E+03  6.762    7.15E+03  6.952    6.65E+03  7.143    6.15E+03
 7.333     4.41E+02  7.524    7.25E+02  7.714    7.91E+02  7.905    6.61E+02
 8.095     7.80E+02  8.286    6.45E+02  8.476    5.85E+02  8.667    3.97E+02
 8.857     2.78E+02  9.048    2.93E+02  9.238    2.84E+02  9.429    2.51E+02
 9.619     2.19E+02  9.809    1.87E+02 10.000    1.54E+02 10.190    1.64E+02
10.381     1.73E+02 10.571    1.82E+02 10.762    1.91E+02 10.952    2.00E+02
11.143     2.10E+02 11.333    2.19E+02 11.524    2.29E+02 11.714    2.39E+02
11.905     2.48E+02 12.095    2.65E+02 12.286    2.88E+02 12.476    3.11E+02
12.667     3.35E+02 12.857    3.58E+02 13.048    3.73E+02 13.238    3.61E+02
13.429     3.49E+02 13.619    3.38E+02 13.809    3.26E+02 14.000    3.14E+02
```

Table 25 (continued)

______ Input 9
______ Input 10

172

1.9993	0.8347
2.0093	0.8400
2.0195	0.8457
2.0297	0.8567
2.0401	0.8659
3.7710	0.9642
3.8067	0.9642
3.8435	0.9691
3.8808	0.9700
3.9188	0.9701
3.9576	0.9696
3.9971	0.9683
4.0375	0.9644
4.0787	0.9599
4.1207	0.9560
4.1636	0.9478
4.2074	0.0145
4.2521	0.0067
4.2978	0.0063
4.3445	0.0001
12.0150	0.2219
12.4720	[illegible]
12.8730	0.1592
13.3020	0.1383
13.7590	0.1221

Table 25 (continued)

```
    6                                                                                ____________ Input 11
3.1         .1          3.2         .5          3.3         .8          4.5         .8          ____________ Input 12
4.6         .5          4.7         .1                                                          ____________ Input 13
    5
2.          5.    E+103.          7.    E+104.          9.    E+104.6          1.    E+11       ____________ Input 14
5.          9.    E+10
  187                                                                                           ____________ Input 15
 1.000E+00 2.726E-02 1.100E+00 5.077E-02 1.200E+00 3.541E-02 1.300E+00 1.685E-02               ____________ Input 16
 1.400E+00 5.832E-03 1.500E+00 1.794E-02 1.600E+00 2.202E-02 1.700E+00 1.549E-02
 1.800E+00 6.991E-03 1.900E+00 1.682E-05 2.000E+00 1.633E-03 2.100E+00 6.961E-03
 2.200E+00 7.259E-03 2.300E+00 5.464E-03 2.400E+00 3.266E-03 2.500E+00 7.656E-04
 2.600E+00 0.        2.700E+00 0.        2.800E+00 0.        2.900E+00 5.763E-05
 3.000E+00 8.412E-05 3.100E+00 1.580E-04 3.200E+00 9.946E-05 3.300E+00 8.559E-05
 3.400E+00 3.479E-04 3.500E+00 5.707E-04 3.600E+00 7.103E-04 3.700E+00 8.110E-04
 3.800E+00 7.903E-04 3.900E+00 7.394E-04 4.000E+00 6.524E-04 4.100E+00 4.011E-04
 4.200E+00 0.        4.300E+00 0.        4.400E+00 0.        4.500E+00 6.672E-05
 4.600E+00 1.705E-04 4.700E+00 2.316E-04 4.800E+00 1.900E-04 4.900E+00 9.888E-05
 5.000E+00 4.603E-05 5.100E+00 2.797E-05 5.200E+00 5.853E-06 5.300E+00 2.139E-06
 5.400E+00 0.        5.500E+00 0.        5.600E+00 0.        5.700E+00 0.
 5.800E+00 0.        5.900E+00 0.        6.000E+00 0.        6.100E+00 0.
 6.200E+00 0.        6.300E+00 0.        6.400E+00 0.        6.500E+00 0.
 6.600E+00 0.        6.700E+00 0.        6.800E+00 0.        6.900E+00 0.
 7.000E+00 0.        7.100E+00 0.        7.200E+00 0.        7.300E+00 5.203E-08
 7.400E+00 2.163E-07 7.500E+00 6.301E-07 7.600E+00 1.788E-06 7.700E+00 4.109E-06
 7.800E+00 3.887E-06 7.900E+00 6.028E-06 8.000E+00 1.263E-05 8.100E+00 2.196E-05
 8.200E+00 2.150E-05 8.300E+00 2.488E-05 8.400E+00 2.631E-05 8.500E+00 2.567E-05
 8.600E+00 2.709E-05 8.700E+00 2.639E-05 8.800E+00 2.549E-05 8.900E+00 2.312E-05
 9.000E+00 2.157E-05 9.100E+00 2.146E-05 9.200E+00 1.993E-05 9.300E+00 1.352E-05
 9.400E+00 7.732E-06 9.500E+00 9.759E-06 9.600E+00 5.719E-06 9.700E+00 7.500E-06
 9.800E+00 8.034E-06 9.900E+00 9.921E-06 1.000E+01 1.166E-05 1.010E+01 1.277E-05
 1.020E+01 1.282E-05 1.030E+01 1.274E-05 1.040E+01 1.244E-05 1.050E+01 1.217E-05
 1.060E+01 1.190E-05 1.070E+01 1.145E-05 1.080E+01 1.079E-05 1.090E+01 1.001E-05
 1.100E+01 9.728E-06 1.110E+01 9.355E-06 1.120E+01 7.107E-06 1.130E+01 7.214E-06
 1.140E+01 6.000E-06 1.150E+01 6.955E-06 1.160E+01 7.301E-06 1.170E+01 7.271E-06
 1.180E+01 7.630E-06 1.190E+01 5.981E-06 1.200E+01 5.519E-06 1.210E+01 5.018E-06
 1.220E+01 3.684E-06 1.230E+01 3.120E-06 1.240E+01 2.860E-06 1.250E+01 2.843E-06
```

Table 25 (continued)

```
$TRAJ RS=30000.,IV=600.,DT=.[illegible],IL=5.[illegible]B,THTAIS=-79.[illegible]83,PHITS=90.1873,[illegible]=1.32,      ____________ Namelist TRAJ
TFL=0.,DF=26,TE=2500.,TN=469.,TS=340.,ETN=.8,ETS=.8,ETE=.8,
ASPECT=10.,TMAX=10.$
$SUN RLAT=45.,RLONG=0.,MON=1,DAY=28.,HR=14.,PHL=180.$                                                ____________ Namelist SUN
 6 34                                                                                                ____________ LOWTRAN Inputs
2.830E+03 1.245E+03 5.374E+02 2.257E+02 1.193E+02 8.992E+01 6.341E+01 5.893E+01
6.073E+01 5.822E+01 5.679E+01 5.320E+01 5.589E+01 5.159E+01 5.052E+01 4.747E+01
4.514E+01 4.460E+01 4.317E+01 3.636E+01 2.669E+01 1.935E+01 1.456E+01 1.114E+01
8.831E+00 7.434E+00 2.239E+00 5.893E-01 1.551E-01 4.084E-02 1.078E-02 5.553E-05
1.970E-08-0.
1.379E+04 5.034E+03 1.845E+03 6.735E+02 2.454E+02
  0.0 1.013E+03 300.0    1.9E 01     5.6E-05 1.013E+03 294.0     1.4E 01     6.0E-05
  1.0 9.040E+02 294.0    1.3E+01     5.6E-05 9.020E+02 290.0     9.3E+00     6.0E-05
  2.0 8.050E+02 288.0    9.3E+00     5.4E-05 8.020E+02 285.0     5.9E+00     6.0E-05
  3.0 7.150E+02 284.0    4.7E+00     5.1E-05 7.100E+02 279.0     3.3E+00     6.2E-05
  4.0 6.330E+02 277.0    2.2E+00     4.7E-05 6.280E+02 273.0     1.9E+00     6.4E-05
  5.0 5.590E+02 270.0    1.5E+00     4.5E-05 5.540E+02 267.0     1.0E+00     6.6E-05
  6.0 4.920E+02 264.0    8.5E-01     4.3E-05 4.870E+02 261.0     6.1E-01     6.9E-05
  7.0 4.320E+02 257.0    4.7E-01     4.1E-05 4.260E+02 255.0     3.7E-01     7.5E-05
  8.0 3.780E+02 250.0    2.5E-01     3.9E-05 3.720E+02 248.0     2.1E-01     7.9E-05


    1                                                                                                ____________ Input 19
    0                                                                                                ____________ Input 20
100.       180.                                                                                      ____________ Input 21
   10   20   20   30                                                                                 ____________ Input 22
    2   .5                                                                                           ____________ Input 31
   25   50   55   50                                                                                 ____________ Input 32
20000.     20000.                                                                                    ____________ Input 33
```

Table 26

Sample Output

```
ARRAY SIZE    I=    64   J=   64


        DUMMY BACKGROUND TAPE
 KEY  T(DEG K)     EMISS        RHO    RANGE(M)
 6        .124      .750       .900 20000.000
 8        .124      .600       .001 50000.000
 7        .124      .750       .100 20000.000
TRAJ MODE NO BANDS LOW BOUND(MICRONS) UPPER BND(MICRONS) TARGET NAME
     1         1             3.800              4.200      DUMMYTGT
                             0.000              0.000

 MODEL ATM HAZE OPT PATH TYPE EMISS NSAI ELV SENSOR(M)    INCREMENTS(MICRONS)
   2       1       2           1  1          15.00          .04000

                  SCAN TIME(SEC) OPTICS DIA(M) DETECTOR WIDTH(M) DETECTOR LENGTH(M) DETECTOR OVERLAP(M)
                       1.000           .100         .4000E-04          .4000E-03           .4000E-04
      FOCAL LENGTH(M)  CUTOFF FRED.(HZ)  BACKGROUND ELV(DEG)  RMS NOISE LEVEL(V)  PEAK RESPONSIVITY(V/W)  PEAK DSTAR(CM/HZ**2/W)
            .150         10000.000             80.000          .100000E-02          .100000E+09           .100000E+12

  WAVELENGTH         OPTICAL          DETECTIVITY      RESPONSIVITY      SOLAR IRRAD
  (MICRONS)        TRANSMISSION      (CM/HZ**2/W)         (V/W)          (W/CM**2)


  .377E+01          .800E+00          .853E+11          .853E+08          .797E-03
 .380E+01          .800E+00          .860E+11          .860E+08          .789E-03
 .384E+01          .800E+00          .868E+11          .868E+08          .771E-03
 .388E+01          .800E+00          .875E+11          .875E+08          .752E-03
 .391E+01          .800E+00          .883E+11          .883E+08          .727E-03
 .395E+01          .800E+00          .891E+11          .891E+08          .694E-03
 .399E+01          .800E+00          .898E+11          .898E+08          .659E-03
 .403E+01          .800E+00          .905E+11          .905E+08          .571E-03
 .407E+01          .800E+00          .912E+11          .912E+08          .468E-03
 .412E+01          .800E+00          .919E+11          .919E+08          .340E-03
 .416E+01          .800E+00          .926E+11          .926E+08          .168E-03
 .420E+01          .800E+00          .934E+11          .934E+08          0.
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Table 26 (continued)

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                    ***** TARGET INFORMATION *****

INIT. RANGE(M)  VELOCITY(M/SEC)  DIAMETER(M)  LENGTH(M)  THETA POSITION(DEG)  PHI POSITION(DEG)
  30000.000        600.000          .660        5.280          79.908              90.189

       NOSE LENGTH(M)  TAILPIPE DIA(M)  TAILPIPE TEMP(K)  NOSE TEMP(K)  SKIN TEMP(K)
           1.320           28.000           2500.000         409.000       348.000

            NOSE EMISSIVITY      SKIN EMISSIVITY      TAILPIPE EMISSIVITY
                 .800                 .800                   .800

                 VEIW ANGLE(DEG)              MAX. ENCOUNTER TIME(SEC)
                     10.000                          10.000

                         ***** SUN INFORMATION *****

                       LATITUDE(DEG)   LONGITUDE(DEG)
                           45.000           0.000

                       MONTH              DAY             HOUR
                         1                28.        14.

                               TRUE BEARING L.O.S(DEG)
                                       180.000
TARGET SIGNITURE(WATTS/STR/MICRON)
   MICRONS         NOSE           BODY          TAILPIPE        PLUME          TOTAL

    3.766          4.521          1.290          0.000         121.638        127.449
    3.802          4.709          1.364          0.000         121.316        127.389
    3.839          4.902          1.442          0.000         120.988        127.333
    3.876          5.101          1.524          0.000         120.654        127.279
    3.914          5.305          1.610          0.000         120.290        127.205
    3.953          5.515          1.699          0.000         119.841        127.055
    3.992          5.730          1.793          0.000         119.383        126.906
    4.032          5.951          1.891          0.000         118.915        126.757
    4.073          6.177          1.994          0.000         118.438        126.609
    4.115          6.409          2.100          0.000         518.530        527.038
    4.158          6.645          2.212          0.000        1365.238       1374.095
    4.202          6.887          2.328          0.000        2229.734       2238.949

    AREAS(M**2)
     NOSE             BODY             TAILPIPE        TOTAL
      .41              .61              0.00            1.02
AT TIME"     0.00000 TARGET SIZE IS      .1018E+01   50 M
TGT RANGE(M)       .3000E+05 TGT VOLTAGE      .5683E-01    0.
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Table 26 (continued)

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 TARGET SIGNITURE(WATTS/STR/MICRON)
    MICRONS        NOSE           BODY           TAILPIPE       PLUME          TOTAL

    3.766          4.521          1.290          0.000          121.638        127.449
    3.802          4.709          1.364          0.000          121.316        127.389
    3.839          4.902          1.442          0.000          120.988        127.333
    3.876          5.101          1.524          0.000          120.654        127.279
    3.914          5.305          1.610          0.000          120.290        127.205
    3.953          5.515          1.699          0.000          119.841        127.055
    3.992          5.730          1.793          0.000          119.383        126.906
    4.032          5.951          1.891          0.000          118.915        126.757
    4.073          6.177          1.994          0.000          118.438        126.609
    4.115          6.409          2.100          0.000          518.530        527.038
    4.158          6.645          2.212          0.000         1365.238       1374.095
    4.202          6.887          2.328          0.000         2229.734       2238.949

    AREAS(M**2)
     NOSE           BODY           TAILPIPE       TOTAL
      .41            .61           0.00           1.02
 AT TIME"     1.00000 TARGET SIZE IS      .1018E+01  SQ M
 TGT RANGE(M)      .2940E+05 TGT VOLTAGE      .5931E-01    0.
 TARGET SIGNITURE(WATTS/STR/MICRON)
    MICRONS        NOSE           BODY           TAILPIPE       PLUME          TOTAL

    3.766          4.521          1.290          0.000          121.638        127.449
    3.802          4.709          1.364          0.000          121.316        127.389
    3.839          4.902          1.442          0.000          120.988        127.333
    3.876          5.101          1.524          0.000          120.654        127.279
    3.914          5.305          1.610          0.000          120.290        127.205
    3.953          5.515          1.699          0.000          119.841        127.055
    3.992          5.730          1.793          0.000          119.383        126.906
    4.032          5.951          1.891          0.000          118.915        126.757
    4.073          6.177          1.994          0.000          118.438        126.609
    4.115          6.409          2.100          0.000          518.530        527.038
    4.158          6.645          2.212          0.000         1365.238       1374.095
    4.202          6.887          2.328          0.000         2229.734       2238.949

    AREAS(M**2)
     NOSE           BODY           TAILPIPE       TOTAL
      .41            .61           0.00           1.02
 AT TIME"     2.00000 TARGET SIZE IS      .1018E+01  SQ M
 TGT RANGE(M)      .2860E+05 TGT VOLTAGE      .6196E-01    0.
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Table 26 (continued)

1 NORMALIZED BACKGROUND

J	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
I 1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
I 2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
I 3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
I 4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
I 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
I 6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I 7	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I 8	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I 9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I11	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I12	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I14	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I15	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I16	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I17	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I18	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I19	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I20	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I26	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I27	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I29	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I30	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I34	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I36	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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I43	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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Table 26 (continued)

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Table 26 (continued)

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FROM COPY FURNISHED TO DDC

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 TGT RANGE(M)      .3000E+05 TGT VOLTAGE      .5683E-01    0.
1TRANSFORMED VALUE REAL    IMAG     SCALE FACTOR=  .10E+03  INTERVAL NO.  1
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 I62   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 9 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
 I63   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6 413 5 5 6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
 I64   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4 6 8 6 6 4 6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
```

Section 5

CONCLUSIONS

The initial development of the Infrared Search and Track System Evaluation Model is now complete; however, the refinements and modifications required to make the code more flexible and enable it to reach its full potential is far from complete. IRSTEM contains a number of unique features, which are expected to make it a valuable tool for analyzing electro-optical sensors. These features include the detailed, determinsitic background description which obviates the need for simplifying assumptions about the background statistics. The cloud reflection and radiation computations, the inclusion of sun glints and the ability to input detailed sensor characteristics are also expected to be useful analysis features. In addition, the separation of spectrally- and spatially-dependent effects, is expected to facilitate future IRSTEM modifications. The overall goal of this code is to produce an accurate time-history of the voltage response from each detector so that analysts can evaluate different signal processing techniques. Such analyses should predict the operational performance of surveillance sensors better than can now be done with the statistical background threshold-crossing processing analysis.

The code described in this report is now operating but has undergone only limited testing to date. It is expected that a series of modifications and corrections will be required to fully debug the program and bring it to its full potential. In addition, there are a number of limitations associated with the present version of IRSTEM which should be corrected as time allows. One of the major limitations is the small field-of-view which is necessitated by the tradeoff between the required sensor resolution and computer core limitations. It is felt that the basic 64 by 64 array of 0.2 mr pixels can provide statistically meaningful results without overloading the computer. If one wishes to increase the field-of-view, this can be done by inputting a larger array (IMAX, JMAX), incorporating larger pixels or imposing a moving background. The moving background approach could follow the target and access information from a data tape or simply, fold the background back upon itself as the target moves. The moving background would allow the user to have an effective larger background without increasing the core size or sacrificing sensor resolution.

Even with the size background now modelled in IRSTEM, the code may be too large for some users. Work is underway to reduce the code size by shortening the LOWEM subroutine and reducing the sun glint calculations. Another option is to split the code into two or more pieces. Referring back to Figure 23, one can see that there is a natural break point between the one-time-only calculations and the major time loop. In addition, if the target signature and glint calculations are moved to the one-time only calculations, the calls to LOWEM can be eliminated in the time-loop, and portions of the program can be overlaid to reduce the core size requirements.

Another limitation is the fact that the code models only radially inbound missiles. The graybody signature calculation used for these targets is a simplistic one, and the computations terminate when the target exceeds the pixel size. Finally, jitter and turbulence have not been incorporated into the code as of this time.

Work is underway to expand the capabilities of IRSTEM and eliminate many of the limitations identified above. However, even when these modifications are completed, there is still a large number of options available for increasing the flexibility and utility of IRSTEM. For example, one may wish to incorporate generalized trajectory and signature computations which are time-varying and allow the user to model target maneuvers and missile burnout. Another growth option is to predict false alarm rates. The present code is designed to analyze the probability of target detection against a variety of backgrounds but it is not optimum for analyzing false alarms because of its deterministic approach. There are techniques, however, which can be used to obtain statistical information on the false alarms using the random noise portion of the program. Finally, even though the present code is structured to model the wide field-of-view surveillance systems, the basic methodology is also applicable to FLIRS, reticle seekers and non-scanning sensors.

At present, it appears that IRSTEM testing should continue using existing hardware and field test data whenever available. In addition, it is now ready to predict the performance of advanced concepts. Performing such analyses will not only uncover subtle coding errors but also will lead to logic modifications which will improve the accuracy and utility of IRSTEM.

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Appendix A

IRSTEM Listings

```
      PROGRAM IRST(INPUT,OUTPUT,TAPE5,TAPE6=OUTPUT,TAPE1,TAPE3=TAPE5,TAP
     1E11,TAPE12,TAPE8)
C     PROGRAM IRSTM READS IN A BACKGROUND SCENE AND CONVERTS THE BACKGR
C     OUND TO A SIMULATED VOLTAGE.  A TARGET IS SUPERIMPOSED UPON THE
C     SCENE, AND ITS VOLTAGE CONTRIBUTATION CALCULATED.  THE VOLTAGE
C     ARRAY IS TRANSFORMED FOR EASE OF INCLUDING OPTICAL TRANSFER FCTS.
C     AND ELECTRONIC EFFECTS.  THE MODIFIED ARRAY IS RETRANSFORMED
C     AND NOISE IS ADDED.  IF THE ENCOUNTER TIME HAS NOT BEEN EXCEEDED
C     A NEW POSITION OF THE TARGET IS CALCULATED AND ITS PREVIOUS CALCUL
C     ATIONS ARE REPEATED.
C     INPUT DATA
C     *****************************************************************
C     TAPE 1 CONTAINS THE BACKGROUND
C     CARDS TO DEFINE BACKGROUND CODES.
C     KEY (I), TB(I), EB(I), RHO(I), RB(I)
C     I5, 4 F 10.3
C     SENSOR NAMELIST-
C     XLAML(1), XLAML(2), XLAML(3), XLAML(1), XLAML(2), XLAML(3), TF, D,
C     DX, DY, DLV, FL, FD, ELVS, RNOISE, RDFK, DSTRPH
C     LOWEN DATA
C     MODEL, IHAZE, ITYPE, IEMIS, HS, DV(1), DV(2), DV(3), NSAT
C     4F5, 4F10.3, I5
C     PLUME SIGNITURE TJP
C     N - NUMBER OF POINTS
C     (LAMBDA(I), TJP(I), I=1,N)
C     TRANSMISSION THRU THIS PLUME
C     TGTAU
C     N
C     (LAMBDA (I), TGTAU (I), I=1,N)
C     OPTICAL TRANSMISSION
C     N
C     (LAMBDA (I), TAUO(I), I=1,N)
C     DETECTOR RESPONSE
C     N
C     (LAMBDA(I), RD(I), I=1,N)
C     SOLAR SCATTER
C     N
C     (LAMBDA (I), SR (I), I=1,N)
C     TRAJECTORY NAMELIST
C     RS, TV, DT, TL, THT ATS, PHITS, THF TDL, DP, TE, TH, TS, ETH, ETS,
C     ETE, ASPECT, TMAX
                .
                .
```

```
C     ARRAY SIZE IS READ FIRST                                          A
C     IMAX, JMAX, NBUG                                                  A  43
C     3I5                                                               A  44
C     SUB NAMELIST                                                      A  45
C     RLAT, RLONG, MON, DAY, HR, PHL.                                   A  46
      DIMENSION HOL(5)                                                  A  47
      DIMENSION VARRY(64,64,6)                                          A  48
      DIMENSION IBKG(64,64)                                             A  49
      DIMENSION VT(3), VE(3)                                            A  50
      DIMENSION TVEFF(64,64,3), H(64,64,3), V(64,64,6)                  A  51
      DIMENSION EFF(64,64,3)                                            A  52
      EQUIVALE■

      EQUIVALENCE (VARRY(1,1,1),VEFF(1,1,1))                            A  53
      EQUIVALENCE (TVEFF(1,1,1),VEFF(1,1,1)), (H(1,1,1),VEFF(1,1,1))    A  54
      EQUIVALENCE (L,LL), (EFF(1,1,1),VEFF(1,1,1)), (V(1,1,1),VARRY(1,1, A  55
     11))                                                               A  56
      COMPLEX VEFF,TVEFF,EFF,H                                          A  57
      DIMENSION YNEW(100,3)                                             A  58
      EQUIVALENCE (DUM(1),YNEW(1,1))                                    A  59
      DIMENSION V12(20,3), VCODE(20,3)                                  A  60
      COMMON /INTG/ NFU(3),LL,BU(3),BL(3),DV,CV(3),NBANDS               A  61
      COMMON /INTP/ DUM(300),IFLAG,LM,VV                                A  62
      COMMON /LOW/ TAUA(100),APR(100)                                   A  63
      DIMENSION TOTRAN(2000)                                            A  64
      REAL INTERP                                                       A  65
      DIMENSION RH(299)                                                 A  66
      LOGICAL FIRST                                                     A  67
      COMMON /TTRAJ/ RS,TV,DT,TL,ELVS,THTATS,PHITS,TF,MODET,II,JJ,R,ASPE A  68
     1CT,T,AT,IERROR,TJ(100,3)                                          A  69
      COMMON /CLDS/ XX(200),YY(200)                                     A  70
      DIMENSION DV(3)                                                   A  71
      COMMON /REST/ TOTRAN,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IZ8,IZ9,IZ10,IZ11 A  72
     1,IZ12,RZ1,RZ2,RZ3,RZ4                                             A  73
      COMMON /GLT/ RLAT,RLONG,MON,DAY,HR,THL,PHL,IC1,IC2,IC3,IC4,IC5,IC6 A  74
     1,RD(100,3),TAUD(100,3),XLAMU(3),XLAML(3),VEFF(64,64,3),INIT       A  75
      DIMENSION LAVEL(16)                                               A  76
      COMMON /FRT/ IBKG,JMAX,IMAX,NBUG                                  A  77
      COMMON /POST/ ANGLE(12),FUNC(12)                                  A  78
      COMMON /INPT/ TB(40),EB(40),RHO(40),RB(40),KEY(40),TJP(100,3),SK(1 A  79
     100,3),IGTAU(100,3)                                                A  80
      COMMON /MISS/ THL,TFL,DF,TE,TN,TS,ETN,ETS,ETE                     A  81
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,HS,NSAT,UAVEL(100,3)       A  82
      COMMON /MISC/ D,FI,C1,C2,DEGRAD,H1,H2                             A  83
      DATA LAVEL/8HBACK GRD,8HUND VOLT,8HAGES AND,8H TARGET ,8HTRANSFOR, A  84
     18HMED VALU,8HES INVE,8HRSE     ,8HTRANSFOR,8HMED VALU,8HE REAL  , A  85
     28H IMAG   ,8HDETECTOR,8H ARRAY V,8HALUES   ,8H        /           A  86
      NAMELIST /SENSOR/ XLAML,XLAMU,TF,D,DX,DY,OVL,FL,FO,ELVS,VNOISE,RDF A  87
     1K,DSTRPK                                                          A  88
      NAMELIST /TRAJ/ RS,TV,DT,TL,THTATS,PHITS,THL,TPL,DF,TE,TN,TS,ETN,E A  89
     1TS,ETE,ASPECT,IMAX                                                A  90
```

