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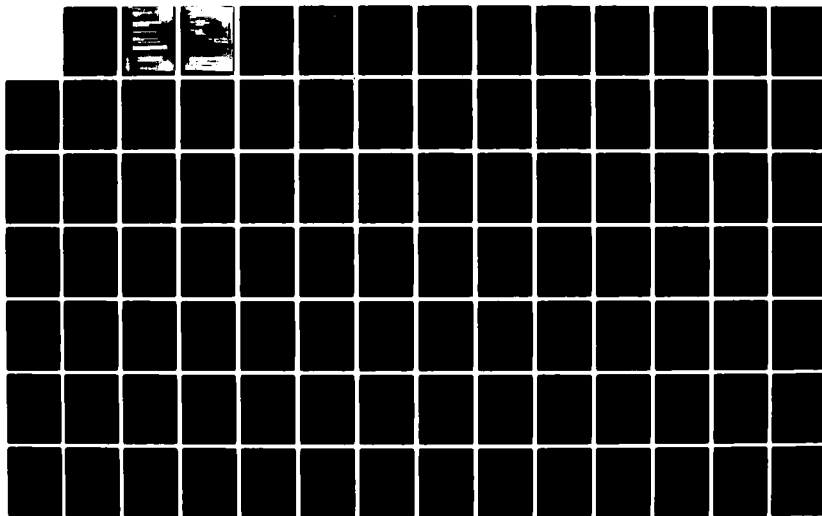
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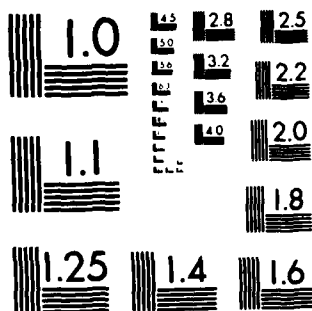
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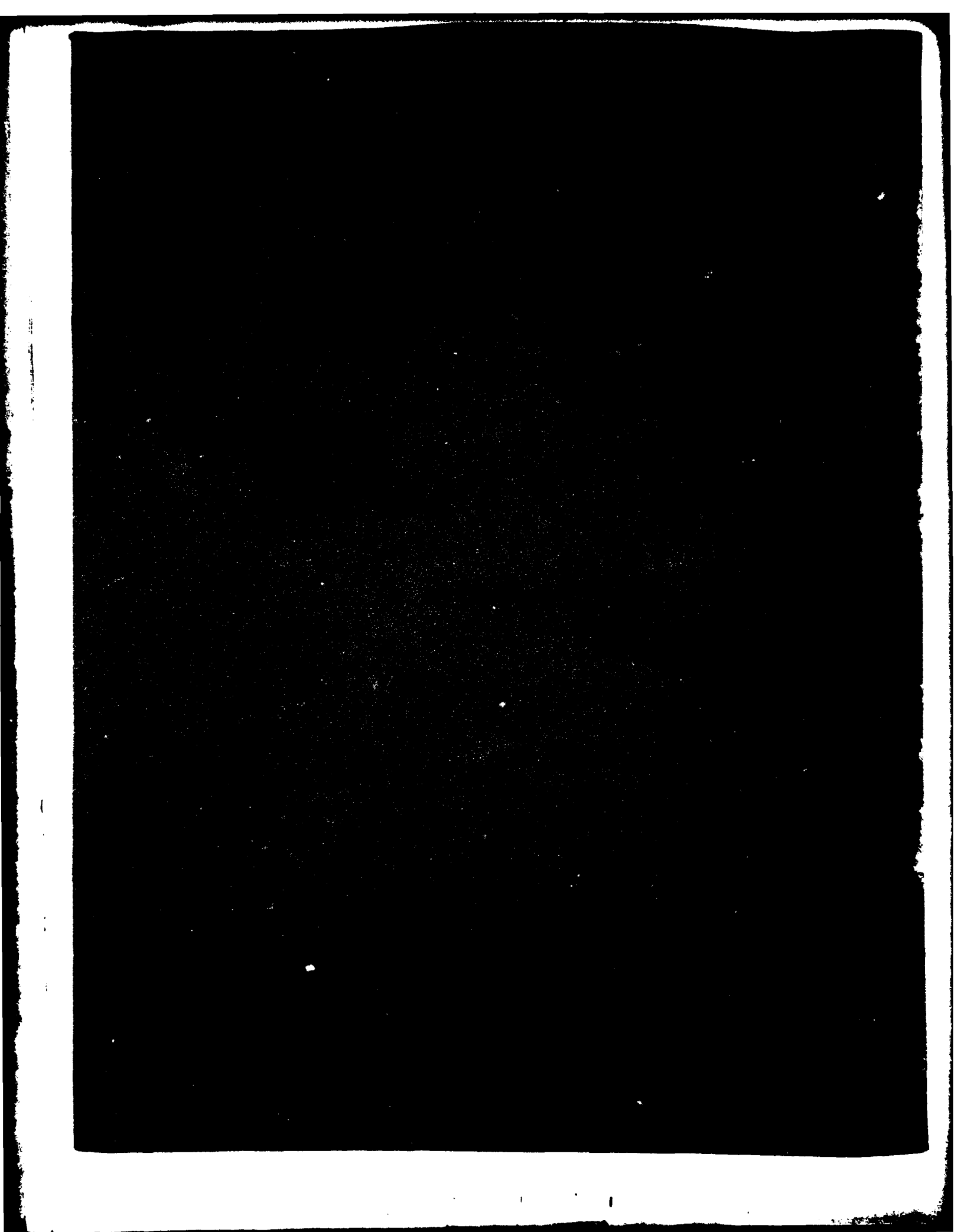
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ACOSS ELEVEN (ACTIVE CONTROL OF SPACE STRUCTURES)

Thomas H. Brooks

David Anding

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The Program Manager at CSDL is Dr. Keto Soosaar, and the Project Engineer is Mr. Thomas Brooks.