```
      READ (5,60) IMAX,JMAX,NBUG
      WRITE (6,41) IMAX,JMAX
      NAMELIST /SUN/ KLAT,KLONG,MON,DAY,HR,FHL
      DATA ANGLE/180.,175.,170.,160.,150.,120.,90.,60.,30.,20.,10.,0./
      DATA FUNC/.0403,.6676,1.,1.335,2.22,2.62,2.28,1.352,.971,.5484,.24
     152,.1238/
      DATA IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IZ8,IZ9,IZ10,IZ11,IZ12,IZ13,RZ1,R
     1Z2,RZ3,RZ4/13*0,4*0.0/
      DATA (RN(I),I=1,146)/-.079343,-1.219219,.461698,.992233,-.775848,.
     1554658,-.554774,.230924,.134307,-.853128,-1.723917,.496544,-.93425
     24,1.519183,-.256887,.236455,-.467867,.014243,-.347621,-.522362,-1.
     3163270,-.496961,.224734,-.755291,.208158,-1.713393,-.675004,-.7809
     4990,-1.388274,1.115947,.812139,.500467,-.528072,1.155407,.529227,-
     5.494804,-1.237654,.299468,.33009,-.149923,1.020168,-1.013077,.6467
     6020,-.441183,.253016,-.250365,1.044540,-.316050,-.690995,-.755572,
     7.681744,-.617016,.460944,-.503854,-.656271,1.483586,.328147,1.6174
     856,-.256450,-.117613,-.942965,-.510706,-1.296794,-.371713,2.092287
     9,-.308648,-.861747,-.021191,-.409629,-1.068629,-.351413,-1.261653,
     $-1.011608,-.071583,.743032,-1.450166,1.928104,.748836,-.111069,1.3
     $28277,1.823332,-.826102,-.126024,-1.006961,-.110219,.755717,-.5171
     $80,.153062,.830632,-.071547,.377123,1.045123,.798937,1.377121,-1.2
     $96711,-3.397998,1.474625,.879686,1.055826,-.213243,2.305242,1.2989
     $06,.122910,.219585,.348630,1.005778,-.317466,-1.173369,-1.421907,.
     $118580,.811142,-.980075,.598512,-2.025535,.664510,-1.376610,.67924
     $7,.882073,.519743,.703484,2.314935,1.592211,-1.390256,.69925,2.334
     $924,-.254226,.486072,-.030223,-1.160253,.159651,.296202,-.531764,1
     $.096545,-.430281,-.983361,-.436159,-.307108,.263646,.507584,-.3417
     $97,-1.326200,.633723,.621773,-1.124973,-.531996,-.279486/
      DATA (RN(I),I=147,150)/1.132636,.014344,-.181414,.261777/
      DATA (RN(I),I=151,297)/.549519,-1.872473,-.094033,.265218,1.062945
     1,1.285046,1.339490,.031439,1.193713,-.313101,-.373977,-1.840981,.6
     223865,-.622982,.476768,.052121,.252179,.187947,.506665,-1.137752,.
     3302823,-2.498582,-.732063,1.339466,-1.504534,.147118,1.544656,-2.6
     476129,.051587,-.084305,-.292148,-.736274,-.787911,.689730,-.641899
     5,.364400,-1.085044,.137600,1.103296,.586549,-.166377,-.328896,1.16
     68238,-.438323,-.284081,1.608374,.494393,.931271,-.872138,-.104247,
     71.058953,.758130,.119628,-.066503,1.117407,1.815280,.551323,.00924
     88,-.032083,-1.523493,-1.008450,.658428,-.213077,.744066,.194250,-1
     9.010402,.859992,-.751910,-.857007,1.249041,-.324138,-2.026291,.027
     $315,-.160744,.037017,-2.813416,.499800,-.438329,.747917,-.744003,-
     $.760301,1.229735,.237972,-.274524,.929275,-2.449252,1.698399,1.851
     $132,-.806495,.509357,-.989149,.485074,-1.420839,-.635592,.033224,-
     $1.173086,-.356632,-.259743,.271913,1.610102,1.541936,.699285,-.651
     $230,-.737717,-.400923,-1.664935,-.545091,1.697278,-.151798,1.18337
     $5,.555535,.043408,1.887838,.879597,-1.381954,.132607,.337884,-1.61
     $0207,.780500,-.035048,-1.305691,-.509979,.680888,1.248494,-1.42712
     $1,.547559,-.042005,-1.970224,-.250219,-.590677,-.359893,.266280,-.
     $870298,-.541234,1.400853,-1.018725,.227413,-.155644,-.750996,.9478
     $59,1.295082,-.502726,3.358024,-.085002,.108730,1.763206,-.146116/
      DATA (RN(I),I=298,299)/.839923,-1.487772/
C       INITIALIZE CONSTANTS
```

```
      DATA FIRST/.TRUE./
      CL=2.997925E8
      HP=6.62554E-34
      HOK=4.79924E-11
      DEGRAD=3.14159365/180.
      IERROR=0
      IZERO=0
      C1=3.713E+04
      C2=1.4388E+04
      RBMIN=999999999999999.
      IFLAG=0
      PI=3.14159265
C       READ BKG TAPE
      READ (1,61) HOL,MXCODE
      WRITE (6,59) HOL
      READ (1,60) ((IBKG(I,J),I=1,IMAX),J=1,JMAX)
C     READ BACKGROUND CODE AND CORRESPONDING VALUES.
      WRITE (6,57)
      DO 1 I=1,MXCODE
      READ (5,52) KEY(I),TB(I),EB(I),RHO(I),RB(I)
    1 WRITE (6,58) KEY(I),TB(K),EB(I),RHO(I),RB(I)
      IF (NBUG.GT.0) WRITE (6,56) (J,J=1,JMAX),(I,(IBKG(I,J),J=1,JMAX),I
     1=1,IMAX)
C     MODIFY BACKGROUND ARRAY SO CODES BECOME INDICES.
      DO 4 I=1,IMAX
      DO 4 J=1,JMAX
      DO 2 K=1,MXCODE
      IF (IBKG(I,J).EQ.KEY(K)) GO TO 3
    2 CONTINUE
    3 IBKG(I,J)=K
      IF (KEY(K).EQ.1) IC1=K
      IF (KEY(K).EQ.2) IC2=K
      IF (KEY(K).EQ.3) IC3=K
      IF (KEY(K).EQ.4) IC4=K
      IF (KEY(K).EQ.5) IC5=K
      IF (KEY(K).EQ.6) IC6=K
    4 CONTINUE
C     FIND MAX AND MIN RANGE.
C     REPLACE DUPLICATE RANGES WITH AN APPROPRIATE INDEX.
      MX=MXCODE-1
      DO 6 K=1,MX
      L=K+1
      IF ((KEY(K)-5).LE.0) GO TO 6
      DO 5 M=L,MXCODE
      IF (RB(M).LT.100) GO TO 6
      IF (RB(K).LT.RBMIN) RBMIN=RB(K)
      IF (RB(K).GT.RBMAX) RBMAX=RB(K)
      IF (RB(M).EQ.RB(K)) RB(M)=K
    5 CONTINUE
    6 CONTINUE
C     READ SENSOR INFO., LOWER INFO., AND WAVE BANDS OF INTEREST
```

```
      READ (5,SENSOR)
      READ (5,54) MODET,NBANDS,XLAML(1),XLAMU(1),NAMET
      READ (5,53) MODEL,IHAZE,ITYPE,IEMIS,HS,DV,NSAI
      WRITE (6,42) MODET,NBANDS,XLAML(1),XLAMU(1),NAMET,(XLAML(J),XLAMU(
     1J),J=2,NBANDS)
      WRITE (6,43) MODEL,IHAZE,ITYPE,IEMIS,NSAI,HS,(DV(I),I=1,NBANDS)
      WRITE (6,44) TF,D,DX,DY,DVL,FL,FD,ELVS,VNOISE,RDPK,DSTRPK
      HI=HS+.001
C     CHANGE WAVELENGTH TO INVERSE CM.
      DO 7 L=1,NBANDS
      CV(L)=INT(10000.*DV(L)/(XLAML(L)*XLAML(L)))
      BL(L)=INT((10000./XLAMU(L))/5.)*5
      BU(L)=INT(((10000./XLAML(L))/5.)+1)*5
      CV(L)=INT(CV(L)/5.)*5.
      IF (CV(L).LT.5) CV(L)=5
      NPU(L)=((BU(L)-BL(L))/CV(L))
      IF (CV(L)*NPU(L)+BL(L).LT.BU(L)) NPU(L)=NPU(L)+1
      NPU(L)=NPU(L)+1
      LM=NPU(L)
      DO 7 I=1,LM
      M=LM-(I-1)
      WAVEL(M,L)=10000./(CV(L)*(I-1)+BL(L))
    7 CONTINUE
C      READ TARGET SIG
      CALL INTER
C     READ IN CURVES AND CHANGE UNITS OF WAVELENGTH TO INVERSE CM.
      DO 8 L=1,NBANDS
      LM=NPU(L)
      DO 8 I=1,LM
    8 TJP(I,L)=YNEW(I,L)
      CALL INTER
      DO 9 L=1,NBANDS
      LM=NPU(L)
      DO 9 I=1,LM
    9 TGTAU(I,L)=YNEW(I,L)
C      READ TRANMISIVITY OF OPTICS
      CALL INTER
      DO 10 L=1,NBANDS
      LM=NPU(L)
      DO 10 I=1,LM
   10 TAUO(I,L)=YNEW(I,L)
C      CALC DETECTOR RESPONSE
      CALL INTER
      DO 11 L=1,NBANDS
      LM=NPU(L)
      DO 11 I=1,LM
      TJ(I,L)=YNEW(I,L)
   11 RD(I,L)=YNEW(I,L)*(RDPK/DSTRPK)
C      SET FLAG FOR SOLAR DATA
      CALL INTER
      DO 12 L=1,NBANDS
```

```
      LM=NPW(L)
      DO 12 I=1,LM
   12 SR(I,L)=YNEW(I,L)
      WRITE (6,46)
      DO 13 L=1,NBANDS
      WRITE (6,45)
      LM=NPW(L)
      WRITE (6,47) (WAVEL(I,L),TAUO(I,L),TJ(I,L),KD(I,L),SR(I,L),I=1,LM)
   13 CONTINUE
C     READ TRAJECTORY INFO.
      READ (5,TRAJ)
      WRITE (6,48) RS,TV,DT,TL,THTATS,PHITS,TNL,DP,TE,TN,TS,ETN,ETS,ETE,
     1ASPECT,TMAX
      READ (5,SUN)
      WRITE (6,49) RLAT,RLONG,MON,DAY,HR,PHL
      ELVS=ELVS*DEGRAD
      PRD=IMAX*JMAX
      IF (NBUG.GT.0) WRITE (6,55) (J,J=1,JMAX),(I,(IBKG(I,J),J=1,JMAX),I
     1=1,IMAX)
C     ONE TIME ONLY CALCULATIONS.
      THTATS=THTATS*DEGRAD
      THETAS=THETAS*DEGRAD
      PHITS=PHITS*DEGRAD
      T=-TF
      I2=IMAX/2
      J2=JMAX/2
      J0=J2+1 ;     I0=I2+1
      IF (IMAX-(I2*2).GT.0) I0=I2
      IF (JMAX-J2*2.GT.0) J0=J2
      YC=2.E-04*FL
      VS=2.*PI*FL/TF
      Y=2.E-04*IMAX*FL
      X=2.E-04*JMAX*FL
      DELTAKX=2.*PI/X
      DELTAKY=2.*PI/Y
      ADET=DX*DY
      INL=(Y-DY)/(DY-OVL)+1.
      J=0
C     THIS BEGINS MAIN LOOP FOR FORMING
C     VOLTAGES TO REPRESENT BACKGROUND.
      DO 22 K=1,MXCODE
      IF (K.EQ.IC1.OR.K.EQ.IC2.OR.K.EQ.IC3.OR.K.EQ.IC4.OR.K.EQ.IC5) GO T
     1O 22
      IF (K.EQ.IC6) GO TO 22
      H2=H1+RB(K)*COS(ELVS)*.001
C     FORM FCTS. AND INTEGRATE FOR EACH WAVEBAND.
      DO 21 L=1,NBANDS
      LM=NPW(L)
      IF (RB(K).GT.100) GO TO 15
      V12(K,L)=V12(IFIX(RB(K)),L)
      JJ=(IFIX(RB(K))-1)*100
```

```
      DO 14 J=1,LM
   14 TAUA(J)=VARRY(JJ+J)
      GO TO 19
C      BOUNDS FOR LOWEN
   15 W1=XLAML(L)
      W2=XLAMU(L)
      VV=DV(L)
      S=RB(K)*.001
      LM=NPW(L)
      CALL LOWEN (MODEL,IHAZE,ITYPE,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IEMIS,RZ
     11,H1,H2,RZ2,S,RZ3,RZ4,W1,W2,VV,IZ8,J,IZ9,IZ10,IZ11,IZ12,TOTRAN,200
     20,NSAT)
      JJ=(K-1)*100
      DO 16 J=1,LM
   16 VARRY(JJ+J)=TAUA(J)
      DO 17 I=1,LM
   17 DUM(I)=APR(I)*TAUO(I,L)*RD(I,L)
      CALL INTEG
C      FIRST INTEGRAL FORMED AND INTEGRATED
      DUM(1)=DUM(1)+10.
      V12(K,L)=DUM(1)
      DO 18 I=1,LM
   18 DUM(I)=SR(I,L)*TAUA(I)*TAUO(I,L)*RD(I,L)
      CALL INTEG
C      SECOND INTEGRAL FORMED AND INTEGRATED
      V12(K,L)=V12(K,L)*RHO(K)*DUM(1)*10000./PI
   19 DO 20 I=1,LM
      XL=WAVEL(I,L)
      F=BLKBDY(TB(K),XL,C1,C2)
C      EMMITANCE CALC
   20 DUM(I)=F*TAUA(I)*TAUO(I,L)*RD(I,L)*1.E+04*EB(K)/PI
      CALL INTEG
C      THIRD INTEGRAL FORMED AND INTEGRATED
      VCODE(K,L)=(V12(K,L)+DUM(1))*D*D*PI*.00000001
   21 CONTINUE
   22 CONTINUE
      DO 23 L=1,NBANDS
      DO 23 I=1,IMAX
      DO 23 J=1,JMAX
   23 VEFF(I,J,L)=VCODE(IBKG(I,J),L)
      CALL SKYCLD
      WRITE (11) VEFF
   24 REWIND 11
      READ (11) VEFF
      CALL GLINT
C      CALL TRAJ ROUTINE TO FIND THE POSITION OF THE TARGET
      CALL TRAJR
      IF (IERROR.NE.0) STOP
      CALL TGTSIG
      ASPECK=1.
C      THIS CONSTANT WILL BE A FUNCION OF ANGLE
```