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Publication of this report does not constitute approval by the Defense Advanced Research Projects Agency or the United States Government of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

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1.0 INTRODUCTION

In support of the Draper Integrated Simulations, Photon Research Associates has developed a computer code capable of generating and manipulating terrestrial scenes as a function of major surveillance system and mission parameters. This code (called GENESSIS) has the capability to interface with the Defense Mapping Agency (DMA) data base of terrestrial scenes as the source of scene input data. Consequently, the code is able to simulate any scene for which DMA data exists.

Because of the desirability to have a functioning code as soon as possible, the code is being developed in two phases (each phase spanning approximately one calendar year). The first phase has provided a functional synthetic scene simulation computer code, although this first-phase code has some limitations. In particular, some of the higher-order phenomena controlling scene radiance (e.g., cloud shadowing) have been neglected, some of the phenomenological treatments utilize simplifying approximations, and the input data base is limited to five terrestrial scenes and two cloud representations. The plan is to eliminate these restrictions during subsequent phases.

This report presents the status of the GENESSIS code at the end of the first phase effort and presents instructions for its use. Code architecture, I/O functions, user operational procedures, and test case outputs are each presented and discussed.

2.0 CODE ARCHITECTURE

The GENESSIS scene simulation is based upon a point-by-point algorithm, a single cycle of which consists of collecting (and in some instances, computing) inputs specific to a single point on the scene, calculating the apparent radiance of that point from the collected inputs, and finally weighting and assigning the calculated radiance to the appropriate pixel in the observer's field of view. If the density of points is large enough, the scene will be properly sampled and the radiances computed by repeated point calculations can be combined to produce an accurate pixel radiance map of the scene. The parameters of these radiance grid points are computed from the three-dimensional scene itself.

Scene data consists of discrete altitude, material type pairs specified at regular intervals on a planar rectangular grid. Continuous surfaces are produced from the discrete scene data using a bi-cubic spline fitting technique. Point data can be computed from these surfaces at any desired spatial resolution.

The computed apparent radiances consist of four terms combined additively. These are reflected solar, thermal emission, reflected sky radiance and path radiance. The respective calculational procedures are discussed in Section 3.4. Each major calculational operation is performed with a separate software module. The atmospheric, geometric and radiance modules have stand-alone capabilities, but are normally executed in sequence to produce a final result.

The simulations' primary output is an $N \times M$ viewer-perspective pixel apparent radiance map. Diagnostic output is also available to check proper code execution.

2.1 Modules

The GENESSIS code is comprised of six (6) modules (subroutine packages) each with a single specific task. These are geometric, atmospheric, heat transfer, radiance, image and ephemeris. These are combined into three major modules each with stand-alone capabilities. Modular stand-alone capabilities allow flexibility of operation while maintaining a simplicity of structure, user interaction and memory requirements.

The geometric module performs shadowing and the viewer perspective projection of the scene. Its output is required by the radiance module.

The atmospheric module supplies atmospheric parameters required by the radiance module. It is run least often since its output covers a wide range of solar and observer geometries.

The radiance module produces a viewer perspective pixel apparent scene radiance map from information supplied by the atmospheric and geometric modules. It calls upon the heat transfer and image modules to produce,

respectively, surface temperatures and viewer image. The heat transfer module currently does not have a stand-alone capability. Both the geometric and radiance modules utilize the ephemeris module.

With the exception of the ephemeris module, these packages are discussed in detail in Sections 3.1-3.5. The ephemeris module computes the altitude-azimuth position of the sun for any specific time, date and observer location. A published user's manual exists for this package.* See Appendix 1 for excerpts of this manual.

2.2 Module Interaction

A flow diagram of the GENESSIS architecture is given in Figure 1 which details module interaction and hierarchy. Although the ephemeris, heat transfer and image modules have stand-alone capabilities, they currently require interaction with other major modules. Plans exist to investigate increases in efficiency and flexibility potentially available by separating these modules. This will be done during Phase II of the contract. Figure 2 details the I/O-module interaction. In this figure GENESSIS is shown as having three major components.

2.3 User Inputs/Control

User inputs are categorized according to purpose. These are geometric, sensor and atmospheric. The elements of these are:

A. Geometric Inputs

1. The date and time of the simulation, used to compute the position of the sun,
2. The latitude and longitude of the viewer subsatellite point,
3. The observer altitude in kilometers.

B. Sensor Inputs

1. The vertical and horizontal angular field of view,
2. Focal plane rotation in degrees,
3. The vertical and horizontal spatial resolution in meters.

C. Atmospheric Inputs

1. Atmospheric model (six LOWTRAN standard atmospheres),
2. Aerosol model,
3. Haze model,
4. Visibility in kilometers.

* Solar Ephemeris Algorithm, W. Wilson. Visibility Laboratory, Scripps Institution of Oceanography, UCSD. SIO Ref. 80-13, July 1980, La Jolla, CA.