```
      DMT=AT/(R*R)
      WRITE (6,51) T,AT
      DO 27 L=1,NBANDS
      W1=XLAML(L)
      W2=XLAMU(L)
      VV=DV(L)
      S=R*.001
      H2=H1+S*COS(THTATS)
      LM=NPW(L)
C      CALL LOWEN FOR TARGET INFO
      LM=NPW(L)
      CALL LOWEN (MODEL,IHAZE,ITYPE,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IEMIS,RZ
     11,H1,H2,RZ2,S,RZ3,RZ4,W1,W2,VV,IZ8,J,IZ9,IZ10,IZ11,IZ12,TOTRAN,200
     20,NSAT)
      DO 25 I=1,LM
   25 DUM(I)=TJ(I,L)*TAUA(I)*RD(I,L)*TAUO(I,L)
      CALL INTEG
C      TARGET SIG FROTIN OF INTEGRAL FRMED AND INTEGRATED
      VT(L)=DUM(1)
      DO 26 I=1,LM
   26 DUM(I)=APR(I)*TAUO(I,L)*RD(I,L)*10.
      CALL INTEG
      VE(L)=DUM(1)
C      LAST PART OF TARGET  INCLDED
      VEFF(II,JJ,L)=VEFF(II,JJ,L)*(1.-DMT*.25E+08)*(D*D*PI*(VT(L)/(4.*R*
     1R)+VE(L))*.00000001))
      IFLAG=IZERO
      IF (DMT.GT.4.E-8) STOP
   27 CONTINUE
      DO 40 L=1,NBANDS
      IF (NBUG.NE.0) CALL SCALR (EFF(1,1,L),L,LAVEL)
      LM=NPW(L)
      ISIGN=-1
      AVGLAM=(XLAMU(L)+XLAML(L))*.5
      WRITE (6,50) R,VEFF(II,JJ,L)
      NUMBER=IZERO
      CALL FIX (ISIGN,NUMBER,EFF(1,1,L))
      IF (NBUG.GT.0) CALL SCALR (EFF(1,1,L),L,LAVEL(9))
C      TRANSFORM BACKGROUND PLUS TARGET
C     INCORPORATE DETECTOR SIZE, OPTICAL TRANSFORM FCT.,
C     AND ELECTRONICS EFFECTS.
      DO 28 I=1,IMAX
      DO 28 J=1,JMAX
   28 IBKG(I,J)=0
      DO 36 I=1,I2
      XK=I*DELTAKX
      XKD=XK*AVGLAM/(2.*PI*D)
      XDR=XK*DX*.5
      DO 36 J=1,J2
      YK=J*DELTAKY
      XYKD=AVGLAM*FL*SQRT(XK*XK+YK*YK)/(2.*PI*D)
```

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```
      YDR=YK*DY*.5
      IF (XYKO.GT.1.) XYKO=.9999
      OTF=2.*(ACOS(XYKO)-XYKO*SQRT(1.-XYKO*XYKO))/PI
      ELC=XK*VS/(2.*FI*FD)
      HELECT=1./(SQRT(1.+ELC*ELC))
      HDET=ADET*SIN(XDR)*SIN(YDR)/(XDR*YDR)
      IF (I+IO.GT.IMAX) GO TO 29
      IF (IBKG(I+IO,JO).NE.0) GO TO 29
      IBKG(I+IO,JO)=1
      H(I+IO,JO,L)=HDET*HELECT*OTF*TVEFF(I+IO,JO,L)
   29 CONTINUE
      IF (J+JO.GT.JMAX) GO TO 31
      IF (IBKG(IO,JO+J).NE.0) GO TO 30
      IBKG(IO,JO+J)=1
      H(IO,JO+J,L)=HDET*HELECT*OTF*TVEFF(IO,JO+J,L)
   30 CONTINUE
      IF (IO+I.GT.IMAX) GO TO 31
      IF (IBKG(IO+I,JO+J).NE.0) GO TO 31
      IBKG(IO+I,JO+J)=1
      H(IO+I,JO+J,L)=HDET*HELECT*OTF*TVEFF(IO+I,JO+J,L)
   31 CONTINUE
      IF (IO+I.GT.IMAX) GO TO 32
      IF (JO-J.LT.1) GO TO 33
      IF (IBKG(IO+I,JO-J).NE.0) GO TO 32
      IBKG(IO+I,JO-J)=1
      H(IO+I,JO-J,L)=HDET*HELECT*OTF*TVEFF(IO+I,JO-J,L)
   32 CONTINUE
      IF (JO-J.LT.1) GO TO 33
      IF (IO-I.LT.1) GO TO 34
      IF (IBKG(IO-I,JO-J).NE.0) GO TO 33
      IBKG(IO-I,JO-J)=1
      H(IO-I,JO-J,L)=HDET*HELECT*OTF*TVEFF(IO-I,JO-J,L)
   33 CONTINUE
      IF (JO+J.GT.JMAX) GO TO 34
      IF (IBKG(IO-I,JO+J).NE.0) GO TO 34
      IBKG(IO-I,JO+J)=1
      H(IO-I,JO+J,L)=HDET*HELECT*OTF*TVEFF(IO-I,JO+J,L)
   34 CONTINUE
      IF (I.EQ.1.AND.J.EQ.1) H(IO,JO,L)=HDET*HELECT*OTF*TVEFF(1,1,L)
      IF (IO-I.LT.1) GO TO 35
      IF (IBKG(IO-I,JO).NE.0) GO TO 35
      IBKG(IO-I,JO)=1
      H(IO-I,JO,L)=HDET*HELECT*OTF*TVEFF(IO-I,JO,L)
   35 IF (JO-J.LT.1) GO TO 36
      IF (IBKG(IO,JO-J).NE.0) GO TO 36
      IBKG(IO,JO-J)=1
      H(IO,JO-J,L)=HDET*HELECT*OTF*TVEFF(IO,JO-J,L)
   36 CONTINUE
      ISIGN=1
      NUMBER=1
      CALL FIX (ISIGN,NUMBER,EFF(1,1,L))
```

```
      IF (NBUG.NE.0) CALL SCALR (EFF(1,1,L),L,LAVEL(5))                 A 448
C     DO INVERSE TRANSFORM                                              A 449
      FIRST=.FALSE.                                                     A 450
      DO 37 I=1,IMAX                                                    A 451
      DO 37 J=1,JMAX                                                    A 452
      EFF(I,J,L)=EFF(I,J,L)/PRD                                         A 453
      ICOUNT=ICOUNT+1                                                   A 454
      IF (ICOUNT.GE.300) ICOUNT=1                                       A 455
      EFF(I,J,L)=EFF(I,J,L)+RN(ICOUNT)*VNOISE                           A 456
   37 CONTINUE                                                          A 457
      IF (NBUG.NE.0) CALL SCALR (EFF(1,1,L),L,LAVEL)                    A 458
C     FIND OUT WHAT EACH DETECTOR SEES.                                 A 459
      DO 39 IN=1,INL                                                    A 460
      DO 38 JX=1,JMAX                                                   A 461
      YI=(DY/2.)+(IN-1)*(DY-OVL)                                        A 462
      II=YI/YC+1                                                        A 463
      YNEW(JX)=VEFF(II,JX,L)                                            A 464
   38 CONTINUE                                                          A 465
      WRITE (12) (YNEW(JX),JX=1,JMAX)                                   A 466
   39 CONTINUE                                                          A 467
   40 CONTINUE                                                          A 468
      IF (T.GT.TMAX) STOP                                               A 469
      GO TO 24                                                          A 470
C                                                                       A 471
   41 FORMAT (1X,14HARRAY SIZE    ,3HI= ,I5,5H   J=,I5)                 A 472
   42 FORMAT (1X,68HTRAJ MODE NO BANDS LOW BOUND(MICRONS) UPPER BND(MICR A 473
     1ONS) TARGET NAME/1X4XI2,8XI1,9XF10.3,8XF10.3,6XA8/2(25XF10.3,9XF10 A 474
     2.3/))                                                             A 475
   43 FORMAT (1X,76H MODEL ATM HAZE OPT PATH TYPE EMISS NSAT ELV SENSOR( A 476
     1M)   INCREMENTS(MICRONS)/1X3XI2,7XI1,8XI2,8XI2,2XI1,5XF10.2,3X,3F1 A 477
     20.5/)                                                             A 478
   44 FORMAT (/20X,85HSCAN TIME(SEC) OPTICS DIA(M) DETECTOR WIDTH(M) DET A 479
     1ECTOR LENGTH(M) DETECTOR OVERLAP(M)/15X,F15.3,1X,F15.3,2X,E15.4,3X A 480
     2,E15.4,4X,E15.4/5X,98HFOCAL LENGTH(M)  CUTOFF FREQ.(HZ)  BACKGROUN A 481
     3D ELV(DEG)  RMS NOISE LEVEL(V)  PEAK RESPONSIVITY(V/W),24H  PEAK D A 482
     4STAR(CM/HZ**2/W)/1X,F15.3,2(3X,F15.3),3(6X,E15.6))                A 483
   45 FORMAT (1H0)                                                      A 484
   46 FORMAT (1H0,75H  WAVELENGTH          OPTICAL         DETECTIVITY   RES A 485
     1PONSIVITY    SOLAR IRRAD/75H    (MICRONS)        TRANSMISSION    (CM/ A 486
     2HZ**2/W)        (V/W)            (W/CM**2))                       A 487
   47 FORMAT (1X5(E10.3,6X))                                            A 488
   48 FORMAT (/45X,30H***** TARGET INFORMATION *****,//15X,95HINIT. RANG A 489
     1E(M)  VELOCITY(M/SEC)  DIAMETER(M)  LENGTH(M)  THETA POSITION(DEG) A 490
     2  PHI POSITION(DEG),/17X,F10.3,6X,F10.3,5X,F10.3,2X,F10.3,5X,F10.3 A 491
     3,5X,F10.3//23X,77HNOSE LENGTH(M)  TAILPIPE DIA(M)  TAILPIPE TEMP(K A 492
     4)  NOSE TEMP(K)  SKIN TEMP(K),/25X,F10.3,5XF10.3,8XF10.3,6XF10.3,4 A 493
     5XF10.3//30X,59HNOSE EMISSIVITY      SKIN EMISSIVITY      TAILPIPE EM A 494
     6ISSIVITY,/33X,F10.3,10X,F10.3,13X,F10.3//35X,50HVELTU ANGLE(DEG)  A 495
     7          MAX. ENCOUNTER TIME(SEC),/38X,F10.3,17X,F10.3)          A 496
   49 FORMAT (/48X,27H***** SUN INFORMATION *****,//44X,31HLATITUDE(DEG) A 497
     1     LONGITUDE(DEG)/46XF10.3,10X,F10.3//44X,35HMONTH            DAY   A 498
```

```
  2            HOUR/45XI3,11XF3.0,10XF3.0//50X,25HTRUE BEARING (.0.5(  A 499
  3DEG)  /55X,F10.3)                                                    A 500
 50 FORMAT (1X,13HTGT RANGE(M) ,E13.4,13H TGT VOLTAGE ,2E13.4)          A 501
 51 FORMAT (1X,10HAT TIME"  ,F10.5,17H TARGET SIZE IS  ,E12.4,6H  SQ M  A 502
  1)                                                                    A 503
 52 FORMAT (I5,4F10.3)                                                  A 504
 53 FORMAT (4I5,4F10.3,I5)                                              A 505
 54 FORMAT (2I5,2E10.3,A8)                                              A 506
 55 FORMAT (1H1,10X,21HNORMALIZED BACKGROUND/1X,1HJ,3X64I2/64(1X,1HI,I  A 507
  12,1X64I2/))                                                          A 508
 56 FORMAT (1H0,10X,10HBACKGROUND/1X,1HJ,3X64I2/64(1X,1HI,I2,1X64I2/))  A 509
 57 FORMAT (1X,44H KEY  T(DEG K)    EMISS       RHO    RANGE(M))        A 510
 58 FORMAT (1XI2,4F10.3)                                                A 511
 59 FORMAT (1H1,10X5A6)                                                 A 512
 60 FORMAT (15I5)                                                       A 513
 61 FORMAT (5A6,I5)                                                     A 514
    END                                                                 A 515
```

```
      REAL FUNCTION INTERP (X,Y,N,ARG)
C     THIS FUNCTION INTERPOLATES THE GIVEN CURVE FOR ANGULAR DEPENDENCE
C     OF PLUME INTENSITY.
      DIMENSION X(12), Y(12)
      IF (X(1).LT.X(N)) GO TO 2
      IF (ARG.LT.X(N)) GO TO 5
      IF (ARG.GT.X(1)) GO TO 4
      DO 1 I=1,N
      IF (ARG-X(I)) 1,6,7
    1 CONTINUE
      GO TO 5
    2 IF (ARG.LT.X(1)) GO TO 5
      DO 3 I=1,N
      IF (X(I)-ARG) 3,6,7
    3 CONTINUE
    4 INTERP=Y(N)
      RETURN
    5 INTERP=Y(1)
      RETURN
    6 INTERP=Y(I)
      RETURN
    7 INTERP=Y(I-1)+(Y(I)-Y(I-1))*(ARG-X(I-1))/(X(I)-X(I-1))
      RETURN
      END
      SUBROUTINE INTER
C     THIS ROUTINE READS IN THE FOLLOWING  TJP, TGTAU, TAUO, KD, SR AS
C     FUNCTIONS OF WAVELENGTHS.  THE WAVEBANDS OF INTEREST ARE ISOLATED
C     AND UP TO 3 CURVES ARE CALCULATED USING LINEAR INTERPOLATION
      COMMON /INTP/ YNEW(100,3),IFLAG,N
      COMMON /CLDS/ XX(200),YY(200)
      COMMON /INTG/ NFW(3),LL,BU(3),BL(3),DV,CV(3),NBANDS
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,NS,NSAT,WAVEL(100,3)
      DIMENSION DV(3)
      IF (IFLAG.GE.5) GO TO 1
      READ (5,9) N
      IF (IFLAG.EQ.0) READ (5,8) (XX(I),YY(I),I=1,N)
      IF (IFLAG.EQ.1) READ (5,7) (XX(I),YY(I),I=1,N)
      IF (IFLAG.GE.2) READ (5,10) (XX(I),YY(I),I=1,N)
    1 CONTINUE
      IFLAG=IFLAG+1
      DO 5 L=1,NBANDS
      LM=NFW(L)
      DO 5 MM=1,LM
      XLAM=WAVEL(MM,L)
      IF (XLAM.GT.XX(1)) GO TO 2
```

```
      THEW(MM,L)=YY(1)
      GO TO 5
    2 IF (XLAM.LT.XX(N)) GO TO 3
      THEW(MM,L)=YY(N)
      GO TO 5
    3 CONTINUE
      DO 4 J=2,N
      IF (XLAM.GT.XX(J).OR.XLAM.LT.XX(J-1)) GO TO 4
      THEW(MM,L)=YY(J-1)+((XLAM-XX(J-1))/(XX(J)-XX(J-1)))*(YY(J)-YY(J-1)
     1)
    4 CONTINUE
    5 CONTINUE
    6 CONTINUE
C
    7 FORMAT (9XF7.4,52XF6.4)
    8 FORMAT (4(F12.3,E8.2))
    9 FORMAT (I5)
   10 FORMAT (8E10.3)
      END
      SUBROUTINE SCALR (EFF,L,LAVEL)
C     THE ROUTINE SCALES THE 64 BY 64 ARRAY AND REPRESENTS IT AS
      DIMENSION LAVEL(4)
      DIMENSION EFF(64,64,1)
      DIMENSION IBKG(64,64)
      COMMON /PRT/ IBKG,JMAX,IMAX
      COMMON /PRT1/ NG(40,2),NOGLT
      COMPLEX EFF
      AVER=0.
      XMAX=0.
      XMIN=1.E+99
      DO 1 I=1,IMAX
      DO 1 J=1,JMAX
      DO 1 K=1,NOGLT
      IF (I.EQ.NG(K,1).AND.J.EQ.NG(K,2)) GO TO 1
      A=SQRT(REAL(EFF(I,J,1))**2+AIMAG(EFF(I,J,1))**2)
      IF (A.LT.XMIN) XMIN=A
      IF (A.GT.XMAX) XMAX=A
    1 CONTINUE
    2 CONTINUE
      DO 3 I=1,40
      EX=10.**(I-1)
      IF (XMIN.GE.100.) EX=1./EX
      IF (XMIN*EX.GE.1..AND.XMIN*EX.LT.100.) GO TO 4
    3 CONTINUE
    4 CONTINUE
      DO 5 I=1,64
      DO 5 J=1,64
    5 IBKG(I,J)=EX*SQRT(REAL(EFF(I,J,1))**2+AIMAG(EFF(I,J,1))**2)
      WRITE (6,6) LAVEL,EX,L,(J,J=1,JMAX),(I,(IBKG(I,J),J=1,JMAX),I=1,IM
     1AX)
      IF (XMAX*EX-XMIN*EX.LE.91) RETURN
```

```
      XMIN=XMAX
      GO TO 2
      RETURN
C
    5 FORMAT (1H1,4A8,15H SCALE FACTOR= ,E8.2,15H  INTERVAL NO. ,I2/1X,1
     1HJ,3X64I2/64(1X,1HI,I2,1X64I2/))
      END
      SUBROUTINE TRAJR
C     THIS ROUTINE CALCULATES THE RANGE AND POSITION OF THE TARGET AS A
C     FUNCTION OF TIME.
      COMMON /ITRAJ/ RS,VT,DT,TL,ELVS,THIATS,PHITS,TF,MODET,II,JJ,R,ASPE
     1CTR,T,IERROR
      COMMON /PRT/ BKG(64,64),JMAX,IMAX
      T=T+TF
      R=RS-VT*T
      II=(-1000.*(-ELVS+THIATS)*FLOAT(IMAX)/10.)+5.+1.
      JJ=5000.*(PHITS-1.5707)*FLOAT(JMAX)/2.+1.
      IF (II.GT.IMAX.OR.JJ.GT.JMAX) WRITE (6,1)
      IF (II.GT.IMAX.OR.JJ.GT.JMAX) IERROR=1
      IF (II.LT.1.OR.JJ.LT.1) WRITE (6,1)
      IF (II.LT.1.OR.JJ.LT.1) IERROR=1
      RETURN
C
    1 FORMAT (1X,24HERROR ON TARGET POSITION)
      END
      SUBROUTINE INTEG
C     THIS ROUTINE USES A SIMPLE TRAPOZOIDAL INTEGRATION METHOD
      COMMON /INTG/ NPW(3),L,BU(3),BL(3)
      COMMON /INTP/ Y(300),IFLAG,N,H
      INTEGER N
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,HS,NSAT,WAVEL(100,3)
      NM1=N-1
      DI=0.
      SUM1=0.
      SUM2=0.
      DO 1 I=1,NM1
      DX=WAVEL(I+1,L)-WAVEL(I,L)
      DX=ABS(DX)
      SUM1=SUM1+DX*Y(I)
      SUM2=SUM2+DX*Y(I+1)
    1 CONTINUE
      Y(1)=(SUM1+SUM2)/2.
      RETURN
C
      END
      SUBROUTINE FIX (ISIGN,NUMBER,U)
C     THIS ROUTINE CALLS THE FAST FOURIER TRANSFORM AND REORDERS THE
C     RESULT OF THE TRANSFORMATION.
      DIMENSION NN(2)
      COMMON /PRT/ IBKG(64,64),JMAX,IMAX,NBUG
      DIMENSION U(64,64)
```

```
      COMPLEX U
      DIMENSION LAVEL(16)
      COMPLEX A1,A2,A3,A4
      DATA LAVEL/16*8H        /
      NN(1)=IMAX
      NN(2)=JMAX
      MLM=64
      MLH=MLM/2
      CALL FOURT (U,NN,2,ISIGN,NUMBER,DUMB)
      DO 1 I=1,MLH
      DO 1 J=1,MLH
      IP=I+MLH
      JP=J+MLH
      A1=U(I,J)*NODD(I+J)
      A2=U(IP,JP)*NODD(IP+JP)
      A3=U(I,JP)*NODD(I+JP)
      A4-U(IP,J)*NODD(IP+J)
      U(I,J)=A2
      U(IP,JP)=A1
      U(IP,J)=A3
      U(I,JP)=A4
    1 CONTINUE
      RETURN
C
      END
      SUBROUTINE SKYCLD
C     THE ROUTINE READS IN THE RADIANCE DUE TO CLOUDS, LOCATES THE SUN
C     OBSERVER AND CLOUD CALCULATES THE SIMULATED VOLTAGE DUE TO CLOUD,
C     CLEAR SKY, AND HAZE.
      COMMON /CLDS/ ZR(200),XR(200)
      DIMENSION YR(8)
      DIMENSION SZA(2,7), AZA(2,7), VA(2,7)
      DIMENSION NI(8), NJ(8), XINT(3)
      COMMON /INTG/ NFU(3),LL,BU(3),BL(3),BV(3),CV(3),NBANDS
      COMMON /LOW/ TAUA(100),AFR(100)
      COMMON /INTP/ DUM(300),IFLAG,LM,HH
      COMMON /REST/ TOTRAN,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IZ8,IZ9,IZ10,IZ11
     1,IZ12,KZ1,KZ2,KZ3,KZ4
      COMMON /ANG/ THO,TH,PH,THN,PHN,ALT,TRUEB
      COMMON /GLT/ RLAT,RLONG,MON,DAY,HR,THL,PHL,IC1,IC2,IC3,IC4,IC5,IC6
     1,RD(100,3),TAUD(100,3),XLAMU(3),XLAML(3),VEFF(64,6,3),INIT
      DIMENSION CLD(100,3)
      COMMON /ITRAJ/ KS,IV,DT,TL,ELVS,THTATS,PHITS,IF,MODEL,IJ,JI,K,ASPE
     1CT,T,AT,IERROR,IJ(100,3)
      COMMON /INPT/ IB(40),EB(40),RHO(40),RD(40),KEY(40),IJP(100,3),SR(1
     100,3),IGTAU(100,3)
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,HS,NSAT,WAVEL(100,3)
      COMMON /MISC/ D,PI,C1,C2,DEGRAD,H1,H2
      DIMENSION YNEW(100,3), TOTRAN(2000)
      EQUIVALENCE (DUM(1),YNEW(1,1))
      COMPLEX VEFF
```

```
      DATA (SZA(1,J),J=1,7)/0.,15.,30.,45.,60.,75.,85./                 H  27
      DATA (AZA(1,J),J=1,5)/0.,45.,90.,135.,180./                       H  28
      DATA (VA(1,J),J=1,7)/0.,15.,30.,45.,60.,75.,85./                  H  29
      DATA (VA(2,J),J=1,6)/0.,2.,4.,6.,8.,10./                          H  30
      DATA (SZA(2,J),J=1,6)/0.,2.,4.,6.,8.,10./                         H  31
      DATA (AZA(2,J),J=1,5)/0.,45.,90.,135.,180./                       H  32
      DATA YK/2.,3.,4.,5.,6.,8.,10.,14./                                H  33
      DO 1 I=1,8                                                        H  34
    1 ZK(I)=YK(I)                                                       H  35
      KK=IC1                                                            H  36
      LM=8                                                              H  37
      CALL SUNLOC                                                       H  38
      THL=180.*DEGRAD-ELVS                                              H  39
      XLOS=90.*DEGRAD-ALT                                               H  40
      THO=0.                                                            H  41
      TH=ABS(XLOS-ELVS)                                                 H  42
      FH=ABS(TRUEB-PHL)                                                 H  43
      NORM=1                                                            H  44
      IF (IC1.EQ.0) GO TO 2                                             H  45
      IC=1                                                              H  46
      NORM=1                                                            H  47
      GO TO 11                                                          H  48
    2 IF (IC6.NE.0) GO TO 3                                             H  49
      CALL DUMK                                                         H  50
      IF (IC4.NE.0) GO TO 5                                             H  51
      CALL DUMK                                                         H  52
      IF (IC5.NE.0) GO TO 7                                             H  53
      CALL DUMK                                                         H  54
      IF (IC2.NE.0) GO TO 8                                             H  55
      CALL DUMK                                                         H  56
      IF (IC3.NE.0) GO TO 9                                             H  57
      RETURN                                                            H  58
    3 CONTINUE                                                          H  59
      READ (5,33) NORM                                                  H  60
      KK=IC6                                                            H  61
      IC=6                                                              H  62
      IC6=0                                                             H  63
    4 CONTINUE                                                          H  64
      N=1                                                               H  65
      LJM=245                                                           H  66
      ICI=7                                                             H  67
      ICJ=5                                                             H  68
      ICK=7                                                             H  69
      GO TO 10                                                          H  70
    5 CONTINUE                                                          H  71
      KK=IC4                                                            H  72
      IC=4                                                              H  73
      IC4=0                                                             H  74
    6 CONTINUE                                                          H  75
      N=2                                                               H  76
      LJM=180                                                           H  77
```

```
      ICI=6
      ICJ=5
      ICK=6
      ICJ=0
      NORM=1
      GO TO 11
    7 IC=5
      KK=IC5
      IC5=0
      GO TO 6
    8 IC=2
      KK=IC2
      IC2=0
      GO TO 4
    9 IC=3
      KK=IC3
      IC3=0
      GO TO 4
   10 CONTINUE
   11 CONTINUE
      DO 30 M=1,NORM
      READ (5,33) NOCELS
      IF (IC.EQ.6) READ (5,31) THN,PHN
      IF (IC.EQ.1) GO TO 19
      IF (IC.EQ.6) CALL GETANG
      THO=THO/DEGRAD
      FH=FH/DEGRAD
      TH=TH/DEGRAD
      DO 12 I=1,8
      XK(I)=0.
   12 YK(I)=0.
      CALL FIND (THO,ICI,SZA,I1,I2,DI)
      CALL FIND (FH,ICJ,AZA,J1,J2,DJ)
      LM=8
      CALL FIND (TH,ICK,VA,K1,K2,DK)
      IK=ICK*(ICJ*(I1-1)+J1-1)+K1
      IQ=ICK*(ICJ*(I2-1)+J2-1)+K2
      DO 13 II=1,IK
   13 READ (8,34) (XK(J),J=1,8)
      IF (IK.EQ.IQ) GO TO 15
      IP=IQ-IK
      IF (IQ.GT.LJM) GO TO 17
      DO 14 II=1,IP
   14 READ (8,34) (YK(J),J=1,8)
   15 CONTINUE
      DI=(DI+DJ+DK)/3.
      DO 16 J=1,8
      XK(J)=XK(J)+(YK(J)-XK(J))*DI
   16 CONTINUE
   17 CONTINUE
      CALL INTER
```

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```
      DO 18 L=1,NBANDS
      LM=NPW(L)
      DO 18 I=1,LM
   18 CLD(I,L)=YNEW(I,L)
   19 CONTINUE
      DO 23 L=1,NBANDS
      LL=L
      W1=XLAML(L)
      W2=XLAMU(L)
      VV=DV(L)
      S=KB(KK)*.001
      H1=H2*COS(ELVS)*KB(KK)*.001
      J=10
      LM=NPW(L)
      CALL LOWEN (MODEL,IHAZE,ITYPE,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IEMIS,KZ
     11,H1,H2,KZ2,S,KZ3,KZ4,W1,W2,VV,IZ8,J,IZ6,IZ10,IZ11,IZ12,TOTRAN,200
     20,NSAT)
      DO 20 I=1,LM
   20 DUM(I)=APR(I)*TAUO(I,L)*RD(I,L)
      CALL INTEG
      XINT(L)=DUM(1)*10.
      IF (IC.NE.1) GO TO 21
      XINT(L)=XINT(L)*D*D*PI*.00000001
      GO TO 23
   21 DO 22 I=1,LM
   22 DUM(I)=CLD(I,L)*TAUO(I,L)*RD(I,L)*TAUA(I)
      CALL INTEG
      XINT(L)=(XINT(L)+DUM(1))*PI*D*D*.00000001
   23 CONTINUE
      IF (NOCELS.NE.0) GO TO 25
      READ (5,32) ICMIN,ICMAX,JCMIN,JCMAX
      DO 24 L=1,NBANDS
      DO 24 I=ICMIN,ICMAX
      DO 24 J=JCMIN,JCMAX
   24 VEFF(I,J,L)=XINT(L)
      GO TO 29
   25 CONTINUE
      DO 28 I=1,NOCELS,8
      READ (5,32) (NI(K),NJ(K),K=1,8)
      DO 27 L=1,NBANDS
      DO 26 K=1,8
      IF (NI(K).EQ.0) GO TO 27
   26 VEFF(NI(K),NJ(K),L)=XINT(L)
   27 CONTINUE
   28 CONTINUE
   29 CONTINUE
   30 CONTINUE
      REWIND 8
      GO TO 2
C
   31 FORMAT (2E10.3)
```

```
   32 FORMAT (16I5)
   33 FORMAT (I5,2E10.3)
   34 FORMAT (6X8E9.4)
      END
      SUBROUTINE DUMR
C     THIS ROUTINE DUMMY READS THE CLOUD RADIANCE RECORDS FOR THOSE NOT
C     USED.
    1 CONTINUE
      READ (8,3) IA
      IF (EOF(8)) 2,1
    2 RETURN
C
    3 FORMAT (A1)
      END
      SUBROUTINE TGTSIG
      REAL BLKBDY
      REAL INTERP
      COMMON /ITRAJ/ RS,TV,DT,TL,ELVS,THTATS,PHITS,TF,MODET,II,JJ,K,ASPE
     1CT,T,AT,IERROR,TJ(100,3)
      COMMON /INTG/ NPW(3),LL,BU(3),BL(3),DV(3),CV(3),NBANDS
      COMMON /MISS/ TNL,TPL,DP,TE,TN,TS,ETN,ETS,ETE
      COMMON /POST/ ANGLE(12),FUNC(12)
      COMMON /INPT/ TB(40),EB(40),RHO(40),RB(40),KEY(40),TJP(100,3),SK(1
     100,3),TGTAU(100,3)
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,HS,NSAT,WAVEL(100,3)
      COMMON /MISC/ D,PI,C1,C2,DEGRAD,H1,H2
C     THIS ROUTINE CALCULATES THE TOTAL TARGET SIGNITURE AND PRESENTED
C     AREA.
      FACTN=1.
      FACTOR=0.
      WRITE (6,2)
      FACTN=COS(ASPECT*DEGRAD)
      IF (ASPECT.GE.90.) FACTN=0.
      IF (ASPECT.GE.90.) FACTOR=COS(ASPECT*DEGRAD)
      AT=0.
      FF=INTERP(ANGLE,FUNC,12,ASPECT)
      AE=DP*DP*PI*.25*FACTOR*(-1.)*1.E+04
      ASPECTR=ASPECT*DEGRAD
      AN=PI*DT*DT*.25*FACTN*DT*TNL*.5*SIN(ASPECTR)
      AN=AN*1.E+04
      AS=TL*DT*SIN(ASPECTR)*10000.
      DO 1 L=1,NBANDS
      LM=NPW(L)
      DO 1 I=1,LM
      XL=WAVEL(I,L)
      TT=TE
      TERM=ETE*BLKBDY(TT,XL,C1,C2)/PI
      PART1=TERM*TGTAU(I,L)*AE
      TT=TN
      TERM=ETN*BLKBDY(TT,XL,C1,C2)/PI
      PAR2=TERM*AN
```

```
      TT=TS
      TERM=ETS*BLKBDY(TT,XL,C1,C2)/PI
      PAR3=TERM*AS
      PAR4=TJP(I,L)*FP
      TJ(I,L)=PAR1+PAR2+PAR3+PAR4
      WRITE (6,3) WAVEL(I,L),PAR2,PAR3,PAR1,PAR4,TJ(I,L)
    1 CONTINUE
      AN=AN*.0001
      AS=AS*.0001
      AE=AE*.0001
      AT=AN+AS+AE
      WRITE (6,4) AN,AS,AE,AT
      RETURN
C
    2 FORMAT (1X,34HTARGET SIGNITURE(WATTS/STR/MICRON)/5X,80H MICRONS
     1    NOSE             BODY             TAILPIPE      PLUME          TO
     2TAL/)
    3 FORMAT (1X6(F10.3,5X))
    4 FORMAT (1H0,5X,11HAREAS(M**2)/6X,51H NOSE            BODY
     1 TAILPIPE        TOTAL/1X4(F10.2,5X))
      END
      REAL FUNCTION BLKBDY (TT,XL,C1,C2)
C     THIS FUNCTION FINDS THE BLACK BODY RADIATION.
      IF (TT.LE..1) GO TO 1
      BLKBDY=C1/(XL**5*(EXP(C2/(XL*TT))-1.))
      RETURN
    1 BLKBDY=0.
      RETURN
      END
      SUBROUTINE FIND (THO,ICI,SZA,J1,J2,D)
C     THIS ROUTINE FINDS THE TWO CURVES OF PATH RADIANCE FOR INTERPOLA
C     TION.
      DIMENSION SZA(8)
      J1=0
      DO 1 I1=1,ICI
      IF (THO.GT.SZA(I1)) GO TO 1
      IF (THO.EQ.SZA(I1)) GO TO 2
      J2=I1
      GO TO 3
    1 J1=I1
      J1=ICI
      D=(THO-SZA(J1))/(360.-SZA(J1))
      J2=J1
      RETURN
      GO TO 3
    2 J1=J2=I1
      D=0.
      RETURN
    3 CONTINUE
      IF (J1.EQ.0) GO TO 2
      D=(THO-SZA(J1))/(SZA(J2)-SZA(J1))
```