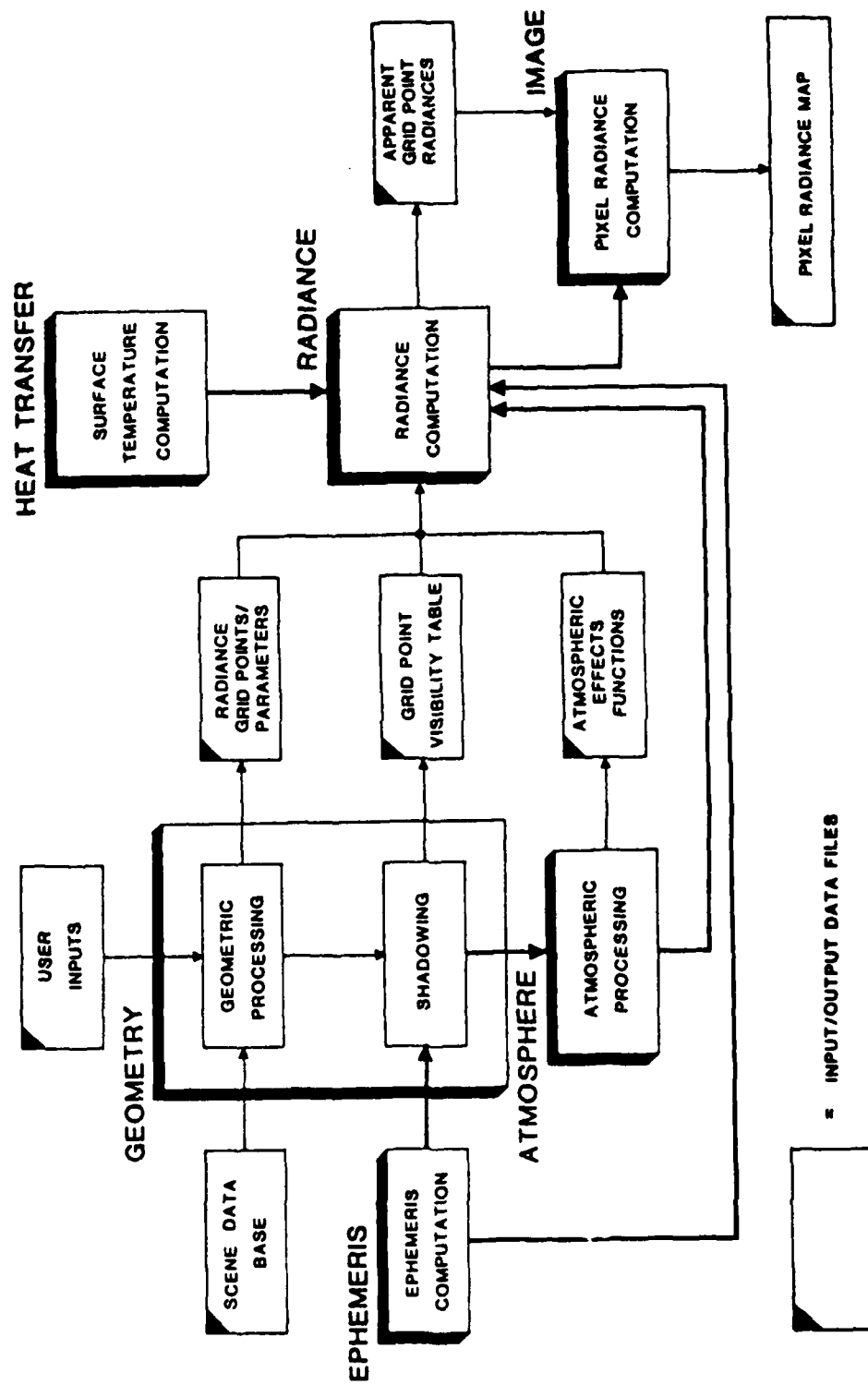


Figure 1. GENESIS Architecture

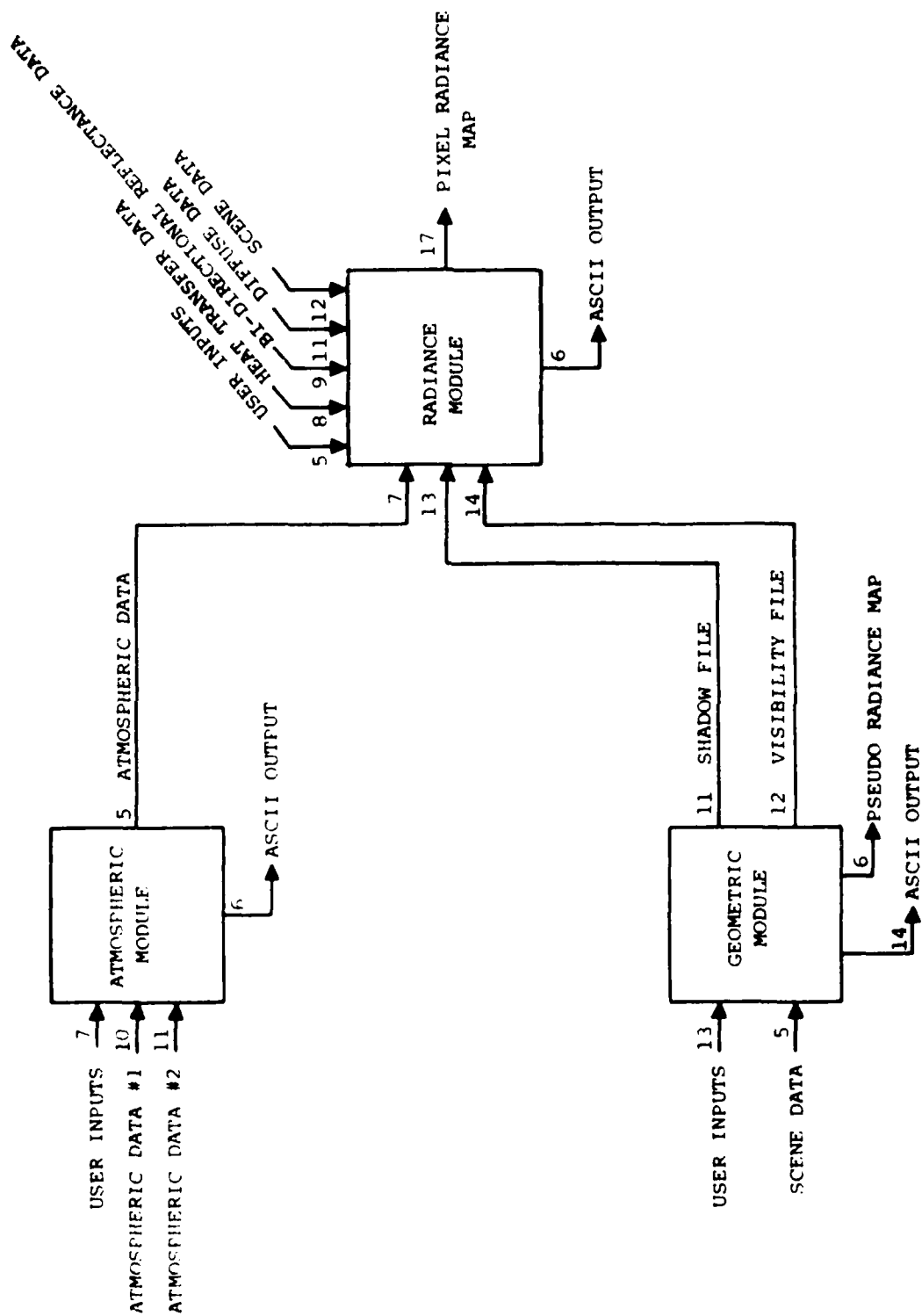


Figure 2. Overall Input/Output File Interaction. Numbers are Fortran Unit Numbers. See Section 6 for More Detail

See Section 6 for a detailed discussion of the user specified inputs.

2.4 Scene Data Base Inputs

Scene data inputs consist of the altitude, material type pairs plus thermal, atmospheric and reflectance data. The elements of these inputs are:

1. Material thermal properties (solar absorptance, thermal emittance, thermal conductance and thermal mass) required by the heat transfer module,
2. Material in-band diffuse reflectance,
3. Cloud in-band bi-directional reflectance,
4. Surface level atmospheric properties (temperature, wind speed and humidity).

A detailed discussion of the scene data base is given in Section 4.

3.0 MODULE DESCRIPTION

3.1 Atmospheric Module

The atmospheric module performs a parametric analysis of a selected standard atmosphere which is primarily a function of spectral bandpass and observer altitude. Four in-band parameters are computed. These are reflected solar, reflected skyshine, path radiance and path transmission.

The reflected components are apparent values, having been attenuated spectrally along the observer's line-of-sight path. Path transmission and path radiance are computed for the path from the surface to the observer. For the reflected components, the atmospheric module calculates spectrally for the path from source to surface to observer. The spectral data are then integrated over wavelength to produce a single in-band value for the entire path.

In order to reduce the long-term costs associated with the computation of atmospheric parameters, and to provide the necessary computational flexibility, it is desirable to have the atmospheric parameters functionally related to altitude. Early investigations showed that these parameters could be represented by polynomials over the altitude range from 0 to 10 km.

Parameters are calculated parametrically for a series of zenith angles and altitudes. At each altitude a polynomial fit versus air mass is computed and stored for reflected solar, path transmission and path radiance. For skyshine, polynomial fits are stored as a function of altitude only. From this data base, polynomial fits versus altitude for each of the four atmospheric parameters are produced for any given solar and observer position.

Since the reflected solar component is also a function of the solar zenith angle, an additional series of cases and curve fits are required to completely describe this parameter.

The coefficients of these curve fits are written to file for use by the radiance module. This output file covers all observer and solar zenith angles and need not be remade unless the bandpass, model atmosphere, observer altitude or atmospheric conditions are changed. Curve fit diagnostics are generated in order to monitor the quality of the polynomial fits.

The atmospheric module utilizes a PRA developed code which is based on LOWTRAN that properly computes reflective or "bent path" atmospheric values.

Figure 3 is a flow diagram of the atmospheric module. Figures 4-7 illustrate sample atmospheric module outputs for the following conditions:

Atmosphere:	Subarctic Summer
Observer Altitude:	100 km
Observer Zenith Angle:	0 degs

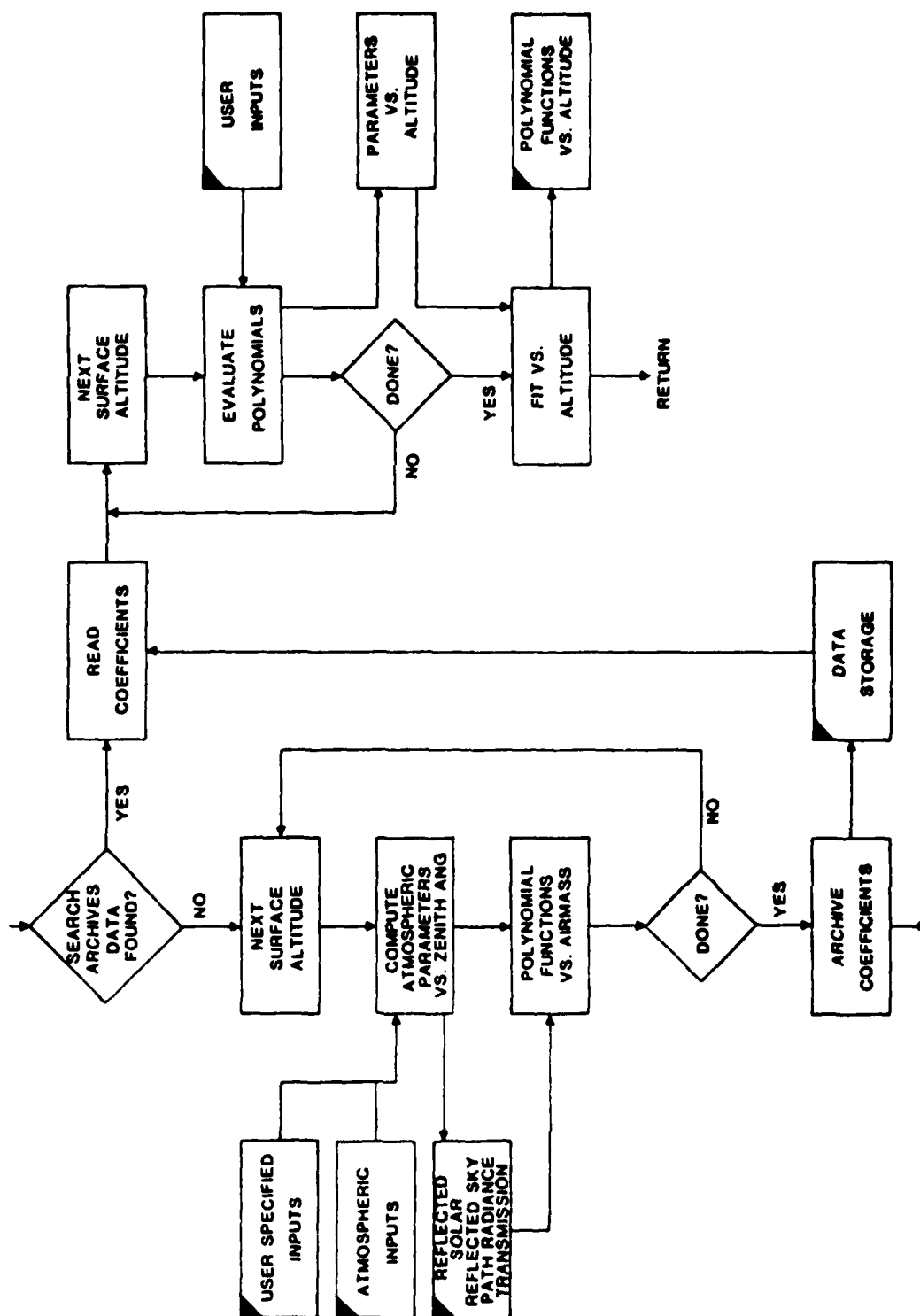


Figure 3. Atmospheric Module