```
      RETURN                                                            L  23
      END                                                               L  24
      SUBROUTINE SUNLOC                                                 M   1
C     THIS ROUTINE LOCATES THE SUN GIVEN THE LONGITUDE, LATITUDE, TIME  M   2
C     AND POSITION OF THE OBSERVER.                                     M   3
      COMMON /GLT/ RLAT,RLONG,MON,DAY,HR,THL,PHL,IC1,IC2,IC3,IC4,IC5,IC6 M   4
     1,RS(100,3),TAUO(100,3),XLAMU(3),XLAML(3),VEFF(64,64,3)            M   5
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,NS,NSAI,WAVEL(100,3)       M   6
      COMMON /IMPT/ TB(40),EB(40),RHO(40),RB(40),KEY(40),TJP(100,3),SR(1 M   7
     100,3),TGTAU(100,3)                                                M   8
      COMMON /ANG/ THO,TH,PH,THN,PHN,ALTS,TRUEB                         M   9
      EQUIVALENCE (RLAT,LAT), (RLONG,LONG)                              M  10
      COMMON /MISC/ D,PI,C1,C2,DEGRAD,H1,H2                             M  11
      COMPLEX VEFF                                                      M  12
      REAL LAT,LONG,LHA                                                 M  13
      CONV=DEGRAD                                                       M  14
      TEMP1=(30.*(MON-1)+DAY-80)*CONV                                   M  15
      DEC=(23.4*SIN(TEMP1)+0.5)*CONV                                    M  16
      TEMP2=TEMP1+1.483529864                                           M  17
      ET=-1.8*SIN(TEMP2)-2.5*SIN(2*TEMP2)+0.4*SIN(1.5*TEMP2)-0.1        M  18
      GHA=180+15*HR+ET                                                  M  19
      LHA=(GHA-LONG)*CONV                                               M  20
      LAT=LAT*CONV                                                      M  21
      ALT=ASIN(SIN(LAT)*SIN(DEC)+COS(LAT)*COS(DEC)*COS(LHA))            M  22
      TRUEB=ACOS((SIN(DEC)-SIN(ALT)*SIN(LAT))/(COS(ALT)*COS(LAT)))      M  23
      IF (SIN(LHA).GT.0) TRUEB=2*PI-TRUEB                               M  24
      RETURN                                                            M  25
      END                                                               M  26
      SUBROUTINE GETANG                                                 N   1
C     THIS ROUTINE FINDS THE ANGLES, WITH RESPECT TO THE CLOUD NORMAL,  N   2
C     OF THE SUN AND OBSERVER.                                          N   3
      COMMON /GLT/ RLAT,RLONG,MON,DAY,HR,THL,PHL,IC1,IC2,IC3,IC4,IC5,IC6 N   4
     1,RB(100,3),TAUO(100,3),XLAMU(3),XLAML(3),VEFF(64,6,3),INIT        N   5
      COMMON /ANG/ THO,TH,PH,THN,PHN,ALT,TRUEB                          N   6
      COMMON /MISC/ D,PI,C1,C2,DEGRAD,H1,H2                             N   7
      EQUIVALENCE (THO,THO)                                             N   8
      COMPLEX VEFF                                                      N   9
      PH=0                                                              N  10
      THS=PI/2.-ALT                                                     N  11
      PHS=TRUEB                                                         N  12
      IF (THN.EQ.0) GO TO 3                                             N  13
      THO=ACOS(SIN(THN)*SIN(THS)*COS(PHN-PHS)+COS(THN)*COS(THS))        N  14
      TH=ACOS(SIN(THN)*SIN(THL)*COS(PHN-PHL)+COS(THN)*COS(THL))         N  15
    1 CONTINUE                                                          N  16
      IF (TH.EQ.0.OR.THO.EQ.0) GO TO 2                                  N  17
      CTHD=SIN(THS)*SIN(THL)*COS(PHS-PHL)+COS(THS)*COS(THL)             N  18
      PH=PI-ACOS((CTHD-COS(TH)*COS(THO))/(SIN(TH)*SIN(THO)))            N  19
    2 CONTINUE                                                          N  20
      RETURN                                                            N  21
    3 TH=THL                                                            N  22
      THO=THS                                                           N  23
```

```
      GO TO 1
      END
      SUBROUTINE GLINT
C     THIS ROUTINE CALCULATES THE VOLTAGES DUE TO GLINT POINTS.
C     THE GLINT POINTS ARE PREDETERMINED BUT ARE TURNED ON WITH A RANDOM
C     NUMBER CALL.
      COMMON /ITRAJ/ RS,TV,DT,TL,ELVS,THTATS,PHITS,TF,MODEI,II,JJ,K
      COMMON /INTG/ NPU(3),LL,BU(3),BL(3),BV(3),CV(3),NBANDS
      COMMON /LOU/ TAUA(100),APR(100)
      COMMON /INTP/ DUM(300),IFLAG,LM,MM
      COMMON /REST/ TOTRAN,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IZ8,IZ9,IZ10,IZ11
     1,IZ12,RZ1,RZ2,RZ3,RZ4
      COMMON /GLT/ RLAT,RLONG,MON,DAY,HR,THL,PHL,IC1,IC2,IC3,IC4,IC5,IC6
     1,RD(100,3),TAUD(100,3),XLAMU(3),XLAML(3),VEFF(64,64,3),INIT
      COMPLEX VEFF
      DIMENSION TOTRAN(2000)
      COMMON /PRIT1/ NG(40,2),NOGLT
      DIMENSION VGLNT(40,3)
      COMMON /CONST/ MODEL,IHAZE,ITYPE,IEMIS,HS,HSAT,WAVEL(100,3)
      COMMON /IMPT/ TB(40),EB(40),RHO(40),RB(40),KEY(40),TJP(100,3),SR(1
     100,3),IGTAU(100,3)
      COMMON /MISC/ D,PI,C1,C2,DEGRAD,H1,H2
      DIMENSION RGLNT(40)
      CONSTK=.833*2800./PI
      IF (INIT.NE.0) GO TO 3
      INIT=1
      READ (5,7) NOGLT,PSG
      READ (5,6) (NG(I,1),NG(I,2),I=1,NOGLT)
      READ (5,5) (RGLNT(I),I=1,NOGLT)
      DO 2 J=1,NOGLT
      DO 2 L=1,NBANDS
      XBAR=(XLAML(L)+XLAMU(L))*.5*1.E-04
      SUNGK=CONSTK*(30.+.02*RGLNT(J)*100.*XBAR)**(-2)
      W1=XLAML(L)
      W2=XLAMU(L)
      S=RGLNT(J)*.001
      H2=H1+RGLNT(J)*COS(ELVS)*.001
      VV=BV(L)
      LM=NPU(L)
      LM=NPU(L)
      CALL LOWEM (MODEL,IHAZE,ITYPE,IZ1,IZ2,IZ3,IZ4,IZ5,IZ6,IZ7,IEMIS,RZ
     11,H1,H2,RZ2,S,RZ3,RZ4,W1,W2,VV,IZ8,J,IZ6,IZ10,IZ11,IZ12,TOTRAN,200
     20,HSAT)
      DO 1 I=1,LM
      DUM(I)=SR(I,L)*TAUA(I)*TAUD(I,L)*RD(I,L)
    1 CONTINUE
      CALL INTEG
      VGLNT(J,L)=DUM(1)*PI*D*D*SUNGK*.25*.8
    2 CONTINUE
    3 CONTINUE
      DO 4 I=1,NBANDS
```

```
      KN=KANF(A)
      DO 4 M=1,NOGLT
      IF (KN.LE.FSG) GO TO 4
      VEFF(NG(M,1),NG(M,2),L)=VEFF(NG(M,1),NG(M,2),L)+VGLNT(M,L)
    4 CONTINUE
      RETURN
C
    5 FORMAT (8E10.3)
    6 FORMAT (16I5)
    7 FORMAT (I5,E10.3)
      END
```

```
      SUBROUTINE FOURT(DATA,NN,NDIM,ISIGN,IFORM,WORK)                   IRSTM  866
C     CONTROL DATA 6600 VERSION                                         IRSTM  868
C                                                                       IRSTM  869
C     ABSTRACT                                                          IRSTM  870
C                                                                       IRSTM  871
C        FOURT PERFORMS AN N-DIMENSIONAL FAST FOURIER TRANSFORM ON AN   IRSTM  872
C     N-DIMENSIONAL ARRAY OF COMPLEX DATA.  THE TRANSFORM PERFORMED     IRSTM  873
C     MAY BE EXPRESSED AS FOLLOWS --                                    IRSTM  874
C                                                                       IRSTM  875
C        TRANSFORM(J1,J2,...)=SUM(DATA(I1,I2,...)*W1**((I1-1)*(J1-1))   IRSTM  876
C                                      *W2**((I2-1)*(J2-1))             IRSTM  877
C                                      *...)                            IRSTM  878
C        WHERE I1 AND J1 RUN FROM 1 TO NN(1), AND                       IRSTM  879
C              I2 AND J2 RUN FROM 1 TO NN(2), ETC.                      IRSTM  880
C        AND                                                            IRSTM  881
C             W1 = EXP(ISIGN*2*PI*SQRT(-1)/NN(1)) , ETC.                IRSTM  882
C                                                                       IRSTM  883
C        FOR ONE DIMENSION, THE TRANSFORM IS PRECISELY                  IRSTM  884
C                                                                       IRSTM  885
C        TRANSFORM(J1) = SUM(DATA(I1)*W1**((I1-1)*(J1-1)))              IRSTM  886
C                                                                       IRSTM  887
C     FOURT IS FASTEST WHEN THE NUMBER OF DATA VALUES IN EACH           IRSTM  888
C        DIMENSION IS A HIGHLY COMPOSITE (FACTORABLE) NUMBER.           IRSTM  889
C                                                                       IRSTM  890
C     DESCRIPTION OF PARAMETERS                                         IRSTM  891
C        DATA -- COMPLEX ARRAY IN WHICH THE DATA TO BE TRANSFORMED      IRSTM  892
C                IS PLACED.  UPON RETURN TO CALLING PROGRAM DATA        IRSTM  893
C                CONTAINS THE TRANSFORM VALUES.                         IRSTM  894
C        NN    - INTEGER ARRAY GIVING THE (POSITIVE) NUMBER OF POINTS,  IRSTM  895
C                OR VALUES, IN EACH DIMENSION, RESPECTIVELY.            IRSTM  896
C        NDIM  - NUMBER OF DIMENSIONS (INTEGER)  NDIM.GE.1              IRSTM  897
C        ISIGN - INTEGER GIVING DIRECTION OF TRANSFORM TO BE DONE.      IRSTM  898
C                = -1 IMPLIES FORWARD                                   IRSTM  899
C                = +1 IMPLIES BACKWARD                                  IRSTM  900
C        IFORM - INTEGER PARAMETER DESCRIBING THE FORM OF THE DATA.     IRSTM  901
C                = 1 IMPLIES THE DATA IS COMPLEX (NON-TRIVIALLY).       IRSTM  902
C                = 0 IMPLIES THE DATA IS ACTUALLY REAL.  I.E., THE      IRSTM  903
C                    IMAGINARY PART OF EACH COMPLEX ELEMENT OF DATA     IRSTM  904
C                    IS ZERO.  FOURT IS SIGNIFICANTLY FASTER WHEN       IRSTM  905
C                    IFORM=0.                                           IRSTM  906
C        WORK  - COMPLEX WORK ARRAY.  WORK MUST BE DIMENSIONED AS       IRSTM  907
C                LARGE AS THE LARGEST DIMENSION OF DATA WHICH IS NOT    IRSTM  908
C                A POWER OF TWO.  IF ALL DIMENSIONS OF DATA ARE         IRSTM  909
C                POWERS OF TWO THEN WORK IS A DUMMY ARGUMENT.           IRSTM  910
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C                                                                        IRSTM   911
C     WRITTEN BY N M BRENNER, MIT LINCOLN LAB                            IRSTM   912
C     PREPARED FOR SANDIA MATH PROG LIB BY R E JONES  ORG 9422           IRSTM   913
C                                                                        IRSTM   914
      DIMENSION DATA(1),NN(1),IFACT(32),WORK(1)                          IRSTM   915
C     DIMENSION MES(8)                                                   IRSTM   916
C     DATA (MES=0,62H A DIMENSION OR THE NUMBER OF DIMENSIONS WAS ZERO O IRSTM   917
C    1R NEGATIVE.)                                                       IRSTM   918
C                                                                        IRSTM   919
      TWOPI = 6.283185307179586                                          IRSTM   920
      RTHLF = 0.7071067811865475                                         IRSTM   921
      IF(NDIM-1)930,1,1                                                  IRSTM   922
    1 NTOT=2                                                             IRSTM   923
      DO 2 IDIM=1,NDIM                                                   IRSTM   924
C     IF(NN(IDIM))930,930,2                                              IRSTM   925
    2 NTOT=NTOT*NN(IDIM)                                                 IRSTM   926
      NP1=2                                                              IRSTM   927
      DO 910 IDIM=1,NDIM                                                 IRSTM   928
      N=NN(IDIM)                                                         IRSTM   929
      NP2=NP1*N                                                          IRSTM   930
      IF(N-1)930,900,5                                                   IRSTM   931
    5 M=N                                                                IRSTM   932
      NTWO=NP1                                                           IRSTM   933
      IF=1                                                               IRSTM   934
      IDIV=2                                                             IRSTM   935
   10 IQUOT=M/IDIV                                                       IRSTM   936
      IREM=M-IDIV*IQUOT                                                  IRSTM   937
      IF(IQUOT-IDIV)50,11,11                                             IRSTM   938
   11 IF(IREM)20,12,20                                                   IRSTM   939
   12 NTWO=NTWO+NTWO                                                     IRSTM   940
      IFACT(IF)=IDIV                                                     IRSTM   941
      IF=IF+1                                                            IRSTM   942
      M=IQUOT                                                            IRSTM   943
      GOTO 10                                                            IRSTM   944
   20 IDIV=3                                                             IRSTM   945
      INON2=IF                                                           IRSTM   946
   30 IQUOT=M/IDIV                                                       IRSTM   947
      IREM=M-IDIV*IQUOT                                                  IRSTM   948
      IF(IQUOT-IDIV)60,31,31                                             IRSTM   949
   31 IF(IREM)40,32,40                                                   IRSTM   950
   32 IFACT(IF)=IDIV                                                     IRSTM   951
      IF=IF+1                                                            IRSTM   952
      M=IQUOT                                                            IRSTM   953
      GOTO 30                                                            IRSTM   954
   40 IDIV=IDIV+2                                                        IRSTM   955
      GOTO 30                                                            IRSTM   956
   50 INON2=IF                                                           IRSTM   957
      IF(IREM)60,51,60                                                   IRSTM   958
   51 NTWO=NTWO+NTWO                                                     IRSTM   959
      GOTO 70                                                            IRSTM   960
   60 IFACT(IF)=M                                                        IRSTM   961
```

```
   70 NON2P=NP2/NTWO                                          IRSTM     962
      ICASE=1                                                 IRSTM     963
      IFMIN=1                                                 IRSTM     964
      I1RNG=NP1                                               IRSTM     965
      IF(IDIM-4)74,100,100                                    IRSTM     966
   74 IF(IFORM)71,71,100                                      IRSTM     967
   71 ICASE=2                                                 IRSTM     968
      I1RNG=NP0*(1+NPREV/2)                                   IRSTM     969
      IF(IDIM-1)72,72,100                                     IRSTM     970
   72 ICASE=3                                                 IRSTM     971
      I1RNG=NP1                                               IRSTM     972
      IF(NTWO-NP1)100,100,73                                  IRSTM     973
   73 ICASE=4                                                 IRSTM     974
      IFMIN=2                                                 IRSTM     975
      NTWO=NTWO/2                                             IRSTM     976
      N=N/2                                                   IRSTM     977
      NP2=NP2/2                                               IRSTM     978
      NTOT=NTOT/2                                             IRSTM     979
      I=1                                                     IRSTM     980
      DO 80 J=1,NTOT                                          IRSTM     981
      DATA(J)=DATA(I)                                         IRSTM     982
   80 I=I+2                                                   IRSTM     983
  100 IF(NON2P-1)101,101,200                                  IRSTM     984
  101 NP2HF=NP2/2                                             IRSTM     985
      J=1                                                     IRSTM     986
      DO 150 I2=1,NP2,NP1                                     IRSTM     987
      IF(J-I2)121,130,130                                     IRSTM     988
  121 I1MAX=I2+NP1-2                                          IRSTM     989
      DO 125 I1=I2,I1MAX,2                                    IRSTM     990
      DO 125 I3=I1,NTOT,NP2                                   IRSTM     991
      J3=J+I3-I2                                              IRSTM     992
      TEMPR=DATA(I3)                                          IRSTM     993
      TEMPI=DATA(I3+1)                                        IRSTM     994
      DATA(I3)=DATA(J3)                                       IRSTM     995
      DATA(I3+1)=DATA(J3+1)                                   IRSTM     996
      DATA(J3)=TEMPR                                          IRSTM     997
  125 DATA(J3+1)=TEMPI                                        IRSTM     998
  130 M=NP2HF                                                 IRSTM     999
  140 IF(J-M)150,150,141                                      IRSTM    1000
  141 J=J-M                                                   IRSTM    1001
      M=M/2                                                   IRSTM    1002
      IF(M-NP1)150,140,140                                    IRSTM    1003
  150 J=J+M                                                   IRSTM    1004
      GOTO 300                                                IRSTM    1005
  200 NWORK=2*N                                               IRSTM    1006
      DO 270 I1=1,NP1,2                                       IRSTM    1007
      DO 270 I3=I1,NTOT,NP2                                   IRSTM    1008
      J=I3                                                    IRSTM    1009
      DO 260 I=1,NWORK,2                                      IRSTM    1010
      IF(ICASE-3)210,220,210                                  IRSTM    1011
  210 WORK(I)=DATA(J)                                         IRSTM    1012
```

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```
      WORK(I+1)=DATA(J+1)                                              IRSTN    1013
      GOTO 240                                                         IRSTN    1014
  220 WORK(I)=DATA(J)                                                  IRSTN    1015
      WORK(I+1)=0.0                                                    IRSTN    1016
  240 IFP2=NP2                                                         IRSTN    1017
      IF=IFMIN                                                         IRSTN    1018
  250 IFP1=IFP2/IFACT(IF)                                              IRSTN    1019
      J=J+IFP1                                                         IRSTN    1020
      IF(J-I3-IFP2)260,255,255                                         IRSTN    1021
  255 J=J-IFP2                                                         IRSTN    1022
      IFP2=IFP1                                                        IRSTN    1023
      IF=IF+1                                                          IRSTN    1024
      IF(IFP2-NP1)260,260,250                                          IRSTN    1025
  260 CONTINUE                                                         IRSTN    1026
      I2MAX=I3+NP2-NP1                                                 IRSTN    1027
      I=1                                                              IRSTN    1028
      DO 270 I2=I3,I2MAX,NP1                                           IRSTN    1029
      DATA(I2)=WORK(I)                                                 IRSTN    1030
      DATA(I2+1)=WORK(I+1)                                             IRSTN    1031
  270 I=I+2                                                            IRSTN    1032
  300 IF(NTWO-NP1)600,600,305                                          IRSTN    1033
  305 NP1TW=NP1+NP1                                                    IRSTN    1034
      IPAR=NTWO/NP1                                                    IRSTN    1035
  310 IF(IPAR-2)350,330,320                                            IRSTN    1036
  320 IPAR=IPAR/4                                                      IRSTN    1037
      GOTO 310                                                         IRSTN    1038
  330 DO 340 I1=1,I1RNG,2                                              IRSTN    1039
      DO 340 K1=I1,NTOT,NP1TW                                          IRSTN    1040
      K2=K1+NP1                                                        IRSTN    1041
      TEMPR=DATA(K2)                                                   IRSTN    1042
      TEMPI=DATA(K2+1)
      DATA(K2)=DATA(K1)-TEMPR                                          IRSTN    1044
      DATA(K2+1)=DATA(K1+1)-TEMPI                                      IRSTN    1045
      DATA(K1)=DATA(K1)+TEMPR                                          IRSTN    1046
  340 DATA(K1+1)=DATA(K1+1)+TEMPI                                      IRSTN    1047
  350 MMAX=NP1                                                         IRSTN    1048
  360 IF(MMAX-NTWO/2)370,600,600                                       IRSTN    1049
  370 LMAX=MAX0(NP1TW,MMAX/2)                                          IRSTN    1050
      DO 570 L=NP1,LMAX,NP1TW                                          IRSTN    1051
      M=L                                                              IRSTN    1052
      IF(MMAX-NP1)420,420,380                                          IRSTN    1053
  380 THETA=-TWOPI*FLOAT(L)/FLOAT(4*MMAX)                              IRSTN    1054
      IF(ISIGN)400,390,390                                             IRSTN    1055
  390 THETA=-THETA                                                     IRSTN    1056
C 400 WR=COS(THETA)                                                    IRSTN    1057
C     WI=SIN(THETA)                                                    IRSTN    1058
  400 WR=COS(THETA)                                                    IRSTN    1059
      WI=SIN(THETA)                                                    IRSTN    1060
  410 W2R=WR*WR-WI*WI                                                  IRSTN    1061
      W2I=2.0*WR*WI                                                    IRSTN    1062
      W3R=W2R*WR-W2I*WI                                                IRSTN    1063
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```
      U3I=U2K+UI+U2I+UR                                       IKSTM  1064
  420 DO 530 II=1,IIRNG,2                                     IKSTM  1065
      KMIN=II+IPAK+M                                          IKSTM  1066
      IF(MMAX-NP1)430,430,440                                 IKSTM  1067
  430 KMIN=II                                                 IKSTM  1068
  440 KDIF=IPAK+MMAX                                          IKSTM  1069
  450 KSTEP=4+KDIF                                            IKSTM  1070
      IF(KSTEP-NTOT)460,460,530                               IKSTM  1071
  460 DO 520 K1=KMIN,NTOT,KSTEP                               IKSTM  1072
      K2=K1+KDIF                                              IKSTM  1073
      K3=K2+KDIF                                              IKSTM  1074
      K4=K3+KDIF                                              IKSTM  1075
      IF(MMAX-NP1)470,470,480                                 IKSTM  1076
  470 U1K=DATA(K1)+DATA(K2)                                   IKSTM  1077
      U1I=DATA(K1+1)+DATA(K2+1)                               IKSTM  1078
      U2K=DATA(K3)+DATA(K4)                                   IKSTM  1079
      U2I=DATA(K3+1)+DATA(K4+1)                               IKSTM  1080
      U3K=DATA(K1)-DATA(K2)                                   IKSTM  1081
      U3I=DATA(K1+1)-DATA(K2+1)                               IKSTM  1082
      IF(ISIGN)471,472,472                                    IKSTM  1083
  471 U4K=DATA(K3+1)-DATA(K4+1)                               IKSTM  1084
      U4I=DATA(K4)-DATA(K3)                                   IKSTM  1085
      GOTO 510                                                IKSTM  1086
  472 U4K=DATA(K4+1)-DATA(K3+1)                               IKSTM  1087
      U4I=DATA(K3)-DATA(K4)                                   IKSTM  1088
      GOTO 510                                                IKSTM  1089
  480 T2K=U2K+DATA(K2)-U2I+DATA(K2+1)                         IKSTM  1090
      T2I=U2K+DATA(K2+1)+U2I+DATA(K2)                         IKSTM  1091
      T3K=UK+DATA(K3)-UI+DATA(K3+1)                           IKSTM  1092
      T3I=UK+DATA(K3+1)+UI+DATA(K3)                           IKSTM  1093
      T4K=U3K+DATA(K4)-U3I+DATA(K4+1)                         IKSTM  1094
      T4I=U3K+DATA(K4+1)+U3I+DATA(K4)                         IKSTM  1095
      U3K = DATA (K1)-T2K                                     IKSTM  1096
      U1I = DATA(K1+1)+T2I                                    IKSTM  1097
      U2K = T3K+T4K                                           IKSTM  1098
      U3I = DATA(K1+1)-T2I                                    IKSTM  1099
      U1K = DATA(K1)+T2K                                      IKSTM  1100
      U2I = T3I+T4I                                           IKSTM  1101
      IF(ISIGN)490,500,500                                    IKSTM  1102
  490 U4K=T3I-T4I                                             IKSTM  1103
      U4I=T4K-T3K                                             IKSTM  1104
      GOTO 510                                                IKSTM  1105
  500 U4K=T4I-T3I                                             IKSTM  1106
      U4I=T3K-T4K                                             IKSTM  1107
  510 DATA(K1)=U1K+U2K                                        IKSTM  1108
      DATA(K1+1)=U1I+U2I                                      IKSTM  1109
      DATA(K2)=U3K+U4K                                        IKSTM  1110
      DATA(K2+1)=U3I+U4I                                      IKSTM  1111
      DATA(K3)=U1K-U2K                                        IKSTM  1112
      DATA(K3+1)=U1I-U2I                                      IKSTM  1113
      DATA(K4)=U3K-U4K                                        IKSTM  1114
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  520 DATA(K4+1)=U3I-U4I                                  IRSTN     1115
      KDIF=KSTEP                                          IRSTN     1116
      KMIN=4*(KMIN-I1)+I1                                 IRSTN     1117
      GOTO 450                                            IRSTN     1118
  530 CONTINUE                                            IRSTN     1119
      M=M+LMAX                                            IRSTN     1120
      IF(M-MMAX)540,540,570                               IRSTN     1121
  540 IF(ISIGN)550,560,560                                IRSTN     1122
  550 TEMPR=UR                                            IRSTN     1123
      UR=(UR+UI)*RTHLF                                    IRSTN     1124
      UI=(UI-TEMPR)*RTHLF                                 IRSTN     1125
      GOTO 410                                            IRSTN     1126
  560 TEMPR=UR                                            IRSTN     1127
      UR=(UR-UI)*RTHLF                                    IRSTN     1128
      UI=(TEMPR+UI)*RTHLF                                 IRSTN     1129
      GOTO 410                                            IRSTN     1130
  570 CONTINUE                                            IRSTN     1131
      IPAR=3-IPAR                                         IRSTN     1132
      MMAX=MMAX+MMAX                                      IRSTN     1133
      GOTO 360                                            IRSTN     1134
  600 IF(NON2P-1)700,700,601                              IRSTN     1135
  601 IFP1=NTWO                                           IRSTN     1136
      IF=INON2                                            IRSTN     1137
  610 IFP2=IFACT(IF)*IFP1                                 IRSTN     1138
      THETA=-TWOPI/FLOAT(IFACT(IF))                       IRSTN     1139
      IF(ISIGN)612,611,611                                IRSTN     1140
  611 THETA=-THETA                                        IRSTN     1141
C 612 WSTPR=COS(THETA)                                    IRSTN     1142
C     WSTPI=SIN(THETA)                                    IRSTN     1143
  612 WSTPR=COS(THETA)                                    IRSTN     1144
      WSTPI=SIN(THETA)                                    IRSTN     1145
      DO 650 J1=1,IFP1,NP1                                IRSTN     1146
      THETM=-TWOPI*FLOAT(J1-1)/FLOAT(IFP2)                IRSTN     1147
      IF(ISIGN)614,613,613                                IRSTN     1148
  613 THETM=-THETM                                        IRSTN     1149
C 614 WMINR=COS(THETM)                                    IRSTN     1150
C     WMINI=SIN(THETM)                                    IRSTN     1151
  614 WMINR=COS(THETM)                                    IRSTN     1152
      WMINI=SIN(THETM)                                    IRSTN     1153
      I1MAX=J1+I1RNG-2                                    IRSTN     1154
      DO 650 I1=J1,I1MAX,2                                IRSTN     1155
      DO 650 I3=I1,NTOT,NP2                               IRSTN     1156
      I=1                                                 IRSTN     1157
      WR=WMINR                                            IRSTN     1158
      WI=WMINI                                            IRSTN     1159
      J2MAX=I3+IFP2-IFP1                                  IRSTN     1160
      DO 640 J2=I3,J2MAX,IFP1                             IRSTN     1161
      TWOWR=WR+WR                                         IRSTN     1162
      J3MAX=J2+NP2-IFP2                                   IRSTN     1163
      DO 630 J3=J2,J3MAX,IFP2                             IRSTN     1164
      JMIN=J3-J2+I3                                       IRSTN     1165
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      J=JMIN+IFP2-IFP1                                                  IRSTM    1166
      SR=DATA(J)                                                        IRSTM    1167
      SI=DATA(J+1)                                                      IRSTM    1168
      OLDSR=0.0                                                         IRSTM    1169
      OLDSI=0.0                                                         IRSTM    1170
      J=J-IFP1                                                          IRSTM    1171
  620 STMPR=SR                                                          IRSTM    1172
      STMPI=SI                                                          IRSTM    1173
      SR=TWOWR*SR-OLDSR+DATA(J)                                         IRSTM    1174
      SI=TWOWR*SI-OLDSI+DATA(J+1)                                       IRSTM    1175
      OLDSR=STMPR                                                       IRSTM    1176
      OLDSI=STMPI                                                       IRSTM    1177
      J=J-IFP1                                                          IRSTM    1178
      IF(J-JMIN)621,621,620                                             IRSTM    1179
  621 WORK(I)=WR*SR-WI*SI-OLDSR+DATA(J)                                 IRSTM    1180
      WORK(I+1)=WI*SR+WR*SI-OLDSI+DATA(J+1)                             IRSTM    1181
  630 I=I+2                                                             IRSTM    1182
      WTEMP=WR*WSTPI                                                    IRSTM    1183
      WR=WR*WSTPR-WI*WSTPI                                              IRSTM    1184
  640 WI=WI*WSTPR+WTEMP                                                 IRSTM    1185
      I=1                                                               IRSTM    1186
      DO 650 J2=I3,J2MAX,IFP1                                           IRSTM    1187
      J3MAX=J2+NP2-IFP2                                                 IRSTM    1188
      DO 650 J3=J2,J3MAX,IFP2                                           IRSTM    1189
      DATA(J3)=WORK(I)                                                  IRSTM    1190
      DATA(J3+1)=WORK(I+1)                                              IRSTM    1191
  650 I=I+2                                                             IRSTM    1192
      IF=IF+1                                                           IRSTM    1193
      IFP1=IFP2                                                         IRSTM    1194
      IF(IFP1-NP2)610,700,700                                           IRSTM    1195
  700 GOTO(900,800,900,701),ICASE                                       IRSTM    1196
  701 NHALF=N                                                           IRSTM    1197
      N=N+N                                                             IRSTM    1198
      THETA=-TWOPI/FLOAT(N)                                             IRSTM    1199
      IF(ISIGN)703,702,702                                              IRSTM    1200
  702 THETA=-THETA                                                      IRSTM    1201
C 703 WSTPR=COS(THETA)                                                  IRSTM    1202
C     WSTPI=SIN(THETA)                                                  IRSTM    1203
  703 WSTPR=COS(THETA)                                                  IRSTM    1204
      WSTPI=SIN(THETA)                                                  IRSTM    1205
      WR=WSTPR                                                          IRSTM    1206
      WI=WSTPI                                                          IRSTM    1207
      IMIN=3                                                            IRSTM    1208
      JMIN=2*NHALF-1                                                    IRSTM    1209
      GOTO 725                                                          IRSTM    1210
  710 J=JMIN                                                            IRSTM    1211
      DO 720 I=IMIN,NTOT,NP2                                            IRSTM    1212
      SUMR=(DATA(I)+DATA(J))/2.0                                        IRSTM    1213
      SUMI=(DATA(I+1)+DATA(J+1))/2.0                                    IRSTM    1214
      DIFR=(DATA(I)-DATA(J))/2.0                                        IRSTM    1215
      DIFI=(DATA(I+1)-DATA(J+1))/2.0                                    IRSTM    1216
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      TEMPR=UR+SUMI+UI+DIFR                                         IRSTM    1217
      TEMPI=UI+SUMI-UR+DIFR                                         IRSTM    1218
      DATA(I)=SUMR+TEMPR                                            IRSTM    1219
      DATA(I+1)-DIFI+TEMPI                                          IRSTM    1220
      DATA(J)=SUMR-TEMPR                                            IRSTM    1221
      DATA(J+1)=-DIFI+TEMPI                                         IRSTM    1222
  720 J=J+NP2                                                       IRSTM    1223
      IMIN=IMIN+2                                                   IRSTM    1224
      JMIN=JMIN-2                                                   IRSTM    1225
      UTEMP=UR+USTPI                                                IRSTM    1226
      UR=UR+USTPR-UI+USTPI                                          IRSTM    1227
      UI=UI+USTPR+UTEMP                                             IRSTM    1228
  725 IF(IMIN-JMIN)710,730,740                                      IRSTM    1229
  730 IF(ISIGN)731,740,740                                          IRSTM    1230
  731 DO 735 I=IMIN,NTOT,NP2                                        IRSTM    1231
  735 DATA(I+1)=-DATA(I+1)                                          IRSTM    1232
  740 NP2=NP2+NP2                                                   IRSTM    1233
      NTOT=NTOT+NTOT                                                IRSTM    1234
      J=NTOT+1                                                      IRSTM    1235
      IMAX=NTOT/2+1                                                 IRSTM    1236
  745 IMIN=IMAX-2+NHALF                                             IRSTM    1237
      I=IMIN                                                        IRSTM    1238
      GOTO 755                                                      IRSTM    1239
  750 DATA(J)=DATA(I)                                               IRSTM    1240
      DATA(J+1)=-DATA(I+1)                                          IRSTM    1241
  755 I=I+2                                                         IRSTM    1242
      J=J-2                                                         IRSTM    1243
      IF(I-IMAX)750,760,760                                         IRSTM    1244
  760 DATA(J)=DATA(IMIN)-DATA(IMIN+1)                               IRSTM    1245
      DATA(J+1)=0.0                                                 IRSTM    1246
      IF(I-J)770,780,780                                            IRSTM    1247
  765 DATA(J)=DATA(I)                                               IRSTM    1248
      DATA(J+1)=DATA(I+1)                                           IRSTM    1249
  770 I=I-2                                                         IRSTM    1250
      J=J-2                                                         IRSTM    1251
      IF(I-IMIN)775,775,765                                         IRSTM    1252
  775 DATA(J)=DATA(IMIN)+DATA(IMIN+1)                               IRSTM    1253
      DATA(J+1)=0.0                                                 IRSTM    1254
      IMAX=IMIN                                                     IRSTM    1255
      GOTO 745                                                      IRSTM    1256
  780 DATA(1)=DATA(1)+DATA(2)                                       IRSTM    1257
      DATA(2)=0.0                                                   IRSTM    1258
      GOTO 900                                                      IRSTM    1259
  800 IF(I1RNG-NP1)805,900,900                                      IRSTM    1260
  805 DO 860 I3=1,NTOT,NP2                                          IRSTM    1261
      I2MAX=I3+NP2-NP1                                              IRSTM    1262
      DO 860 I2=I3,I2MAX,NP1                                        IRSTM    1263
      IMIN=I2+I1RNG                                                 IRSTM    1264
      IMAX=I2+NP1-2                                                 IRSTM    1265
      JMAX=2*I3+NP1-IMIN                                            IRSTM    1266
      IF(I2-I3)820,820,810                                          IRSTM    1267
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810 JMAX=JMAX+NP2                                   IRSTM    1268
820 IF(IDIM-2)850,850,830                           IRSTM    1269
830 J=JMAX+NP0                                      IRSTM    1270
    DO 840 I-IMIN,IMAX,2                            IRSTM    1271
    DATA(I)=DATA(J)                                 IRSTM    1272
    DATA(I+1)=-DATA(J+1)                            IRSTM    1273
840 J=J-2                                           IRSTM    1274
850 J-JMAX                                          IRSTM    1275
    DO 860 I=IMIN,IMAX,NP0                          IRSTM    1276
    DATA(I)=DATA(J)                                 IRSTM    1277
    DATA(I+1)=-DATA(J+1)                            IRSTM    1278
860 J=J-NP0                                         IRSTM    1279
900 NP0-NP1                                         IRSTM    1280
    NP1=NP2                                         IRSTM    1281
910 NPREV=N                                         IRSTM    1282
920 RETURN                                          IRSTM    1283
930 CONTINUE                                        IRSTM    1284
    STOP 50                                         IRSTM    1285
    RETURN                                          IRSTM    1286
    END                                             IRSTM    1287
```