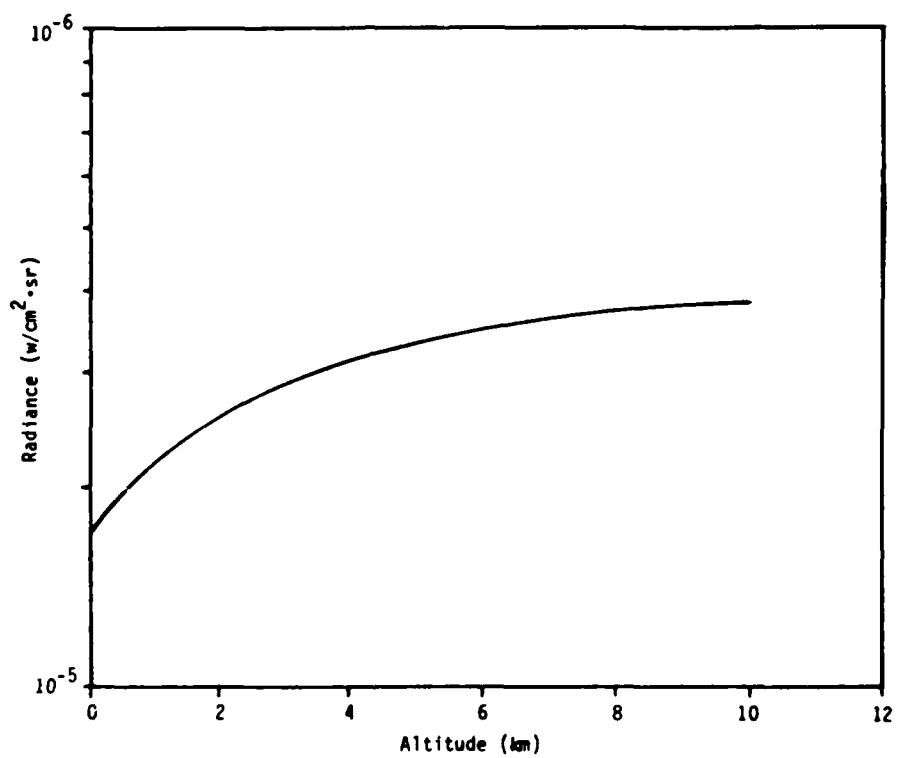


Figure 4. Apparent Reflected Solar Radiance Versus Altitude

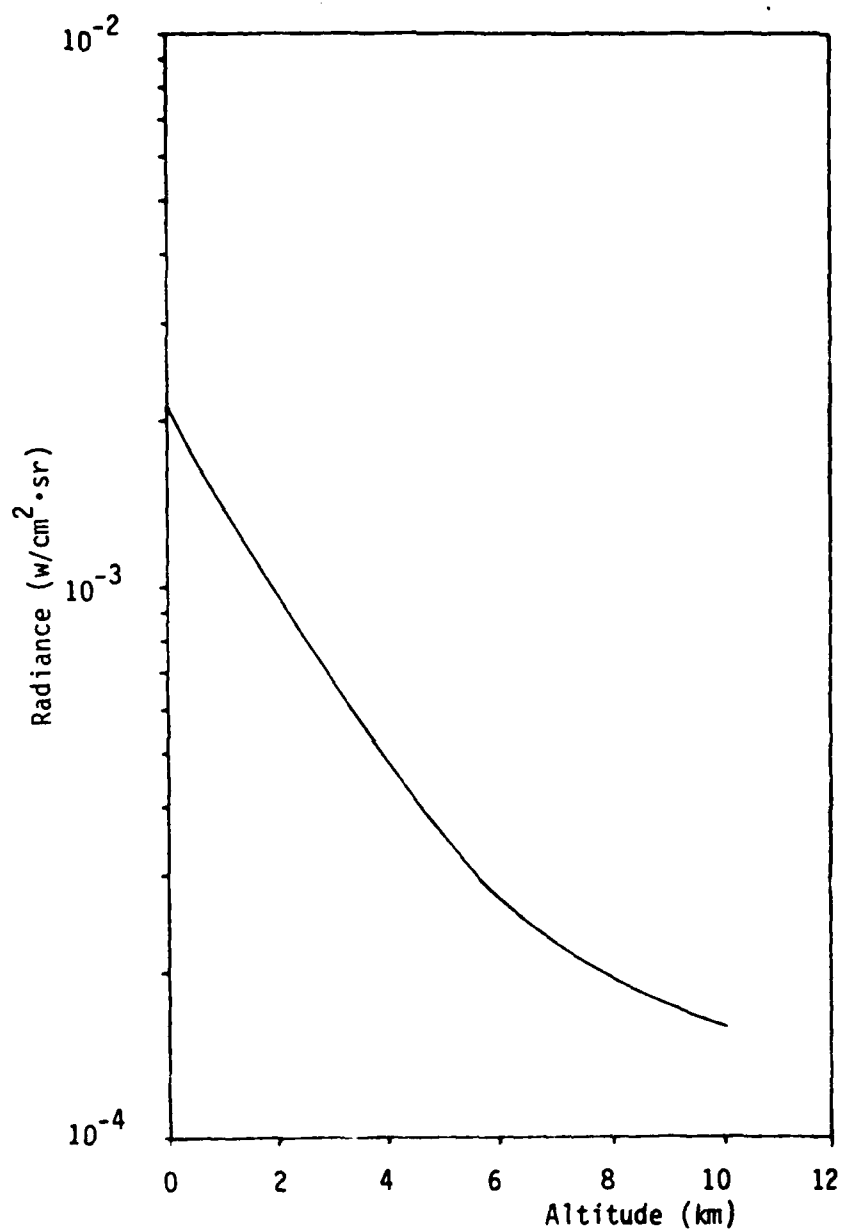


Figure 5. Skyshine Apparent Radiance
Versus Altitude

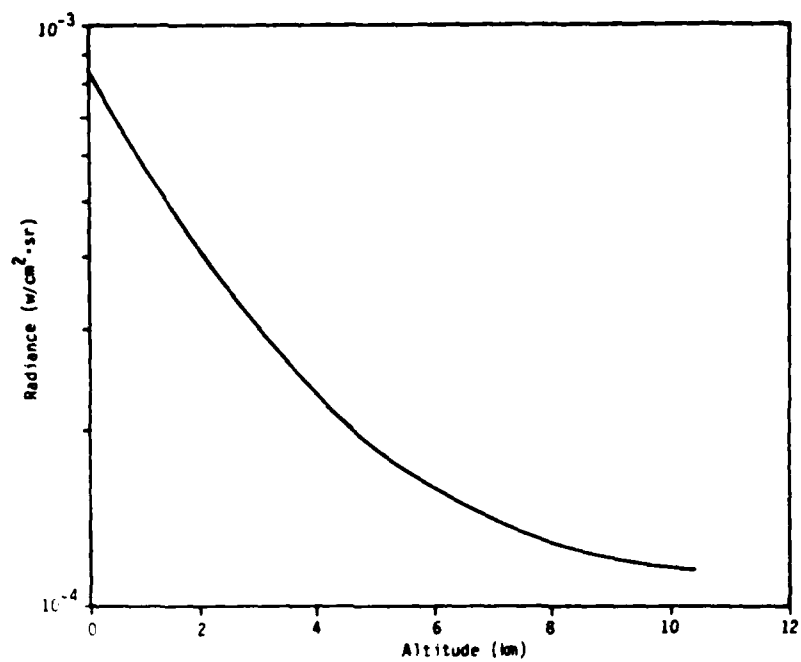


Figure 6. Path Radiance Versus Altitude (Km)

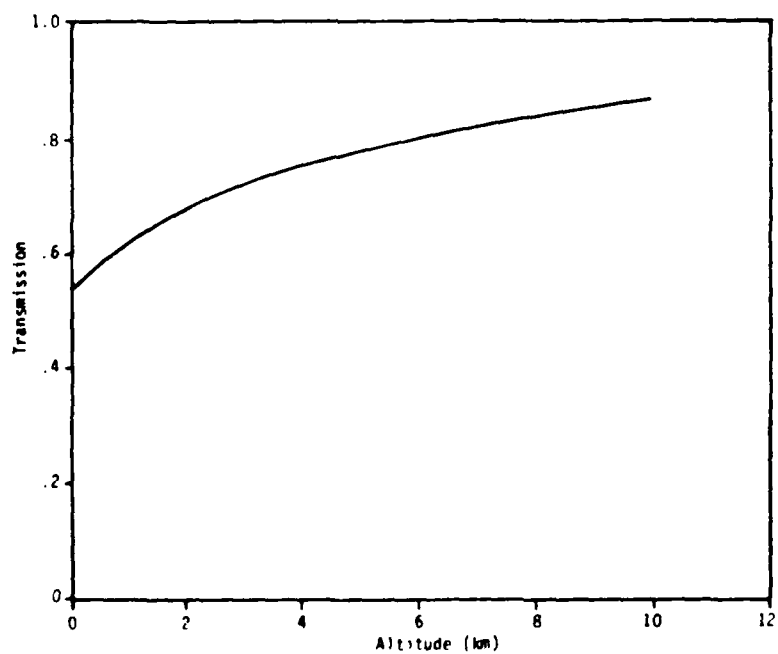


Figure 7. Path Transmission Versus Altitude

Sun Zenith Angle: 64 degs
Band: 7.5-12.0 μm

3.2 Geometry

The geometric module supplies information regarding the visibility, orientation and projection of scene radiance grid points. It creates a high resolution altitude map by bi-cubic spline interpolation on a DMA data base. For each interpolated point it provides the following information:

- Point in shadow or in sun,
- Point visible or not,
- Geometric information such as altitude, normal vector, direction cosines to the sun and to the observer,
- Material type.

All geometric calculations are based on an earth-centered Cartesian coordinate system.

Surfaces and normal vectors are produced from the scene data using the bi-cubic spline fitting technique. In the event grid points are required at a higher resolution than the scene input data, they are generated from the spline-fit produced surfaces. The interpolation forms a bi-cubic patch for each grid rectangle in the data base. This rectangle is evenly divided into a sub-grid of predetermined size. The bi-cubic spline is evaluated at each of these sub-grid points. For more detailed information, see: A. R. Forrest, "On Coons' and Other Methods for the Representation of Curved Surfaces," Computer Graphics and Image Processing (1972) 1 (pp 341-359).

The visibility and shadowing of each grid point is determined using a hidden line masking technique. This is done by slicing the high-resolution data base along grid-lines, so that these slices are approximately perpendicular to the line of sight. A point is visible if the line of sight from the sensor to the point does not intersect an intervening surface. The same criterion is used for the shadowing determination. The scene is processed twice, once for the observer and once for the sun.

Shadowing and visibility information are stored in intermediate files. During the radiance calculation, these files are used to decide if the interpolated points are visible and whether they receive solar illumination. Points not visible to the observer are ignored. Points not seen by the sun are in shadow and are treated accordingly by the radiance module. The hidden line masking technique is illustrated in Figures 8-10. Projection of each point into the observer's image plane completes the primary tasks of the geometric module. The module is diagrammed in Figure 11.

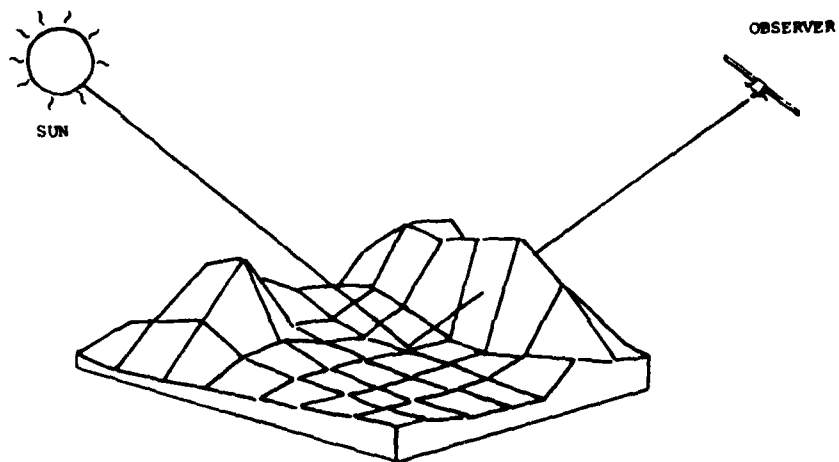


Figure 8. Schematic Demonstration of Geometric Module Procedure. Grid is the Interpolated Scene Data Base, i.e., "Radiance Grid Points". Example is for Radiance Point (I,J) which is Not Visible by the Observer but Illuminated by the Sun

SCENE IS SLICED ALONG GRID LINES IN ONE OF TWO DIRECTIONS. A RADIANCE POINT IS VISIBLE IF AND ONLY IF THERE IS A CLEAR LINE OF SIGHT FROM THE OBSERVER TO POINT. IN THIS EXAMPLE, THE POINT IS NOT VISIBLE.