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..
      SUBROUTINE LOWEM (MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,          IRSTM    1288
     1IEMISS,RO,H1,H2,ANGLE,RANGE,BETA,VIS,WAVE1,WAVE2,DELAM,IXY,ISF,     IRSTM    1289
     2IWRITE,IJK,ISTATE,IAFLG,TOTRAN,LW,NSAT)                              IRSTM    1290
      COMMON /PRT/ IBKG,JMAX,IMAX,NBUG
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,ML,RE,CW,CD,PI    IRSTM    1291
      COMMON KMAX                                                          IRSTM    1292
      DIMENSION WD(7,34),HZ1(34),HZ2(6),AHAZE(34),AHZ2(20)                 IRSTM    1293
      DIMENSION TR(67),FW(67),FD(67),HZ(2),TX(11),VH(11),W(11),E(11)       IRSTM    1294
      COMMON C1(2580),C2(1575),C3(540),C4(133),C5(15),C8(102)              IRSTM    1295
      DIMENSION VX(45),C7(45),C7A(45)                                      IRSTM    1296
      DIMENSION HMIX(34)  , WLAY(34,11),BB(66), TLEV(66)                   IRSTM    1297
      DIMENSION TSCAT(66),TOTRA(2000)                                      IRSTM    1298
      DIMENSION WAVE(2000),XWAVE(2000),TOTAL(2000),TOTRAN(2000)            IRSTM    1299
      COMMON/LOW/TAUA(100),APR(100)                                        IRSTM    1300
      COMMON/INTP/DUM(300),IFLAG,LM,HHD
C HMIX(I)=HNO3 VOLUME MIXING RATIOS TIMES E+09 FROM EVANS PROFILE          IRSTM    1301
      DATA HMIX/9*0.,0.1,0.33,0.8,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3. IRSTM    1302
     17,4.2,5.2,6.0,3.8,2.6,0.22,6*0.0/                                    IRSTM    1303
C     PLANCK RADIANCE FUNCTION ..........                                  IRSTM    1304
C                                                                          IRSTM    1305
      FF(T,V)=1.191062E-13*(V**5)/(EXP(1.438828*V/T)-1.)                   IRSTM    1306
C       MILLIWATTS. CM-2 ST-1 MICRON-1                                     IRSTM    1307
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A                            IRSTM    1308
      DATA HZ(1)/5H23 KM/,HZ(2)/5H 5 KM/                                   IRSTM    1309
      DATA WAVUP/1.6324098/,WAVDN/1.25E-04/                                IRSTM    1310
C                                                                          IRSTM    1311
C                                                                          IRSTM    1312
C*****************************************************************         IRSTM    1313
C                                                                          IRSTM    1314
C  IF WAVELENGTH .GE. 0.25 MICRONS OR .LT. 0.707107 MICRONS, DELAM         IRSTM    1315
C  MUST BE .GT. 0.001 MICRONS.                                             IRSTM    1316
C                                                                          IRSTM    1317
C  IF WAVELENGTH .GE. 0.707107 MICRONS OR .LT. 7.07107 MICRONS, DELAM      IRSTM    1318
C  MUST BE .GT. 0.1 MICRONS.                                               IRSTM    1319
C                                                                          IRSTM    1320
C  IF WAVELENGTH .GE. 7.707107 MICRONS OR .LT. 15.81139 MICRONS, DELAM     IRSTM    1321
C  MUST BE .GT. 0.5 MICRONS.                                               IRSTM    1322
C                                                                          IRSTM    1323
C  IF WAVELENGTH .GE. 15.81139 MICRONS OR .LT. 28.57 MICRONS, DELAM        IRSTM    1324
C  MUST BE .GT. 1.63265 MICRONS.                                           IRSTM    1325
C                                                                          IRSTM    1326
C*****************************************************************         IRSTM    1327
C                                                                          IRSTM    1328
C                                                                          IRSTM    1329
C*********************************************************************** IRSTM    1330
C     PROGRAM LOWEM CALCULATES THE TRANSMITTANCE AND RADIANCE OF THE ATM IRSTM    1331
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C     FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT 20 CM-1      IRSTN     1332
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.                   IRSTN     1333
C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.    ATMOSPHERE IRSTN     1334
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER- IRSTN     1335
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.  IRSTN     1336
C     INTERVAL TO 100 KM.                                                 IRSTN     1337
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTN     1338
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS   IRSTN     1339
C                                                                         IRSTN     1340
C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,KO  FORMAT(10I IRSTN     1341
C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS                     FORMAT(6F10.3)  IRSTN     1342
C   CARD 3 V1, V2, DV                                     FORMAT(3F10.3)  IRSTN     1343
C   CARD 4 IXY                                            FORMAT(I3)      IRSTN     1344
C                                                                         IRSTN     1345
C     MODEL-1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE IRSTN     1346
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,   IRSTN     1347
C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY           IRSTN     1348
C     MODEL-0 FOR HORIZ. PATH WHEN METEOROL. DATA USED:INSTEAD OF CARD 2 IRSTN     1349
C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSIT IRSTN     1350
C     (GM.M-3),O3 DENSITY(GM.M-3), VIS(KM),RANGE(KM) WITH FORMAT 429.    IRSTN     1351
C     MODEL-7 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.      IRSTN     1352
C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN:  IRSTN     1353
C     ALTITUDE(KM.),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY, IRSTN     1354
C     O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.      IRSTN     1355
C     NOTE THAT EITHER DEW PT. TEMP.OR REL. HUMIDITY CAN BE USED.        IRSTN     1356
C                                                                         IRSTN     1357
C     M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.   IRSTN     1358
C                                                                         IRSTN     1359
C     IF IHAZE-0 NO AEROSOL SCATTERING IS COMPUTED                        IRSTN     1360
C     IHAZE -1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN          IRSTN     1361
C     CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))                          IRSTN     1362
C     IHAZE - 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS. IRSTN     1363
C     HAZE MODELS RESPECTIVELY IF VIS -0 ON CARD 2                        IRSTN     1364
C                                                                         IRSTN     1365
C     ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH              IRSTN     1366
C     ITYPE=3,VERTICAL OR SLANT PATH TO SPACE                             IRSTN     1367
C     ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES                IRSTN     1368
C     ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH       IRSTN     1369
C                                                                         IRSTN     1370
C     IEMISS=0 TRANSMITTANCE MODE                                         IRSTN     1371
C     IEMISS-1 RADIANCE MODE                                              IRSTN     1372
C                                                                         IRSTN     1373
C     H1=OBSERVER ALTITUDE (KM)                                           IRSTN     1374
C     H2-SOURCE  ALTITUDE (KM)                                            IRSTN     1375
C     ANGLE- ZENITH ANGLE AT H1 (DEGREES)                                 IRSTN     1376
C     RANGE-PATH LENGTH (KM)                                              IRSTN     1377
C     BETA-EARTH CENTRE ANGLE                                             IRSTN     1378
C     VIS - VISUAL RANGE AT SEA LEVEL (KM)                                IRSTN     1379
C     (IF ITYPE-1 READ H1 AND RANGE;IF ITYPE-3 READ H1 AND ANGLE.         IRSTN     1380
C     IF ITYPE-2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)      IRSTN     1381
C                                                                         IRSTN     1382
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C     V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE                IRSTM    1383
C     V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE                   IRSTM    1384
C     DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED            IRSTM    1385
C     NOTE: DV MUST BE A MULTIPLE OF 5 CM-1                                IRSTM    1386
C                                                                          IRSTM    1387
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTM    1388
      IXY=0                                                                IRSTM    1389
      KDUM=0                                                               IRSTM    1390
      KMAX=11                                                              IRSTM    1391
      IF(ISP.GT.0) GO TO 10                                                IRSTM    1392
      READ (3,400) IATM,NL                                                 IRSTM    1393
      READ (3,401) (HZ1(I),I=1,NL)                                         IRSTM    1394
      READ (3,401) (HZ2(I),I=1,5)                                          IRSTM    1395
      HZ2(6)=HZ1(6)                                                        IRSTM    1396
      DO 1 J=1,3                                                           IRSTM    1397
      K2=2+J                                                               IRSTM    1398
      K1=K2-1                                                              IRSTM    1399
      DO 1 I=1,NL                                                          IRSTM    1400
    1 READ (3,402) Z(I),(P(K,I),T(K,I),WH(K,I),WO(K,I),K=K1,K2)            IRSTM    1401
      READ (3,431) (VX(I),C7(I),C7A(I),I=1,44)                             IRSTM    1402
      READ (3,403) (TK(I),FU(I),FD(I),I=1,67)                              IRSTM    1403
      READ (3,404) (C1(I),I=1,2580)                                        IRSTM    1404
      READ (3,404) (C2(I),I=1,1575)                                        IRSTM    1405
      READ (3,404) (C3(I),I=1,540)                                         IRSTM    1406
      READ (3,405) (C4(I),I=1,133)                                         IRSTM    1407
      READ (3,404) (C5(I),I=1,15)                                          IRSTM    1408
      READ (3,405) (C8(I),I=1,102)                                         IRSTM    1409
   10 PI=3.14159265                                                        IRSTM    1410
      CA=PI/180.                                                           IRSTM    1411
      IF=0                                                                 IRSTM    1412
    2 CONTINUE                                                             IRSTM    1413
      DO 1002 I=1,34                                                       IRSTM    1414
      DO 1002 J=1,KMAX                                                     IRSTM    1415
 1002 WLAY(I,J)=0.                                                         IRSTM    1416
      RE=6371.23                                                           IRSTM    1417
      IFIND=0                                                              IRSTM    1418
      IF(IEMISS.EQ.1.AND.IWRITE.GT.1) WRITE(1,1170)                        IRSTM    1419
      IF(IEMISS.EQ.0.AND.IWRITE.GT.1) WRITE(1,1171)                        IRSTM    1420
      LENSTO =LEN                                                          IRSTM    1421
      IF(IWRITE.GT.1) WRITE(1,400) MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2       IRSTM    1422
     1,M3,ML,IEMISS,RO                                                     IRSTM    1423
  200 M=MODEL                                                              IRSTM    1424
      IF (M.EQ.1) RE=6378.39                                               IRSTM    1425
      IF (M.EQ.4) RE=6356.91                                               IRSTM    1426
      IF (M.EQ.5) RE=6356.91                                               IRSTM    1427
      IF(IXY.GT.3) GO TO 8                                                 IRSTM    1428
      IF(RO.NE.0.0) RE=RO                                                  IRSTM    1429
      IF(M.EQ.7.AND.IM.NE.0)GO TO 4                                        IRSTM    1430
      IF (MODEL.EQ.0) GO TO 4                                              IRSTM    1431
  300 CONTINUE                                                             IRSTM    1433
      IF(IWRITE.GT.1) WRITE(1,425) H1,H2,ANGLE,RANGE,BETA,VIS              IRSTM    1434
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      X1=RE+H1                                                          IRSTM    1435
      IF (ITYPE.EQ.3) GO TO 530                                         IRSTM    1436
      IF (ITYPE.EQ.1) GO TO 8                                           IRSTM    1437
      X2=RE+H2                                                          IRSTM    1438
      IF (RANGE.EQ.0.) GO TO 5                                          IRSTM    1439
      IF(IWRITE.GT.1) WRITE(1,428) H1,H2,ANGLE,RANGE,BETA,VIS           IRSTM    1440
      IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3                               IRSTM    1441
      ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA            IRSTM    1442
      GO TO 7                                                           IRSTM    1443
 3    X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)           IRSTM    1444
      H2=X2-RE                                                          IRSTM    1445
      GO TO 7                                                           IRSTM    1446
 4    CONTINUE                                                          IRSTM    1447
      IF(ML.LE.0)ML=1                                                   IRSTM    1448
      DO 540 K=1,ML                                                     IRSTM    1449
      AHAZE(K)=0.0                                                      IRSTM    1450
      IF(M.EQ.0)READ(1,429) H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),        IRSTM    1451
     1VIS,RANGE                                                         IRSTM    1452
      IF(M.EQ.0.AND.IWRITE.GT.1) WRITE(1,430) H1,P(7,1),TMP,DP,RH,      IRSTM    1453
     1WH(7,K),WO(7,K),VIS,RANGE                                         IRSTM    1454
C     IF(M.GT.0)READ 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K) IRSTM    1455
      J=IFIX(Z(K)+1.0E-6)+1.                                            IRSTM    1456
      IF(M.EQ.0)Z(K)=H1                                                 IRSTM    1457
      IF(Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                            IRSTM    1458
      IF(Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                           IRSTM    1459
      IF(Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                           IRSTM    1460
      IF(J.GT.33)J=33                                                   IRSTM    1461
      FAC=Z(K)-FLOAT(J-1)                                               IRSTM    1462
      IF(J.LT.26) GO TO 500                                             IRSTM    1463
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                 IRSTM    1464
      IF(J.GE.31) FAC=(Z(K)-50.0)/20.                                   IRSTM    1465
      IF(J.GE.32) FAC=(Z(K)-70.0)/30.                                   IRSTM    1466
      IF(FAC.GT.1.0) FAC=1.0                                            IRSTM    1467
 500  L=J+1                                                             IRSTM    1468
      T(7,K)=TMP+273.15                                                 IRSTM    1469
      IF(M1.GT.0)T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                  IRSTM    1470
      TT=273.15/T(7,K)                                                  IRSTM    1471
      IF(RH.LE.0.0) TT=273.15/(273.15+DP)                               IRSTM    1472
      IF(WH(7,K).LE.0.0) WH(7,K)=F(TT)                                  IRSTM    1473
      IF(M2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC              IRSTM    1474
      IF(RH.GT.0.0) WH(7,K)=0.01*RH*WH(7,K)                             IRSTM    1475
      IF(M3.GT.0)WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC              IRSTM    1476
      IF(Z(K).GE.5.0)GO TO 520                                          IRSTM    1477
      IF(AHAZE(K).EQ.0.0)AHZ2(K)=HZ2(J)*(HZ2(L)/HZ2(J))**FAC            IRSTM    1478
  520 IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ1(J)*(HZ1(L)/HZ1(J))**FAC           IRSTM    1479
      IF(MODEL.EQ.0)GO TO 8                                             IRSTM    1480
      IF(K.EQ.1.AND.IWRITE.GT.1) WRITE(1,441)                           IRSTM    1481
      IF(IWRITE.GT.1) WRITE(1,429) Z(K),P(7,K),TMP,DP,RH,WH(7,K),       IRSTM    1482
     1WO(7,K),AHAZE(K)                                                  IRSTM    1483
 540  CONTINUE                                                          IRSTM    1484
      IN=0                                                              IRSTM    1485
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      HL=HL                                                             IRSTM    1486
      H1=0                                                              IRSTM    1487
      H2=0                                                              IRSTM    1488
      H3=0                                                              IRSTM    1489
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD IRSTM    1490
C     MODEL ATMOSPHERES                                                 IRSTM    1491
      GO TO 300                                                         IRSTM    1492
560   IF (RANGE.GT.0.0) GO TO 580                                       IRSTM    1493
      IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1                               IRSTM    1494
      GO TO 8                                                           IRSTM    1495
580   ITYPE=2                                                           IRSTM    1496
      BETA=ACOS(0.5*(RANGE*RANGE/(X2*X1)-X2/X1-X1/X2))/CA               IRSTM    1497
5     IF (BETA.EQ.0.) GO TO 6                                           IRSTM    1498
      IFIND=1                                                           IRSTM    1499
      BET=CA*BETA                                                       IRSTM    1500
      X2=RE+H2                                                          IRSTM    1501
      ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA                       IRSTM    1502
      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)                                   IRSTM    1503
      BET=BETA                                                          IRSTM    1504
      GO TO 8                                                           IRSTM    1505
6     RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2                               IRSTM    1506
      IF (RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))       IRSTM    1507
7     IF(ANGLE.NE.0.OR.ANGLE.NE.180.)BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)   IRSTM    1508
      IF (ANGLE.LT.0.) ANGLE=ANGLE+PI                                   IRSTM    1509
      IF (RANGE.LT.0.0) RANGE=-RANGE                                    IRSTM    1510
      BET=BET/CA                                                        IRSTM    1511
      IF(IWRITE.GT.1) WRITE(1,428)  H1,H2,ANGLE,RANGE,BET,VIS           IRSTM    1512
8     CONTINUE                                                          IRSTM    1513
      SUMA=0.                                                           IRSTM    1514
      IF(DELAM.GT.WAVUP.OR.DELAM.LT.WAVDN) GO TO 1600                   IRSTM    1515
      V1 = 10000./WAVE2                                                 IRSTM    1516
      V2 = 10000./WAVE1                                                 IRSTM    1517
      DV = V2*DELAM/WAVE1                                               IRSTM    1518
      V1=INT(V1/5.)*5.                                                  IRSTM    1519
      V2=(INT(V2/5.)+1)*5.                                              IRSTM    1520
      DV=INT(DV/5.)*5.                                                  IRSTM    1521
      IF(DV.LT.5.)DV=5.                                                 IRSTM    1522
      IF(IXY.LE.2.AND.IWRITE.GT.1) WRITE(1,406) V1,V2,DV                IRSTM    1523
      IF (ITYPE.EQ.1.AND.IWRITE.GT.1) WRITE(1,407) H1,RANGE             IRSTM    1524
      IF (ITYPE.EQ.2.AND.IWRITE.GT.1) WRITE(1,408) H1,H2,ANGLE          IRSTM    1525
      IF (ITYPE.EQ.3.AND.IWRITE.GT.1) WRITE(1,409) H1,ANGLE             IRSTM    1526
      IF (MODEL.EQ.0) M=7                                               IRSTM    1527
      IF (VIS.GT.0.0.AND.IWRITE.GT.1) WRITE(1,417) VIS                  IRSTM    1528
      IF(VIS.LT.2.0.AND.VIS.GT.0.0.AND.IWRITE.GT.1) WRITE(1,416)        IRSTM    1529
      IF (M.EQ.1.AND.IWRITE.GT.1) WRITE(1,410) M                        IRSTM    1530
      IF (M.EQ.2.AND.IWRITE.GT.1) WRITE(1,411) M                        IRSTM    1531
      IF (M.EQ.3.AND.IWRITE.GT.1) WRITE(1,412) M                        IRSTM    1532
      IF (M.EQ.4.AND.IWRITE.GT.1) WRITE(1,413) M                        IRSTM    1533
      IF (M.EQ.5.AND.IWRITE.GT.1) WRITE(1,415) M                        IRSTM    1534
      IF (M.EQ.6.AND.IWRITE.GT.1) WRITE(1,414) M                        IRSTM    1535
      IF ([illegible].EQ.0.AND.IWRITE.GT.1) WRITE(1,426)                IRSTM    1536
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      IF(VIS.LE.0.0.AND.IHAZE.GT.0.AND.IWRITE.GT.1) WRITE(1,415)          IRSTM    1537
     1IHAZE,HZ(IHAZE)                                                      IRSTM    1538
      AVU=10000./V1                                                        IRSTM    1539
      ALAM=10000./V2                                                       IRSTM    1540
      IF(IWRITE.GT.1) WRITE(1,418) V1,V2,DV,ALAM,AVU                       IRSTM    1541
      AVU=0.5E-4*(V1+V2)                                                   IRSTM    1542
      AVU=AVU*AVU                                                          IRSTM    1543
      CO=77.46+.459*AVU                                                    IRSTM    1544

      CW=43.487-0.3473*AVU                                                 IRSTM    1545
      IF (IFIND.EQ.1) GO TO 15                                             IRSTM    1546
    9 IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LEN,NL)                  IRSTM    1547
      IFIND=0                                                              IRSTM    1548
      IF (JP.EQ.0.AND.IWRITE.GT.1) WRITE(1,427)                            IRSTM    1549
      IF (ITYPE.EQ.1) GO TO 15                                             IRSTM    1550
      DO 11 K=1,KMAX                                                       IRSTM    1551
      VH(K)=0.0                                                            IRSTM    1552
   11 CONTINUE                                                             IRSTM    1553
      BETA=0.0                                                             IRSTM    1554
      SR=0.0                                                               IRSTM    1555
      IP=0                                                                 IRSTM    1556
C****  NOW DEFINE CONSTANT PRESSURE PATH QUANTITES  EH(1-8)                IRSTM    1557
      Y=CA*ANGLE                                                           IRSTM    1558
      SPHI=SIN(Y)                                                          IRSTM    1559
      R1=(RE+H1)*SPHI                                                      IRSTM    1560
      IF (H1.GT.Z(NL)) GO TO 13                                            IRSTM    1561
      GO TO 15                                                             IRSTM    1562
   13 X=(RE+Z(NL))/(RE+H1)                                                 IRSTM    1563
      IF (SPHI.GT.X) GO TO 14                                              IRSTM    1564
      H1=Z(NL)                                                             IRSTM    1565
      J1=NL                                                                IRSTM    1566
      SPHI=SPHI/X                                                          IRSTM    1567
      ANGLE=180.-ASIN(SPHI)/CA                                             IRSTM    1568
      R1=(RE+H1)*SPHI                                                      IRSTM    1569
      GO TO 15                                                             IRSTM    1570
   14 HMIN=R1-RE                                                           IRSTM    1571
      IF(IWRITE.GT.1) WRITE(1,433) HMIN                                    IRSTM    1572
      GO TO 95                                                             IRSTM    1573
   15 DO 17 I=1,ML                                                         IRSTM    1574
      PS=P(M,I)/1013.0                                                     IRSTM    1575
      TS=273.15/T(M,I)                                                     IRSTM    1576
      IF(M1.GT.0.AND.M.LT.7)TS=273.15/T(M1,I)                              IRSTM    1577
      X=PS*TS                                                              IRSTM    1578
      PI=PS*SQRT(TS)                                                       IRSTM    1579
      D=0.1*WH(M,I)                                                        IRSTM    1580
      IF(M2.GT.0.AND.M.LT.7) D=0.1*WH(M2,I)                                IRSTM    1581
      EH(1,I)=D*PI**0.9                                                    IRSTM    1582
      EH(2,I)=X*PI**0.75                                                   IRSTM    1583
      EH(4,I)=0.78084*PI*X                                                 IRSTM    1584
      PPW=4.56E-5*D*273.15/TS                                              IRSTM    1585
      EH(5,I)=D*PPW*EXP(6.08*(296.0/T(M,I)-1.0))+.002*D*(PS-PPW)           IRSTM    1586
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C       IF SAT OPTION IS TURNED ON SO THAT WHITE S H2O
C       CONTINUUM IS USED, MAKE UNITS COMATIBLE
      IF(NSAT.NE.1) EM(10,I)=D*(PPW+0.12*(PS-PPW))*
     *EXP(4.56*(296.0/T(M,I)-1.0))
      IF(NSAT.EQ.1) EM(10,I)=D*(PPW+0.12*(PS-PPW))*
     *EXP(10.0483*(296.0/T(M,I)-1.0))
      EM(6,I)=X
      HAZE=HZ1(I)
      IF(M.EQ.7) HAZE=AHAZE(I)
      IF(Z(I).GE.5.0) GO TO 150
       IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)
      IF(IHAZE.EQ.2.AND.M.EQ.7)HAZE=AHZ2(I)
      IF(VIS.LE.0.0) GO TO 150
      IF(M.NE.7)HAZE= 6.389*((HZ2(I)-HZ1(I))/VIS+HZ1(I)/5.0-HZ2(I)/23.0)
      IF (M.NE.7) GO TO 150
      HAZE=6.389*((AHZ2(I)-AHAZE(I))/VIS+AHAZE(I)/5.0-AHZ2(I)/23.0)
  150 IF(HAZE.LT.0.0) HAZE=0.0
      EM(7,I)=3.5336E-4*HAZE
      IF(MODEL.EQ.7) EM(7,I)=HAZE/AHAZE(1)
      EM(8,I)=46.6667*WO(M,I)
      IF(M3.GT.0.AND.M.LT.7) EM(8,I)=46.667*WO(M3,I)
      EM(3,I)=EM(8,I)*PT**0.4
C EM(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM
      EM(11,I)=PS*TS*HMIX(I)*1.0E-04
      EM(9,I)=1.0
      REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)
      IF (I.EQ.ML) GO TO 16
      IF (MODEL.EQ.0.AND.I.GE.1) GO TO 26
      T2=T(M,I+1)
      W2=WH(M,I+1)
      IF(M1.GT.0)T2=T(M1,I+1)
      IF(M2.GT.0)W2=WH(M2,I+1)
      PPW=4.56E-6*W2*T2
      EM(9,I)=0.5*(REF+1.0E-6*(CO*P(M,I+1)/T2-PPW*CW))
 16   IF (I.EQ.ML) EM(9,I)=0.
      IF (H1.GE.Z(I)) J1=I
      IF((IFIND.EQ.0.OR.JP.EQ.0).AND.IWRITE.GT.1) WRITE(1,434) I,Z(I),
     1(EM(K,I),K=1,KMAX)
      EM(9,I)=EM(9,I)+1.0
  17  CONTINUE
 170  IF (IFIND.EQ.1) GO TO 9
      IP=-1
      IK=0
      X1=H1
      CALL POINT (H1,YN,N,NP1,TX,IP)
      J1=N
      TX1=TX(9)
      DO 18 K=1,KMAX
 18   E(K)=TX(K)
      IF (ITYPE.EQ.1) GO TO 25
      IF (ITYPE.EQ.3) H2=Z(ML)
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      IF (ANGLE.GT.90.0) GO TO 20                                       IRSTN    1638
19    IF (ANGLE.GT.90.0.AND.NF1.GT.0) J1=J1+1                           IRSTN    1639
      J2=NL                                                             IRSTN    1640
      IF (ITYPE.EQ.3) GO TO 20                                          IRSTN    1641
      CALL FOINT (H2,YN,N,NF,TX,IF)                                     IRSTN    1642
      J2=N                                                              IRSTN    1643
      IF (NF.GT.0) J2=J2-1                                              IRSTN    1644
20    DO 21 K=1,KMAX                                                    IRSTN    1645
      IF(K.EQ.9) GO TO 21                                               IRSTN    1646
      EH(K,J1)=E(K)                                                     IRSTN    1647
      IF (ITYPE.EQ.3) GO TO 21                                          IRSTN    1648
      EH(K,J2+1)=TX(K)                                                  IRSTN    1649
21    CONTINUE                                                          IRSTN    1650
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)                                 IRSTN    1651
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                        IRSTN    1652
      IF (JP.EQ.0.AND.IWRITE.GT.1) WRITE(1,420)                         IRSTN    1653
      DO 25 I=J1,J2                                                     IRSTN    1654
      X1=Z(I)                                                           IRSTN    1655
      X2=Z(I+1)                                                         IRSTN    1656
      IF (I.EQ.J1) X1=H1                                                IRSTN    1657
      IF (I.EQ.J2) X2=H2                                                IRSTN    1658
      DZ=X2-X1                                                          IRSTN    1659
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)                                       IRSTN    1660
      DS=DZ                                                             IRSTN    1661
C***** UPWARD TRAJECTORY                                                 IRSTN    1662
      RX=(RE+X1)/(RE+X2)                                                IRSTN    1663
      THETA=ASIN(SPHI)/CA                                               IRSTN    1664
      PHI=ASIN(SPHI*RX)/CA                                              IRSTN    1665
      BET=THETA-PHI                                                     IRSTN    1666
      SALP=RX*SPHI                                                      IRSTN    1667
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                   IRSTN    1668
      BETA=BETA+BET                                                     IRSTN    1669
      PSI=BETA+PHI-ANGLE                                                IRSTN    1670
      PHI=180.-PHI                                                      IRSTN    1671
      SK=SK+DS                                                          IRSTN    1672
      DO 1024 K=1,KMAX                                                  IRSTN    1673
      EV=DS*EH(K,I)                                                     IRSTN    1674
      IF (I.EQ.NL) GO TO 22                                             IRSTN    1675
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 23                  IRSTN    1676
      IF (EH(K,I).EQ.EH(K,I+1)) GO TO 24                                IRSTN    1677
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))                 IRSTN    1678
      GO TO 24                                                          IRSTN    1679
22    IF (EH(K,I).EQ.0.0) GO TO 23                                      IRSTN    1680
      IF (EH(K,I-1).EQ.0.0) GO TO 23                                    IRSTN    1681
      IF (EH(K,I).EQ.EH(K,I-1)) GO TO 24                                IRSTN    1682
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))                                     IRSTN    1683
      GO TO 24                                                          IRSTN    1684
23    EV=0.                                                             IRSTN    1685
24    VH(K)=VH(K)+EV                                                    IRSTN    1686
 1024 WLAY(I,K)=EV                                                      IRSTN    1687
      IF (JP.EQ.0.AND.IWRITE.GT.1) WRITE(1,435) I,X1,(VH(I),I=1,8),PSI, IRSTN    1688
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      [illegible],DELTA,THETA,SR                                IRSTN    1689
      IF (I.GE.J1) GO TO 25                                     IRSTN    1690
      IF (I+1.EQ.J2) EH(9,I+1)=YN                               IRSTN    1691
      IF (I.EQ.J1) EH(9,I)=TX1                                  IRSTN    1692
      RR=EH(9,I+1)/EH(9,I)                                      IRSTN    1693
      SPHI=SPHI*RA/RR                                           IRSTN    1694
      IF (SALF.GE.RR) SPHI=SALF                                 IRSTN    1695
25    CONTINUE                                                  IRSTN    1696
      GO TO 47                                                  IRSTN    1697
C**** HORIZONTAL PATH                                            IRSTN    1698
26    DO 27 K=1,KMAX                                            IRSTN    1699
      U(K)=RANGE*EH(K,1)                                        IRSTN    1700
      IF (MODEL.GT.0) U(K)=RANGE*TX(K)                          IRSTN    1701
      IF(IEMISS.NE.0)ULAY(J1,K)=U(K)                            IRSTN    1702
27    CONTINUE                                                  IRSTN    1703
      GO TO 49                                                  IRSTN    1704
28    CONTINUE                                                  IRSTN    1705
C****   DOWNWARD TRAJECTORY                                     IRSTN    1706
      K2=0                                                      IRSTN    1707
      IF (NP1.EQ.1) J1=J1-1                                     IRSTN    1708
      J2=J1+1                                                   IRSTN    1709
      YN1=YN                                                    IRSTN    1710
      J=J1+1                                                    IRSTN    1711
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 30                   IRSTN    1712
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 30                  IRSTN    1713
      CALL POINT (H2,YN,N,NP2,TX,IP)                            IRSTN    1714
      DO 29 K=1,KMAX                                            IRSTN    1715
29    U(K)=TX(K)                                                IRSTN    1716
      TX2=TX(9)                                                 IRSTN    1717
      YN2=YN                                                    IRSTN    1718
      IF (H2.LT.H1) N=N2                                        IRSTN    1719
      J2=N                                                      IRSTN    1720
      IF (J1.EQ.J2) TX2=TX1*YN2/EH(9,N)                         IRSTN    1721
      IF (H2.GT.H1) TX1=TX2                                     IRSTN    1722
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2                        IRSTN    1723
30    AO=(RE+H1)*SPHI*YN1                                       IRSTN    1724
      IF (H2.GE.H1) YN2=YN1                                     IRSTN    1725
      DO 31 I=1,J1                                              IRSTN    1726
      HMIN=AO/EH(9,I)-RE                                        IRSTN    1727
      IF (I.EQ.J1) HMIN=AO/YN1-RE                               IRSTN    1728
      JMIN=I                                                    IRSTN    1729
      IF (HMIN.LE.Z(I+1)) GO TO 32                              IRSTN    1730
31    CONTINUE                                                  IRSTN    1731
32    X=HMIN                                                    IRSTN    1732
      IF (HMIN.LE.0) GO TO 34                                   IRSTN    1733
      CALL POINT (X,YN,N,NP,TX,IP)                              IRSTN    1734
      JMIN=N                                                    IRSTN    1735
      TX3=TX(9)                                                 IRSTN    1736
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2*TX(9)/EH(9,N)             IRSTN    1737
      IF(TX3.LT.0.0)TX3=TX(9)                                   IRSTN    1738
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 33                        IRSTN    1739
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      HMIN=A0/TX3-RE                                                    IRSTM    1740
      IF (ABS(X-HMIN).GT.0.0001) GO TO 32                               IRSTM    1741
   33 IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3                                 IRSTM    1742
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3                                 IRSTM    1743
      IF (H2.GE.H1) TX2=TX3                                             IRSTM    1744
      IF (H2.GE.H1) J2=N                                                IRSTM    1745
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN                                IRSTM    1746
      IF(IWRITE.GT.1) WRITE(1,436) HMIN                                 IRSTM    1747
      IF(H2.LT.HMIN)J2=N                                                IRSTM    1748
      IF (H2.LT.HMIN.AND.IWRITE.GT.1) WRITE(1,440) HMIN                 IRSTM    1749
      GO TO 35                                                          IRSTM    1750
   34 IF(IWRITE.GT.1) WRITE(1,436) HMIN                                 IRSTM    1751
      IF (H2.LT.H1) GO TO 35                                            IRSTM    1752
      IF ((ITYPE.EQ.3.OR.H2.GE.H1).AND.IWRITE.GT.1) WRITE(1,437)        IRSTM    1753
      ITYPE=2                                                           IRSTM    1754
      TX2=EH(9,1)                                                       IRSTM    1755
      JMIN=0                                                            IRSTM    1756
      J2=1                                                              IRSTM    1757
      H2=0.0                                                            IRSTM    1758
      H=0.0                                                             IRSTM    1759
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                      IRSTM    1760
   35 IF (JP.EQ.0.AND.IWRITE.GT.1) WRITE(1,420)                         IRSTM    1761
      DO 40 I=1,NL                                                      IRSTM    1762
      J=J-1                                                             IRSTM    1763
      KEF=EH(9,J)                                                       IRSTM    1764
      IF (I.EQ.1) KEF=YN1                                               IRSTM    1765
      IF (I.EQ.1.AND.K2.EQ.1) KEF=YN2                                   IRSTM    1766
      IF (J.EQ.J2.AND.K2.EQ.0) KEF=TX2                                  IRSTM    1767
      IF (I.NE.1) X1=Z(J+1)                                             IRSTM    1768
      X2=Z(J)                                                           IRSTM    1769
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H                                     IRSTM    1770
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN                                IRSTM    1771
      HM=(RE+X1)*SPHI-RE                                                IRSTM    1772
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM                                IRSTM    1773
      RX=(RE+X1)/(RE+X2)                                                IRSTM    1774
      DS=X1-X2                                                          IRSTM    1775
      ALP=90.0                                                          IRSTM    1776
       THET=ASIN(SPHI)/CA                                               IRSTM    1777
      SALP=RX*SPHI                                                      IRSTM    1778
      IF(ABS(X2-HM).GT.1.0E-5)ALP=ASIN(SALP)/CA                         IRSTM    1779
      BET=ALP-THET                                                      IRSTM    1780
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI                  IRSTM    1781
      THETA=180.0-THET                                                  IRSTM    1782
      BETA=BETA+BET                                                     IRSTM    1783
      PSI=BETA-ALP ANGLE+180.0                                          IRSTM    1784
      SR=SR+DS                                                          IRSTM    1785
      DO 1039 K=1,KMAX                                                  IRSTM    1786
      AJ=EH(K,J)                                                        IRSTM    1787
      BJ=EH(K,J+1)                                                      IRSTM    1788
      IF (J.EQ.J1) BJ=E(K)                                              IRSTM    1789
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=U(K)                   IRSTM    1790
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      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)                              IRSTM    1791
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)                  IRSTM    1792
      IF (K2.EQ.0) GO TO 36                                             IRSTM    1793
      IF (J.EQ.J2) BJ=W(K)                                              IRSTM    1794
      IF (J.EQ.JMIN) AJ=TX(K)                                           IRSTM    1795
36    IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 38                              IRSTM    1796
      IF (AJ.EQ.BJ) GO TO 37                                            IRSTM    1797
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)                                         IRSTM    1798
      GO TO 39                                                          IRSTM    1799
37    EV=DS*AJ                                                          IRSTM    1800
      GO TO 39                                                          IRSTM    1801
38    EV=0.0                                                            IRSTM    1802
39    VH(K)=VH(K)+EV                                                    IRSTM    1803
 1039 ULAY(J,K)=EV                                                      IRSTM    1804
      IF (JF.EQ.0.AND.IWRITE.GT.1) WRITE(1,435) J,X1,(VH(L),L=1,8),PSI, IRSTM    1805
     1ALF,BETA,THETA,SR                                                 IRSTM    1806
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 45                                IRSTM    1807
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 43                               IRSTM    1808
      IF (J.NE.1) RN=REF/EN(9,J-1)                                      IRSTM    1809
      IF (J.EQ.J2+1) RN=REF/TX2                                         IRSTM    1810
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2                               IRSTM    1811
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3                         IRSTM    1812
      IF (SALF.GE.RN) RN=1.0                                            IRSTM    1813
      SPHI=SALF*RN                                                      IRSTM    1814
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 41                                 IRSTM    1815
40    CONTINUE                                                          IRSTM    1816
41    IF (HMIN.LE.0) GO TO 47                                           IRSTM    1817
      IF (LEN.EQ.0.AND.IWRITE.GT.1) WRITE(1,438)                        IRSTM    1818
      IF (LEN.EQ.0) GO TO 47                                            IRSTM    1819
      IF (LEN.EQ.1.AND.IWRITE.GT.1) WRITE(1,439)                        IRSTM    1820
      K2=1                                                              IRSTM    1821
      X1=X2                                                             IRSTM    1822
      IF (ABS(X1-HMIN).LE.0.001) GO TO 47                               IRSTM    1823
      H=HMIN                                                            IRSTM    1824
      J=J2+1                                                            IRSTM    1825
      IF (NF2.EQ.1) J=J-1                                               IRSTM    1826
      B=BETA                                                            IRSTM    1827
      FH=180.-ASIN(SPHI)/CA                                             IRSTM    1828
      TS=SR                                                             IRSTM    1829
      PS=PSI                                                            IRSTM    1830
      DO 42 K=1,KMAX                                                    IRSTM    1831
42    E(K)=VH(K)                                                        IRSTM    1832
      GO TO 35                                                          IRSTM    1833
43    BETA=2.*BETA-B                                                    IRSTM    1834
      PSI=2.*PSI-PS                                                     IRSTM    1835
      SR=2.*SR-TS                                                       IRSTM    1836
C      LONG PATH  TAKEN                                                 IRSTM    1837
      PHI=FH                                                            IRSTM    1838
      DO 44 K=1,KMAX                                                    IRSTM    1839
44    VH(K)=2.*VH(K)-E(K)                                               IRSTM    1840
      GO TO 47                                                          IRSTM    1841
            .
            .
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45    DO 45 K=1,KMAX                                               IRSTM   1842
46    VH(K)=2.0*VH(K)                                              IRSTM   1843
      BETA=2.0*BETA                                                IRSTM   1844
      SK=2.0*SK                                                    IRSTM   1845
      IF (H2.EQ.H1) GO TO 47                                       IRSTM   1846
      KN=TX1/YH1                                                   IRSTM   1847
      SPHI=SIN(ANGLE*CA)                                           IRSTM   1848
      IF (SPHI.LT.KN) SPHI=SPHI/KN                                 IRSTM   1849
      GO TO 19                                                     IRSTM   1850
47    CONTINUE                                                     IRSTM   1851
      IF(IWRITE.GT.1) WRITE(1,406) HH                              IRSTM   1852
      DO 48 K=1,KMAX                                               IRSTM   1853
      W(K)=VH(K)                                                   IRSTM   1854
48    CONTINUE                                                     IRSTM   1855
49    IF(IWRITE.GT.1) WRITE (1,419)                                IRSTM   1856
      IF(IWRITE.GT.1) WRITE (1,1155)                               IRSTM   1857
      IF(IWRITE.GT.1) WRITE(1,421) (W(I),I=1,8),W(10),W(11)        IRSTM   1858
      IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1                           IRSTM   1859
      IF (ITYPE.EQ.1) J2=J1                                        IRSTM   1860
      IF(IWRITE.GT.1) WRITE(1,1109) J1,J2                          IRSTM   1861
      I=1                                                          IRSTM   1862
      L=1                                                          IRSTM   1863
      IV1=V1/5.0                                                   IRSTM   1864
      IV2=V2/5.+.99                                                IRSTM   1865
      IV1=5*IV1                                                    IRSTM   1866
      IV2=5*IV2                                                    IRSTM   1867
      IF (IV1.LT.350) IV1=350                                      IRSTM   1868
      IF (IV2.GT.50000) IV2=50000                                  IRSTM   1869
      IF (DV.LT.5.) DV=5.                                          IRSTM   1870
      IDV=DV                                                       IRSTM   1871
      IV=IV1-IDV                                                   IRSTM   1872
      ICOUNT=0                                                     IRSTM   1873
      ICAN = 1                                                     IRSTM   1874
      IF(IEMISS.EQ.0) GO TO 50                                     IRSTM   1875
      RADSUM=0.0                                                   IRSTM   1876
      FACTOR=0.5                                                   IRSTM   1877
      IF(IWRITE.GT.1) WRITE(1,1156)                                IRSTM   1878
      IF(IWRITE.GT.1) WRITE(1,1157)                                IRSTM   1879
C****  BEGINING OF TRANSMITTANCE CALCULATIONS                       IRSTM   1880
50    IV=IV+IDV                                                    IRSTM   1881
      IF(IEMISS.EQ.0) GO TO 1200                                   IRSTM   1882
      LEN=0                                                        IRSTM   1883
      TAUG=0                                                       IRSTM   1884
      SUMV=0.                                                      IRSTM   1885
      NLL=NL-1                                                     IRSTM   1886
      I1=J1+1                                                      IRSTM   1887
      IJ=I1+NLL                                                    IRSTM   1888
      DO 1050 K=1,KMAX                                             IRSTM   1889
      E(K)=0.                                                      IRSTM   1890
1050  CONTINUE                                                     IRSTM   1891
      IF (ANGLE.GT.90.0) GO TO 1061                                IRSTM   1892
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      LEN=1.                                                            IRSTM    1893
      IL=JI-1                                                           IRSTM    1894
      HMIN=1.0E-6                                                       IRSTM    1895
      IJ=NLL                                                            IRSTM    1896
 1051 CONTINUE                                                          IRSTM    1897
      TLEV(IJ)=1.0                                                      IRSTM    1898
      TSCAT(IJ)=1.                                                      IRSTM    1899
 1052 IF (LEN.EQ.0) IL=IL-1                                             IRSTM    1900
      IF (LEN.EQ.1) IL=IL+1                                             IRSTM    1901
      IJ=IJ-1                                                           IRSTM    1902
      DO 1054 K=1,KMAX                                                  IRSTM    1903
      U(K)=E(K)*WLAY(IL,K)                                              IRSTM    1904
 1054 CONTINUE                                                          IRSTM    1905
 1250 CONTINUE                                                          IRSTM    1906
      IF(JF.NE.0) GO TO 52                                              IRSTM    1907
      IF (ICOUNT.EQ.0) GO TO 51                                         IRSTM    1908
      IF (ICOUNT.EQ.50) GO TO 51                                        IRSTM    1909
      GO TO 52                                                          IRSTM    1910
 51   ICOUNT=0                                                          IRSTM    1911
      IF (IEMISS.EQ.0.AND.IWRITE.GT.1) WRITE(1,422)                     IRSTM    1912
 52   DO 53 K=1,KMAX                                                    IRSTM    1913
      TX(K)=0.0                                                         IRSTM    1914
      IF (K.LT.4) TX(K)=1.0                                             IRSTM    1915
 53   CONTINUE                                                          IRSTM    1916
      ICOUNT=ICOUNT+1                                                   IRSTM    1917
      SUM=0.0                                                           IRSTM    1918
      V=IV                                                              IRSTM    1919
      I=(IV-350)/5+1                                                    IRSTM    1920
C     ********************  HNO3                                        IRSTM    1921
C     HNO3 ABSORPTION CALCULATION                                       IRSTM    1922
      CALL HNO3 (V,HABS)                                                IRSTM    1923
      TX(11)=HABS*W(11)                                                 IRSTM    1924
      SUM=SUM+TX(11)                                                    IRSTM    1925
      IF(IV.LT.670) GO TO 72                                            IRSTM    1926
      IF(IV.LE.3000) GO TO 61                                           IRSTM    1927
C********   MOLECULAR SCATTERING                                        IRSTM    1928
      C6=9.807E-20*(V**4.0117)                                          IRSTM    1929
      TX(6)=C6*U(6)                                                     IRSTM    1930
      SUM=SUM+TX(6)                                                     IRSTM    1931
      IF (IV.LT.9200) GO TO 72                                          IRSTM    1932
      IF (IV.LT.13000) GO TO 69                                         IRSTM    1933
C********  UV OZONE                                                     IRSTM    1934
      IF (IV.LE.23400) GO TO 54                                         IRSTM    1935
      IF (IV.GE.27500) GO TO 55                                         IRSTM    1936
      GO TO 87                                                          IRSTM    1937
 54   XX=200.0                                                          IRSTM    1938
      XI=(V-13000.0)/XX+1.0                                             IRSTM    1939
      I1=I                                                              IRSTM    1940
      I2=53                                                             IRSTM    1941
      GO TO 56                                                          IRSTM    1942
 55   XX=500.0                                                          IRSTM    1943
            .
            .
            .
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      XI=(V-27500.0)/XX+57.0                                          IRSTN    1944
      L1=57                                                           IRSTN    1945
      L2=102                                                          IRSTN    1946
 56   DO 57 N=L1,L2                                                   IRSTN    1947
      XD=XI-FLOAT(N)                                                  IRSTN    1948
      IF (XD) 59,58,57                                                IRSTN    1949
 57   CONTINUE                                                        IRSTN    1950
 58   TX(8)=W(8)*CB(N)                                                IRSTN    1951
      GO TO 60                                                        IRSTN    1952
 59   TX(8)=CB(N)+XD*(CB(N)-CB(N-1))                                  IRSTN    1953
      TX(8)=W(8)*TX(8)                                                IRSTN    1954
 60   SUM=SUM+TX(8)                                                   IRSTN    1955
      IF(IV.GT.14500)GO TO 87                                         IRSTN    1956
      GO TO 69                                                        IRSTN    1957
C********  WATER VAPOR CONTINUUM 10 MICRON REGION                      IRSTN    1958
  61  IF(IV.GT.1350) GO TO 62                                         IRSTN    1959
      TX(5)=(4.18+5578.0*EXP(-7.87E-3*V))*W(5)                        IRSTN    1960
      GO TO 66                                                        IRSTN    1961
  62  IF(IV.LT.2350) GO TO 68                                         IRSTN    1962
C********  WATER VAPOR CONTINUUM 4 MICRON REGION                       IRSTN    1963
C     NSAI IS SAI OPTION TO USE EITHER BURCH OR WHITE MODEL           IRSTN    1964
      IF(NSAI.EQ.1) GO TO 65                                          IRSTN    1965
      XI=(V-2350.0)/50.0+1.0                                          IRSTN    1966
      DO 63 NN=1,15                                                   IRSTN    1967
      XN=XI-FLOAT(NN)                                                 IRSTN    1968
      TX(5)=C5(NN)                                                    IRSTN    1969
      IF(XN) 64,65,63                                                 IRSTN    1970
  63  CONTINUE                                                        IRSTN    1971
 64   TX(5)=TX(5)+XN*(C5(NN)-C5(NN-1))                                IRSTN    1972
  65  IF(NSAI.EQ.1) TX(5)=2.0528882E-1+8.6530478E-6*                  IRSTN    1973
     *(V-2599.3)**2                                                   IRSTN    1974
      TX(5)=TX(5)*W(10)                                               IRSTN    1975
  66  SUM=SUM+TX(5)                                                   IRSTN    1976
      IF(IV.LE.1350.OR.IV.GT.2740) GO TO 72                           IRSTN    1977
C********   NITROGEN CONTINUUM                                        IRSTN    1978
 68   IF (IV.LT.2080) GO TO 72                                        IRSTN    1979
      K4=I-346                                                        IRSTN    1980
      TX(4)=C4(K4)*W(4)                                               IRSTN    1981
      SUM=SUM+TX(4)                                                   IRSTN    1982
      GO TO 72                                                        IRSTN    1983
C********  WATER VAPOUR                                                IRSTN    1984
 69   IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70                        IRSTN    1985
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 71                       IRSTN    1986
      GO TO 76                                                        IRSTN    1987
 70   I=I-135                                                         IRSTN    1988
      GO TO 72                                                        IRSTN    1989
 71   I=I-255                                                         IRSTN    1990
 72   K1=I                                                            IRSTN    1991
      IF (W(1).LT.1.0E-20) GO TO 76                                   IRSTN    1992
      WSI=ALOG10(W(1))+C1(I)                                          IRSTN    1993
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      IF (US1.LT.-2.3468) TX(1)=1.-.087787*EXP(1.855595*US1)              IRSTM    1994
      IF (US1.LT.-2.3468) GO TO 76                                        IRSTM    1995
      IF (US1.GT.3.5682) GO TO 75                                         IRSTM    1996
      IF (US1.GT.2.0) K1=40                                               IRSTM    1997
      DO 73 K=K1,67                                                       IRSTM    1998
      IF (US1.LE.FU(K)) GO TO 74                                          IRSTM    1999
73    CONTINUE                                                            IRSTM    2000
74    TX(1)=TK(K)+(TK(K-1)-TK(K))*(FU(K)-US1)/(FU(K)-FU(K-1))             IRSTM    2001
      GO TO 76                                                            IRSTM    2002
75    TX(1)=0.0                                                           IRSTM    2003
76    CONTINUE                                                            IRSTM    2004
C++++++++   UNIFORMLY MIXED GASES                                         IRSTM    2005
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 77                              IRSTM    2006
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 78                           IRSTM    2007
      GO TO 83                                                            IRSTM    2008
77    J=I-30                                                              IRSTM    2009
      GO TO 79                                                            IRSTM    2010
78    J=(IV-12950)/5+1516                                                 IRSTM    2011
79    IF(W(2).LT.1.0E-20) GO TO 83                                        IRSTM    2012
      K1=1                                                                IRSTM    2013
      US2=ALOG10(W(2))+C2(J)                                              IRSTM    2014
      IF (US2.LT.-2.3468) TX(2)=1.-.087787*EXP(1.855595*US2)              IRSTM    2015
      IF (US2.LT.-2.3468) GO TO 83                                        IRSTM    2016
      IF (US2.GT.3.5682) GO TO 82                                         IRSTM    2017
      IF (US2.GT.2.0) K1=40                                               IRSTM    2018
      DO 80 K=K1,67                                                       IRSTM    2019
      IF (US2.LE.FU(K)) GO TO 81                                          IRSTM    2020
80    CONTINUE                                                            IRSTM    2021
81    TX(2)=TK(K)+(TK(K-1)-TK(K))*(FU(K)-US2)/(FU(K)-FU(K-1))             IRSTM    2022
      GO TO 83                                                            IRSTM    2023
82    TX(2)=0.0                                                           IRSTM    2024
   83 CONTINUE                                                            LUE       248
C++++++++   OZONE                                                         IRSTM    2026
      IF (IV.LT.575.OR.IV.GT.3270) GO TO 87                               IRSTM    2027
      L=I-45                                                              IRSTM    2028
      K1=1                                                                IRSTM    2029
      IF (W(3).LT.1.0E-20) GO TO 87                                       IRSTM    2030
      US3=ALOG10(W(3))+C3(L)                                              IRSTM    2031
      IF (US3.LT.-1.6778) TX(3)=1.-.055194*EXP(2.367853*US3)              IRSTM    2032
      IF (US3.LT.-1.6778) GO TO 87                                        IRSTM    2033
      IF (US3.GT.3.9345) GO TO 86                                         IRSTM    2034
      IF (US3.GT.1.5) K1=36                                               IRSTM    2035
      DO 84 K=K1,67                                                       IRSTM    2036
      IF (US3.LE.FO(K)) GO TO 85                                          IRSTM    2037
84    CONTINUE                                                            IRSTM    2038
85    TX(3)=TK(K)-(TK(K)-TK(K-1))*(FO(K)-US3)/(FO(K)-FO(K-1))             IRSTM    2039
      GO TO 87                                                            IRSTM    2040
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```
85    TX(3)=0.0                                                            IKSTN   2041
87    CONTINUE                                                             IKSTN   2042
C++++++++   AEROSOL EXTINCTION                                             IKSTN   2043
      ALAM=1.0E+4/V                                                        IKSTN   2044
      XX=0.0                                                               IKSTN   2045
      YY=0.0                                                               IKSTN   2046
      IF (IHAZE.EQ.0.) GO TO 90                                            IKSTN   2047
      DO 88 N=1,44                                                         IKSTN   2048
      XD=ALAM-VX(N)                                                        IKSTN   2049
      IF(XD)89,88,88                                                       IKSTN   2050
   88 CONTINUE                                                             IKSTN   2051
   89 XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)                          IKSTN   2052
      YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)                       IKSTN   2053
   90 TX(10)=YY+U(7)                                                       IKSTN   2054
      TX(7)=XX+U(7)                                                        IKSTN   2055
      SUM=SUM+TX(7)                                                        IKSTN   2056
      TX(9)=SUM                                                            IKSTN   2057
      DO 94 K=4,KMAX                                                       IKSTN   2058
      IF (TX(K).EQ.0.0) GO TO 92                                           IKSTN   2059
      IF (TX(K).LE.0.1) GO TO 91                                           IKSTN   2060
      IF (TX(K).GT.20.) GO TO 93                                           IKSTN   2061
      TX(K)=EXP(-TX(K))                                                    IKSTN   2062
      GO TO 94                                                             IKSTN   2063
91    TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)                                      IKSTN   2064
      GO TO 94                                                             IKSTN   2065
92    TX(K)=1.0                                                            IKSTN   2066
      GO TO 94                                                             IKSTN   2067
93    TX(K)=0.                                                             IKSTN   2068
94    CONTINUE                                                             IKSTN   2069
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)                                        IKSTN   2070
      IF (IV.GE.13000) TX(3)=TX(8)                                         IKSTN   2071
      IF(IEMISS.EQ.0) GO TO 1210                                           IKSTN   2072
      ALAM=1.0E+04/V                                                       IKSTN   2073
      TBAR=(T(M,IL)+T(M,IL+1))*0.5                                         IKSTN   2074
      BB(IJ)=FF(TBAR,V)                                                    IKSTN   2075
      TLEV(IJ)=(TX(9)*TX(10))/(TX(7)*TX(5))                                IKSTN   2076
      TSCAT(IJ)=(TX(7)*TX(6))/TX(10)                                       IKSTN   2077
      DTAU=TLEV(IJ+1)-TLEV(IJ)                                             IKSTN   2078
      IF (DTAU.LT.1.0E-5.AND.TLEV(IJ).LT.1.0E-5) GO TO 1104                IKSTN   2079
      SUMV=SUMV+0.5*BB(IJ)*DTAU*(TSCAT(IJ+1)+TSCAT(IJ))                    IKSTN   2080
      IF (IL.EQ.1.AND.HMIN.LE.0.0) TAUG=TX(9)                              IKSTN   2081
      DO 1103 K=1,KMAX                                                     IKSTN   2082
      E(K)=U(K)                                                            IKSTN   2083
1103  CONTINUE                                                             IKSTN   2084
C      IF (ANGLE.LE.90.0.AND.IL.EQ.33) GO TO 1104                          IKSTN   2085
       IF (ANGLE.LE.90.0.AND.IL.EQ.MLL) GO TO 1104                         IKSTN   2086
       IF (ITYPE.EQ.1) GO TO 1104                                          IKSTN   2087
       IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 1062                        IKSTN   2088
       IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 1104                IKSTN   2089
       IF (ITYPE.EQ.2.AND.LENSTO .EQ.0.AND.IL.EQ.J2) GO TO 1104            IKSTN   2090
       IF (IL.EQ.JMIN.AND.HMIN.GT.0) LEN=1                                 IKSTN   2091
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```
      IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 1104
      IF (LEN.EQ.0) GO TO 1062
      IF (IL.EQ.JMIN.AND.IJ.EQ.IL+NLL) IL=IL-1
      IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 1104
      GO TO 1062
 1104 CONTINUE
      II=I(M,1)
      BBG=FF(II,V)+TAUG
      IF (HMIN.LE.0) SUMV=SUMV+BBG
      SUMVV=SUMV
      IF (IV.GT.IV1) FACTOR=1.0
      IF (IV.GE.IV2) FACTOR=0.5
      SUMV=(1.0E+04/V**2)*SUMV
      KADSUM=KADSUM+DV*FACTOR*SUMV
      IF(IWRITE.GT.1) WRITE(1,1160) V,ALAM,SUMV,SUMVV,KADSUM,IX(9)
      KAFR=LM-KDUM
      KDUM=KDUM+1
      AFR(KAFR)=SUMV
      TAUA(KAFR)=IX(9)
 9875 FORMAT(1X15,2E12.3)
      IF(IWRITE.GT.1) WRITE(1,1160) V,ALAM,SUMV,SUMVV,KADSUM,IX(9)
 1210 IX(10)=1.-IX(10)
      AB=1.-IX(9)
      IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
      SUMA=SUMA+AB*DV
      IF(IEMISS.EQ.1) GO TO 1220
      IF(JP.EQ.0.AND.IWRITE.GT.1) WRITE(1,423) IV,ALAM,IX(9),(IX(K),
     1K=1,7),IX(10),SUMA
      WAVE(ILAM) = ALAM
      TOTAL(ILAM) = IX(9)
      ILAM = ILAM + 1
 1220 CONTINUE
      IF (IV.GE.IV2) GO TO 95
      GO TO 50
   95 RETURN
      AB=1.0-SUMA/(V2-V1)
      IF(IWRITE.GT.1) WRITE(1,424) IV1,IV2,SUMA,AB
      READ(5,1109)IXY
      IF(IWRITE.GT.1) WRITE(1,400) IXY
      IF(IXY.EQ.0) GO TO 100
      GO TO (96,2,97,98,100),IXY
   96 CONTINUE
      RETURN
    2 READ 403, V1,V2,DV
      AVO=10000./V1
      ALAM=10000./V2
      IF(IWRITE.GT.1) WRITE(1,418) V1,V2,DV,ALAM,AVO
      SUMA=0.0
      GO TO 49
   97 IF(MODEL.EQ.0) GO TO 200
      GO TO 300
           :
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90    CONTINUE                                                          IRSTN   2144
      IF (IEMISS.EQ.1.AND.IWRITE.GT.1) WRITE(1,1170)                    IRSTN   2145
      IF (IEMISS.EQ.0.AND.IWRITE.GT.1) WRITE(1,1171)                    IRSTN   2146
      LENSTO =LEN                                                       IRSTN   2147
      IF(IWRITE.GT.1) WRITE(1,400)MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,       IRSTN   2148
     1M2,M3,ML,IEMISS,RO                                                IRSTN   2149
      GO TO 200                                                         IRSTN   2150
100   ILAM = 1                                                          IRSTN   2151
      XWAVE(1) = WAVE(1)                                                IRSTN   2152
      KLAM = 1                                                          IRSTN   2153
1978  IF(XWAVE(KLAM).LT.WAVE(ILAM+1)) ILAM=ILAM + 1                     IRSTN   2154
      TOTRAN(KLAM) = TOTAL(ILAM) + (XWAVE(KLAM) - WAVE(ILAM))*          IRSTN   2155
     1WAVE(ILAM+1)*(TOTAL(ILAM+1)-TOTAL(ILAM))/(WAVE(ILAM+1)-           IRSTN   2156
     2WAVE(ILAM))/XWAVE(KLAM)                                           IRSTN   2157
      IF(KLAM.GE.LW) GO TO 2000                                         IRSTN   2158
      XWAVE(KLAM+1)=WAVE(1)-DELAM*KLAM                                  IRSTN   2159
      KLAM = KLAM + 1                                                   IRSTN   2160
      GO TO 1978                                                        IRSTN   2161
2000  CONTINUE                                                          IRSTN   2162
      LWI=LW                                                            IRSTN   2163
      DO 1988 I=1,LW                                                    IRSTN   2164
      TOTRA(I)=TOTRAN(LWI)                                              IRSTN   2165
      LWI=LWI-1                                                         IRSTN   2166
1988  CONTINUE                                                          IRSTN   2167
      DO 1999 I=1,LW                                                    IRSTN   2168
      TOTRAN(I)=TOTRA(I)                                                IRSTN   2169
1999  CONTINUE                                                          IRSTN   2170
      ISP = 1                                                           IRSTN   2171
      RETURN                                                            IRSTN   2172
1300  IF(IWRITE.GT.1) WRITE(1,450)                                      IRSTN   2173
      STOP                                                              IRSTN   2174
 400  FORMAT(11I3,F10.3)                                                IRSTN   2175
1170  FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE*)         IRSTN   2176
1171  FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE*)     IRSTN   2177
401   FORMAT (8E10.3)                                                   IRSTN   2178
402   FORMAT (F6.1,2(E10.3,F6.1,2E10.3))                                IRSTN   2179
403   FORMAT (4(F6.3,2F7.4))                                            IRSTN   2180
404   FORMAT (15F5.2)                                                   IRSTN   2181
405   FORMAT (8E9.2)                                                    IRSTN   2182
406   FORMAT (7F10.3)                                                   IRSTN   2183
407   FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =, IRSTN   2184
     1F7.3,3H KM)                                                       IRSTN   2185
408   FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1  IRSTN   2186
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)     IRSTN   2187
409   FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H  IRSTN   2188
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)                               IRSTN   2189
410   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)             IRSTN   2190
411   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)   IRSTN   2191
412   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)   IRSTN   2192
413   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )   IRSTN   2193
414   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )   IRSTN   2194
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415   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )   IRSTM   2195
416   FORMAT (/20X,18H        HAZE MODEL ,I1,3H = ,A5,13H VISUAL RANGE)   IRSTM   2196
417   FORMAT (/25X*HAZE MODEL  =*,F5.1,* KM VISUAL RANGE AT SEA LEVEL*)   IRSTM   2197
418   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1 IRSTM   2198
     14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,* - *,F5.2,* MICRONS )*)   IRSTM   2199
419   FORMAT (/10X,38H EQUILAVENT SEA LEVEL ABSORBER AMOUNTS//21X110HWAT IRSTM   2200
     1ER VAPOUR     CO2 ETC.         OZONE     NITROGEN (CONT)  H2O (CONT)  IRSTM   2201
     2    MOL  SCAT        AEROSOL      OZONE(U-V)/24X,7HGM CM-2,10X,2HKM,1 IRSTM   2202
     30X,6HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM,13X,2HKM,10X,6HATM CM)  IRSTM   2203
420   FORMAT (1H1,///10X,*  VERTICAL PROFILES  *,64X,*PSI*,6X,*PHI*,5X,* IRSTM   2204
     1BETA*,4X,*THETA    RANGE*)                                        IRSTM   2205
421   FORMAT (/10X,8H W(1-8)=8(E14.3)/ 74X,E14.3,28X,E14.3/)             IRSTM   2206
422   FORMAT (1H1,/10X,32H  FREQ WAVELENGTH  TOTAL      H2O,5X*HCO2*,5X,6 IRSTM   2207
     14HOZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATED IRSTM   2208
     2 /11X,14H CM-1  MICRONS,8(4X5HTRANS),4X,20H ABS      ABSORPTION )   IRSTM   2209
423   FORMAT (10X,I6,10F9.4,F12.2)                                      IRSTM   2210
424   FORMAT (* INTEGRATED ASORPTION FROM*,I5,* TO*,I5,/*CM-1 =*,F10.2,  IRSTM   2211
     1*,AVERAGE TRANSMITTANCE =*,F6.4)                                  IRSTM   2212
425   FORMAT (10X,7F10.3)                                               IRSTM   2213
426   FORMAT (/20X,*AEROSOL SCATTERING NOT COMPUTED,IHAZE=0*)            IRSTM   2214
427   FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)                       IRSTM   2215
428   FORMAT (10X,* H1=*,F7.3,*KM,H2=*,F7.3,*KM,ANGLE=*,F8.4,*GEOM. RANG IRSTM   2216
     1E =*,F7.2,*KM,BETA=*,F8.5,*,VIS=*,F6.1)                            IRSTM   2217
429   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)                                IRSTM   2218
430   FORMAT(10X,*INPUT METEOROLOGICAL DATA-*/10X,*Z=*,F7.2,* KM, P=*,F7 IRSTM   2219
     1.2,* MB,T=*,F5.1,* C, DEW PT.TEMP*,F5.1,* C, REL HUMIDITY=*,F5.1,  IRSTM   2220
     2* %, H2O DENSITY=*,1PE9.2,* GM M-3*/10X,* OZONE DENSITY=*,E9.2,* G IRSTM   2221
     3M-3, VISUAL RANGE=*,0PF6.1,* KM,RANGE=*,F10.3,* KM *  )            IRSTM   2222
431   FORMAT(4(F6.2,2F7.5))                                             IRSTM   2223
432   FORMAT (* STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED H1= IRSTM   2224
     1 *,F10.3,*ANGLE =*,F10.6)                                         IRSTM   2225
433   FORMAT (* TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE OF IRSTM   2226
     1 APPROACH IS*,F10.2,1X,/,1X,*END OF CALCULATION*)                  IRSTM   2227
434   FORMAT (10X,I4,F6.1,11(E10.3))                                    IRSTM   2228
435   FORMAT (I5,F7.1,8E10.3,4F9.4,F7.1)                                IRSTM   2229
436   FORMAT (* HMIN = *,F10.3)                                         IRSTM   2230
437   FORMAT (* PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 = IRSTM   2231
     1 0.0 KM*)                                                         IRSTM   2232
438   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN.  IRSTM   2233
     1 FOR LONGER PATH SET LEN=1.*)                                     IRSTM   2234
439   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.   IRSTM   2235
     1 FOR SHORT PATH SET LEN = 0 *)                                    IRSTM   2236
440   FORMAT (* H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO    IRSTM   2237
     1  HMIN I.E. H2 = *,F10.3)                                         IRSTM   2238
441   FORMAT(*  MODEL ATMOSPHERE NO. 7*,/ 4X,*Z (KM)*,3X,*P (MB)*,4X,    IRSTM   2239
     1 *T (C) DEW PT *RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.*)              IRSTM   2240
442   FORMAT(*  FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RA IRSTM   2241
     1NGE*,/,*  IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN  IRSTM   2242
     2BY THE TRANSMITTANCE AT 0.55 MICRONS*)                             IRSTM   2243
450   FORMAT(30X,*ERROR, SPECTRAL RESOLUTION  IS OUTSIDE LIMITS*)        IRSTM   2244
1109  FORMAT (9I3)                                                      IRSTM   2245
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 1155 FORMAT (118X,*NITRIC ACID*)                                         IRSTN    2246
 1156 FORMAT (1H1,50X,*RADIANCE(MILLIWATTS/CM2-STER-MICRON)*)             IRSTN    2247
 1157 FORMAT (30X,*FR(CM-1)  WVL(MICRON)     PER CM-1   PER MICRON  ,     IRSTN    2248
     1  INTEGRAL         TRANS*)                                          IRSTN    2249
 1160 FORMAT(30X,F8.1,F13.6,3E13.5,F13.6)                                 IRSTN    2250
      END                                                                 IRSTN    2251
      SUBROUTINE HNO3 (V,HABS)                                            IRSTN    2252
      DIMENSION H1(15), H2(16), H3(13)                                    IRSTN    2253
C ARRAY H1 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM  850 TO 920 CM-1       IRSTN    2254
      DATA H1/2.197,3.911,5.154,8.150,9.217,9.461,11.56,11.10,11.17,12.4 IRSTN    2255
     16,10.49,7.509,6.136,4.899,2.865/                                    IRSTN    2256
C ARRAY H2 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1275 TO1350 CM-1       IRSTN    2257
      DATA H2/2.820,4.611,6.755,8.759,10.51,13.74,18.00,21.51,23.09,21.6 IRSTN    2258
     18,21.32,16.82,16.42,17.87,14.86,8.716/                              IRSTN    2259
C ARRAY H3 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1675 TO1735 CM-1       IRSTN    2260
      DATA H3/5.003,8.803,14.12,19.83,23.31,23.58,23.22,21.09,26.99,25.8 IRSTN    2261
     14,24.79,17.68,9.420/                                                IRSTN    2262
      HABS=0.                                                             IRSTN    2263
      IF (V.GE.850.0.AND.V.LE.920.0) GO TO 1000                           IRSTN    2264
      IF (V.GE.1275.0.AND.V.LE.1350.0) GO TO 1001                         IRSTN    2265
      IF (V.GE.1675.0.AND.V.LE.1735.0) GO TO 1002                         IRSTN    2266
      GO TO 1003                                                          IRSTN    2267
 1000 I=(V-845.)/5.                                                       IRSTN    2268
      HABS=H1(I)                                                          IRSTN    2269
      GO TO 1003                                                          IRSTN    2270
 1001 I=(V-1270.)/5.                                                      IRSTN    2271
      HABS=H2(I)                                                          IRSTN    2272
      GO TO 1003                                                          IRSTN    2273
 1002 I=(V-1670.)/5.                                                      IRSTN    2274
      HABS=H3(I)                                                          IRSTN    2275
 1003 RETURN                                                              IRSTN    2276
      END                                                                 IRSTN    2277
                                                                          IRSTN    2278
      SUBROUTINE POINT (X,YN,N,NP,TX,IP)                                  IRSTN    2279
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,NL,RE,CU,CO,PI    IRSTN    2280
      COMMON KMAX                                                         IRSTN    2281
      DIMENSION TX(11)                                                    IRSTN    2282
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTN    2283
C     SUBROUTINE POINT COMPUTES THE MEAN REFRATIVE INDEX ABOVE AND BELOW  IRSTN    2284
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE    IRSTN    2285
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.                       IRSTN    2286
C                                                                         IRSTN    2287
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTN    2288
C                                                                         IRSTN    2289
C      X IS THE HEIGHT IN QUESTION                                        IRSTN    2290
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X     IRSTN    2291
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X     IRSTN    2292
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0    IRSTN    2293
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X                   IRSTN    2294
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTN    2295
      N=NL                                                                IRSTN    2296
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      NP=0                                                              IRSTM    2297
      IF (X.LT.0.0) X=0.                                                IRSTM    2298
      IF (X.GT.Z(NL)) GO TO 4                                           IRSTM    2299
      DO 1 I=1,NL                                                       IRSTM    2300
      N=I                                                               IRSTM    2301
      IF (X-Z(I)) 2,4,1                                                 IRSTM    2302
1     CONTINUE                                                          IRSTM    2303
2     J2=N                                                              IRSTM    2304
      N=N-1                                                             IRSTM    2305
      FAC=(X-Z(N))/(Z(J2)-Z(N))                                         IRSTM    2306
      PX1=P(M,N)*(P(M,J2)/P(M,N))**FAC                                  IRSTM    2307
      TX1=T(M,N)*(T(M,J2)/T(M,N))**FAC                                  IRSTM    2308
      UX1=UH(M,N)*(UH(M,J2)/UH(M,N))**FAC                               IRSTM    2309
      TX(3)=CO*PX1/TX1-4.56E-6*UX1*TX1*CU                               IRSTM    2310
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*UH(M,J2)*T(M,J2)*CU              IRSTM    2311
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*UH(M,N)*T(M,N)*CU                  IRSTM    2312
      TX(9)=0.5E-6*(TX(2)+TX(3))                                        IRSTM    2313
      YN=0.5E-6*(TX(1)+TX(3))                                           IRSTM    2314
      IF (IP.EQ.0) GO TO 9                                              IRSTM    2315
      DO 3 K=1,KMAX                                                     IRSTM    2316
      IF(K.EQ.9) GO TO 3                                                IRSTM    2317
      TX(K)=0.0                                                         IRSTM    2318
      IF (EH(K,N).EQ.0.0) GO TO 3                                       IRSTM    2319
      IF (EH(K,N).GT.1000.0) GO TO 3                                    IRSTM    2320
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC                             IRSTM    2321
3     CONTINUE                                                          IRSTM    2322
      GO TO 9                                                           IRSTM    2323
4     NP=1                                                              IRSTM    2324
      IF (IP.EQ.0) GO TO 6                                              IRSTM    2325
      DO 5 K=1,KMAX                                                     IRSTM    2326
5     TX(K)=EH(K,N)                                                     IRSTM    2327
6     TX(9)=EH(9,N)-1.                                                  IRSTM    2328
      YN=0.0                                                            IRSTM    2329
C*****  CARDS B 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED             IRSTM    2330
      IF (N.GT.1) YN=EH(9,N-1)-1.0                                      IRSTM    2331
9     CONTINUE                                                          IRSTM    2332
      IF (IP.EQ.1) PRINT 400, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)          IRSTM    2333
      TX(9)=TX(9)+1.                                                    IRSTM    2334
      YN=YN+1.                                                          IRSTM    2335
      RETURN                                                            IRSTM    2336
C                                                                       IRSTM    2337
400   FORMAT (/,* FROM POINT- HEIGHT=*,F10.4,* KM,N=*,I3,*,NP=*,I2,*,REF IRSTM    2338
     1. INDEX ABOVE + BELOW X=*,2E11.4,*,IP=*,I3,/,12X,*EQUIV. ABSORBER  IRSTM    2339
     2AMOUNTS PER KM AT X=*,8E10.3)                                     IRSTM    2340
      END                                                               IRSTM    2341
      SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,NL)                           IRSTM    2342
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),UH(7,34),M,NL,RE,CU,CO,PI   IRSTM    2343
      COMMON KMAX                                                       IRSTM    2344
      DIMENSION TX(11)                                                  IRSTM    2345
C*********************************************************************** IRSTM    2346
C                                                                       IRSTM    2347
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C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)       IRSTM    2348
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA      IRSTM    2349
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),   IRSTM    2350
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.    IRSTM    2351
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL   IRSTM    2352
C     ATMOSPHERE.                                                       IRSTM    2353
C                                                                       IRSTM    2354
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.  IRSTM    2355
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ IRSTM    2356
      IP=99                                                             IRSTM    2357
      CA=PI/180.                                                        IRSTM    2358
      X1=RE+H1                                                          IRSTM    2359
      X2=RE+H2                                                          IRSTM    2360
      LEN=0.                                                            IRSTM    2361
      IT=0                                                              IRSTM    2362
      B1=B1+CA                                                          IRSTM    2363
      IF(B1.EQ.0.0)B1=ACOS(X2/X1)                                       IRSTM    2364
      TANG=X2+SIN(B1)/(X2+COS(B1)-X1)                                   IRSTM    2365
      THET=ATAN(TANG)                                                   IRSTM    2366
      IF (THET.LT.0.0) THET=THET+PI                                     IRSTM    2367
      SPHI=SIN(THET)                                                    IRSTM    2368
      ANG=THET/CA                                                       IRSTM    2369
C     PRINT 404, B1,ANG,TANG                                            IRSTM    2370
      TN=THET                                                           IRSTM    2371
      TN=TN-0.5+CA                                                      IRSTM    2372
1     ANGLE=THET                                                        IRSTM    2373
      FBT=0.                                                            IRSTM    2374
      BETA=0.                                                           IRSTM    2375
      BET1=0                                                            IRSTM    2376
      BET2=0                                                            IRSTM    2377
      FBT1=0                                                            IRSTM    2378
      FBT2=0                                                            IRSTM    2379
      FBT3=0.0                                                          IRSTM    2380
      IF(B1.LE.0.0) GO TO 2                                             IRSTM    2381
C     PRINT 400, IT                                                     IRSTM    2382
      Y=2.+THET                                                         IRSTM    2383
      IF (Y-PI.GT.1.0E-6) GO TO 9                                       IRSTM    2384
      IF (IP.EQ.100) GO TO 6                                            IRSTM    2385
      XMIN=X2+COS(B1)-RE                                                IRSTM    2386
      IF (XMIN-H1) 8,4,4                                                IRSTM    2387
    2 HMIN=H2                                                           IRSTM    2388
      H2=H1                                                             IRSTM    2389
      H1=HMIN                                                           IRSTM    2390
1     ANGLE=0.5+PI                                                      IRSTM    2391
      THET=ANGLE                                                        IRSTM    2392
      SPHI=1.0                                                          IRSTM    2393
      ANG=ANGLE/CA                                                      IRSTM    2394
C     PRINT 404, B1,ANG,SPHI                                            IRSTM    2395
4     IP=100                                                            IRSTM    2396
      CALL POINT (H1,YN,N,NP,IX,IP)                                     IRSTM    2397
      JJ=N                                                              IRSTM    2398
```
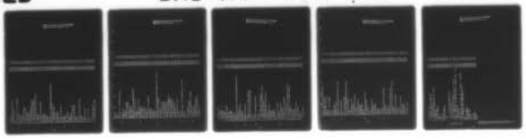

AD-A060 174 SCIENCE APPLICATIONS INC ALBUQUERQUE N MEX F/G 17/5
INFRARED SEARCH AND TRACK EVALUATION MODEL (IRSTEM).(U)
AUG 78 L N PECKHAM, L L DORAN N00173-77-C-0236
UNCLASSIFIED SAI-A64-995-199 NL

3 OF 3
AD
A060 174



END
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```
      TX1=TX(9)
5     CALL POINT (H2,YN,N,NP,TX,IP)
      IF (NF.EQ.1) N=N-1
      J2=N
      IF (J1.EQ.J2) TX1=TX1+YN EH(9,J1)
6     DO 7 J=J1,J2
      X1=RE+Z(J)
      X2=RE+Z(J+1)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2) X2=RE+H2
      SALF=X1+SPHI/X2
      ALF=ASIN(SALF)
      RN=EH(9,J+1)/EH(9,J)
      IF ((J+1).EQ.J2) RN=YN/EH(9,J)
      IF (J.EQ.J1) RN=EH(9,J+1)/TX1
      IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1
      BET=THET-ALF
      FB=-TAN(ALF)
      IF (J.NE.J1) FB=FB+TAN(THET)
      FBT=FBT+FB
      BETA=BETA+BET
      TH1=THET/CA
      BE=BET/CA
      C=ALF/CA
C     PRINT 402, J,Z(J),THET,ALF,BET,BETA,FBT,FB,TH1,BE,C
      IF (X2.EQ.RE+H2) C=PI-ALF
      IF (SALF.GE.RN) RN=1.
      SPHI=SALF/RN
      THET=ASIN(SPHI)
7     CONTINUE
      IF(B1.LE.0.0) GO TO 29
      GO TO 26
8     CONTINUE
      TANG=-TANG
      ANGLE=PI-ANGLE
      TA=ANGLE
      ANG=ANGLE/CA
C     PRINT 404, B1,ANG,TANG
      IF (H1.LE.0.0) GO TO 3
9     CONTINUE
      IP=101
      CALL POINT (H1,YN,N,NP1,TX,IP)
      TX1=TX(9)
      YN1=YN
      IF (NP1.EQ.1) N=N-1
      J2=NL
      IF (M.EQ.7) J2=ML
      J1=N
      J=J1+1
      IF (H2.GE.H1) GO TO 13
      CALL POINT (H2,YN,N,NP,TX,IP)
                   .
                   .
                   .
```

```
      TX2=TX(9)                                                         IKSTN 2450
      YN2=YN                                                            IKSTN 2451
      J2=N                                                              IKSTN 2452
      IF (J1.EQ.J2) TX2=YN1+TX(9)-EH(9,J1)                              IKSTN 2453
10    J=J-1                                                             IKSTN 2454
      X1=RE+Z(J+1)                                                      IKSTN 2455
      X2=RE+Z(J)                                                        IKSTN 2456
      IF (J.EQ.J1) X1=RE+H1                                             IKSTN 2457
      IF (J.EQ.J2) X2=RE+H2                                             IKSTN 2458
      SALP=X1*SPHI/X2                                                   IKSTN 2459
      HMIN=X1*SPHI-RE                                                   IKSTN 2460
C     PRINT 402, J,X1,Z(J),SPHI,SALP,HMIN,RE                            IKSTN 2461
      IF (SALP.LE.1.0) GO TO 11                                         IKSTN 2462
      SALP=SPHI                                                         IKSTN 2463
      IF (HMIN.GT.H2) GO TO 18                                          IKSTN 2464
11    ALP=ASIN(SALP)                                                    IKSTN 2465
      THET=ASIN(SPHI)                                                   IKSTN 2466
      BET=ALP-THET                                                      IKSTN 2467
      BET1=BET1+BET                                                     IKSTN 2468
      FB=TAN(ALP)                                                       IKSTN 2469
      IF (J.NE.J1) FB=FB-TAN(THET)                                      IKSTN 2470
      FBT1=FBT1+FB                                                      IKSTN 2471
      TH1=THET/CA                                                       IKSTN 2472
      BE=BET/CA                                                         IKSTN 2473
      AL=ALP/CA                                                         IKSTN 2474
C     PRINT 402, J,X2,THET,ALP,BET1,BET,BMIN,HMIN,FBT1,TH1,BE,AL        IKSTN 2475
      IF (X2.EQ.RE+H2) C=PI-ALP                                         IKSTN 2476
      REF=EH(9,J)                                                       IKSTN 2477
      IF (J.EQ.J1) REF=YN1                                              IKSTN 2478
      IF (J.EQ.J2) REF=TX2                                              IKSTN 2479
      IF (J.EQ.1) GO TO 12                                              IKSTN 2480
      RN=EH(9,J)/EH(9,J-1)                                              IKSTN 2481
      IF (J.EQ.J1) RN=YN1/EH(9,J-1)                                     IKSTN 2482
      IF(J.EQ.J2+1) RN=REF/TX2                                          IKSTN 2483
      IF(J.EQ.J2) RN=REF/YN2                                            IKSTN 2484
      IF (SALP.GE.RN) RN=1.                                             IKSTN 2485
      SPHI=SALP*RN                                                      IKSTN 2486
      IF (Z(J).LE.H2) GO TO 12                                          IKSTN 2487
      GO TO 10                                                          IKSTN 2488
12    X1=X2                                                             IKSTN 2489
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 13                  IKSTN 2490
      GO TO 14                                                          IKSTN 2491
13    J=J-1                                                             IKSTN 2492
      X1=RE+Z(J+1)                                                      IKSTN 2493
      IF (J.EQ.J1) X1=RE+H1                                             IKSTN 2494
      IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2                                 IKSTN 2495
14    X2=RE+Z(J)                                                        IKSTN 2496
      HMIN=X1*SPHI-RE                                                   IKSTN 2497
      IF (HMIN.LE.0.0) GO TO 25                                         IKSTN 2498
      IF (Z(J).LT.HMIN) GO TO 18                                        IKSTN 2499
      REF=EH(9,J)                                                       IKSTN 2500
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      IF (J.EQ.J2) KE1=TN                                               IKSTM    2501
      SALP=X1*SPHI/X2                                                   IKSTM    2502
      THET=ASIN(SPHI)                                                   IKSTM    2503
      ALP=ASIN(SALP)                                                    IKSTM    2504
      BET=ALP-THET                                                      IKSTM    2505
      FB=TAN(ALP)-TAN(THET)                                             IKSTM    2506
      FBT2=FBT2+FB                                                      IKSTM    2507
      BET2=BET2+BET                                                     IKSTM    2508
      BMIN=BET1+BET2                                                    IKSTM    2509
      AL=ALP/CA                                                         IKSTM    2510
      TH1=THET/CA                                                       IKSTM    2511
C     PRINT 402, J,X2,THET,ALP,BET2,BET,BMIN,HMIN,FBT2,TH1,BE,AL        IKSTM    2512
      KN=KEF/EH(9,J-1)                                                  IKSTM    2513
      IF (SALP.GE.KN) KN=1.0                                            IKSTM    2514
      SPHI=SALP*KN                                                      IKSTM    2515
      GO TO 13                                                          IKSTM    2516
17    TX3=YN1+TX(9)-EH(9,J1)                                            IKSTM    2517
      YN1=TX3                                                           IKSTM    2518
      IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)                           IKSTM    2519
      IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)                           IKSTM    2520
      KN=1.0                                                            IKSTM    2521
      GO TO 19                                                          IKSTM    2522
18    CALL POINT (HMIN,YN,N,NP,TX,IP)                                   IKSTM    2523
      IP=102                                                            IKSTM    2524
      TX3=TX(9)                                                         IKSTM    2525
      IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17                                IKSTM    2526
      IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)                     IKSTM    2527
      IF (HMIN.GT.H2) TX3=TX(9)                                         IKSTM    2528
      IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17                              IKSTM    2529
      KN=KEF/TX3                                                        IKSTM    2530
      IF (SALP.GE.KN) KN=1.                                             IKSTM    2531
      SPHI=SALP*KN                                                      IKSTM    2532
      X=X1*SPHI-KE                                                      IKSTM    2533
      DIF=ABS(HMIN-X)                                                   IKSTM    2534
      HMIN=X                                                            IKSTM    2535
      IF (DIF-1.0E-5) 19,19,18                                          IKSTM    2536
19    X2=KE+HMIN                                                        IKSTM    2537
C     PRINT 403, HMIN,DIF,KN                                            IKSTM    2538
      THET=ASIN(SPHI)                                                   IKSTM    2539
      IF(KN.EQ.1.0) FBT3=-TAN(THET)                                     IKSTM    2540
      IF (KN.EQ.1) GO TO 20                                             IKSTM    2541
      BNX=(TX3-1.0)*ALOG((TX3-1.0)/(KEF-1.0))/(X2-X1)                   IKSTM    2542
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*BNX)))                      IKSTM    2543
20    BET=0.5*PI-THET                                                   IKSTM    2544
      BET2=BET2+BET                                                     IKSTM    2545
      BMIN=BET1+BET2                                                    IKSTM    2546
      IF (H2.GE.H1) GO TO 23                                            IKSTM    2547
      BET=BET1+2.*BET2                                                  IKSTM    2548
      DB1=B1-BET1                                                       IKSTM    2549
      DB2=BET-B1                                                        IKSTM    2550
21      DB3=ABS(BMIN-B1)                                                IKSTM    2551
```

```
      IF(BB3.GT.BB1.AND.BB2.GT.BB1) GO TO 25                             IKSTN  2552
      IF(BB2.GT.BB3) GO TO 22                                            IKSTN  2553
      IF(BB2.GT.BB1)  GO TO 25                                           IKSTN  2554
      BETA-BET                                                           IKSTN  2555
      FBT-FBT1+2.0+(FBT2+FBT3)                                           IKSTN  2556
      LEN=1.                                                             IKSTN  2557
      GO TO 26                                                           IKSTN  2558
 22   BETA-BET1+BET2                                                     IKSTN  2559
      FBT=FBT1+FBT2+FBT3                                                 IKSTN  2560
C     PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1                       IKSTN  2561
      GO TO 26                                                           IKSTN  2562
 23   BETA=2.0+(BET1+BET2)                                               IKSTN  2563
      LEN-1.                                                             IKSTN  2564
      FBT=2.0+(FBT1+FBT2+FBT3)                                           IKSTN  2565
      PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1                       IKSTN  2566
      IF (H2.EQ.H1) GO TO 26                                             IKSTN  2567
      IF=103                                                             IKSTN  2568
      IF (NP1.EQ.1) J1=J1+1                                              IKSTN  2569
      SPHI=SIN(ANGLE)                                                    IKSTN  2570
      IF (Z(J1+1).LE.H2) GO TO 24                                        IKSTN  2571
      KN=TX1/YN1                                                         IKSTN  2572
      IF (SPHI.GE.KN) KN=1.                                              IKSTN  2573
      SPHI=SPHI/KN                                                       IKSTN  2574
      THET=ASIN(SPHI)                                                    IKSTN  2575
      GO TO 5                                                            IKSTN  2576
 24   CALL POINT (H2,YN,N,NP,TX,IF)                                      IKSTN  2577
      TX1=TX1+YN-EN(9,J1)                                                IKSTN  2578
      KN=TX1/YN1                                                         IKSTN  2579
      J2=J1                                                              IKSTN  2580
      IF (SPHI.GE.KN) KN=1.                                              IKSTN  2581
      SPHI=SPHI/KN                                                       IKSTN  2582
      THET=ASIN(SPHI)                                                    IKSTN  2583
      GO TO 5                                                            IKSTN  2584
 25   BETA-BET1                                                          IKSTN  2585
      LEN-0.                                                             IKSTN  2586
      FBT=FBT1                                                           IKSTN  2587
 26   THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)                                 IKSTN  2588
      BBETA=BETA/CA                                                      IKSTN  2589
      B=BET1/CA                                                          IKSTN  2590
      TH1-THET/CA                                                        IKSTN  2591
      PRINT 404, BETA,BBETA,FBT,TH1,TANG                                 IKSTN  2592
      IF (THET.GT.TN.OR.THET.LT.TM) THET-(TN+TM)/2.                      IKSTN  2593
      TH1-THET/CA                                                        IKSTN  2594
      PRINT 404, BET1,B,FBT,TH1                                          IKSTN  2595
      TN1-TN/CA                                                          IKSTN  2596
      TM1-TM/CA                                                          IKSTN  2597
      PRINT 405, TN,TM,TN1,TM1                                           IKSTN  2598
      SPHI=SIN(THET)                                                     IKSTN  2599
      TANG-TAN(THET)                                                     IKSTN  2600
      II=II+1                                                            IKSTN  2601
      DBE-ABS(B1-BETA)                                                   IKSTN  2602
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```
      DIN=ABS(ANGLE-THET)
      IF (IT.EQ.10) THET=0.5*(ANGLE+THET)
      IF (IT.EQ.10) GO TO 28
      IF (DNE.GT.1.0E-7.AND.DIN.GT.1.0E-7) GO TO 1
   28 ANGLE=THET/CA
      PRINT 406, ANGLE,IT
      RETURN
   29 H1=H2
      ANGLE=C/CA
      PRINT 406, ANGLE,IT
      RETURN
C
  400 FORMAT (//* ITERATION NUMBER *,I3,//)
  401 FORMAT (I6,E16.7,8F13.8)
  402 FORMAT (I4,F10.4,6E13.4,4F10.4/)
  403 FORMAT (*  HMIN=*,F14.6,*  DIF=*,E14.6,*  FK=*,E16.8)
  404 FORMAT (* TOTAL BETA = *,E14.6,F15.6,*,FBT = *,E14.6,* THET =*,F10
     1.6,*TANG=*,F10.6)
  405 FORMAT (5F12.8)
  406 FORMAT (8X,/1H*,*ZENITH ANGLE =*,F7.3,* DEGREES -  RECOMPUTED
     1 FROM SUBROUTINE ANGL (ITERATION*,I3,*)*)
      END
      FUNCTION NODD(I)
      DIMENSION NO(2)
      DATA NO/1,-1/
      J=I/2
      K=I-2*J+1
      NODD=NO(K)
      RETURN
*EOR
*EOF
*EOR
*EOF
*EOR
*EOF
*EOR
*EOF
*EOR
*EOF
*EOR
*EOF
*EOR
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