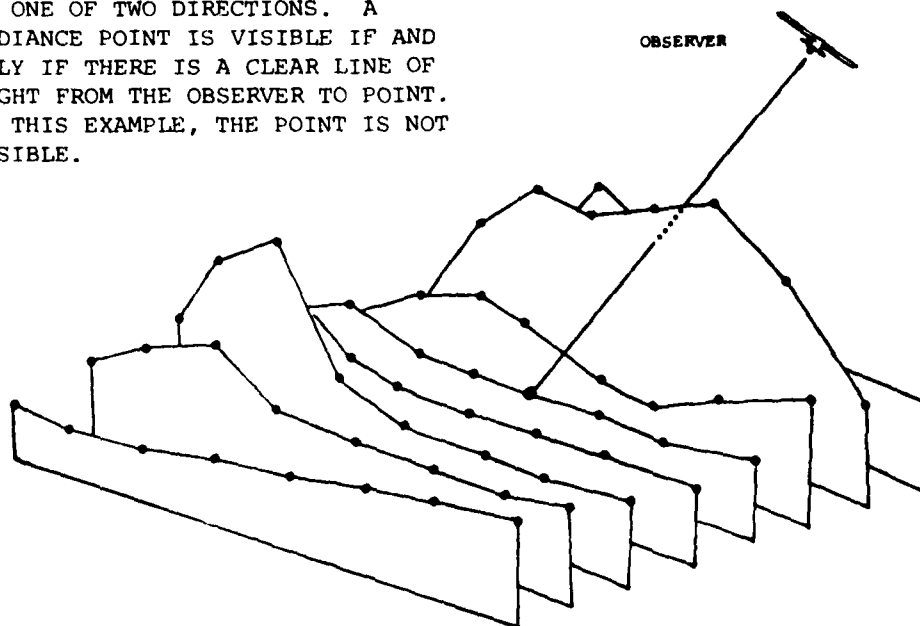


Figure 9. Example of Hidden Line Masking Technique Used to Determine Visibility of Radiance Grid Point (I,J). Scene Sliced for Observer

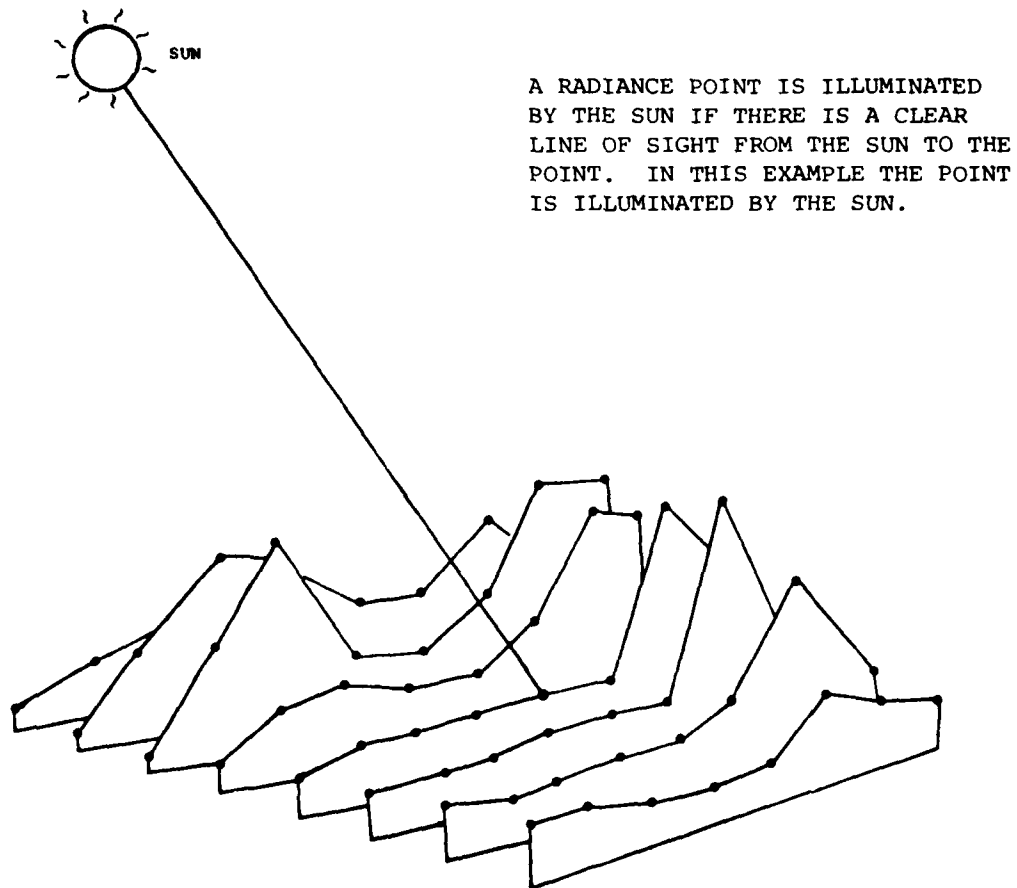


Figure 10. Example of Hidden Line Masking Technique
Used to Determine Shadowing of Point (1,1)
Scene Sliced for Sun

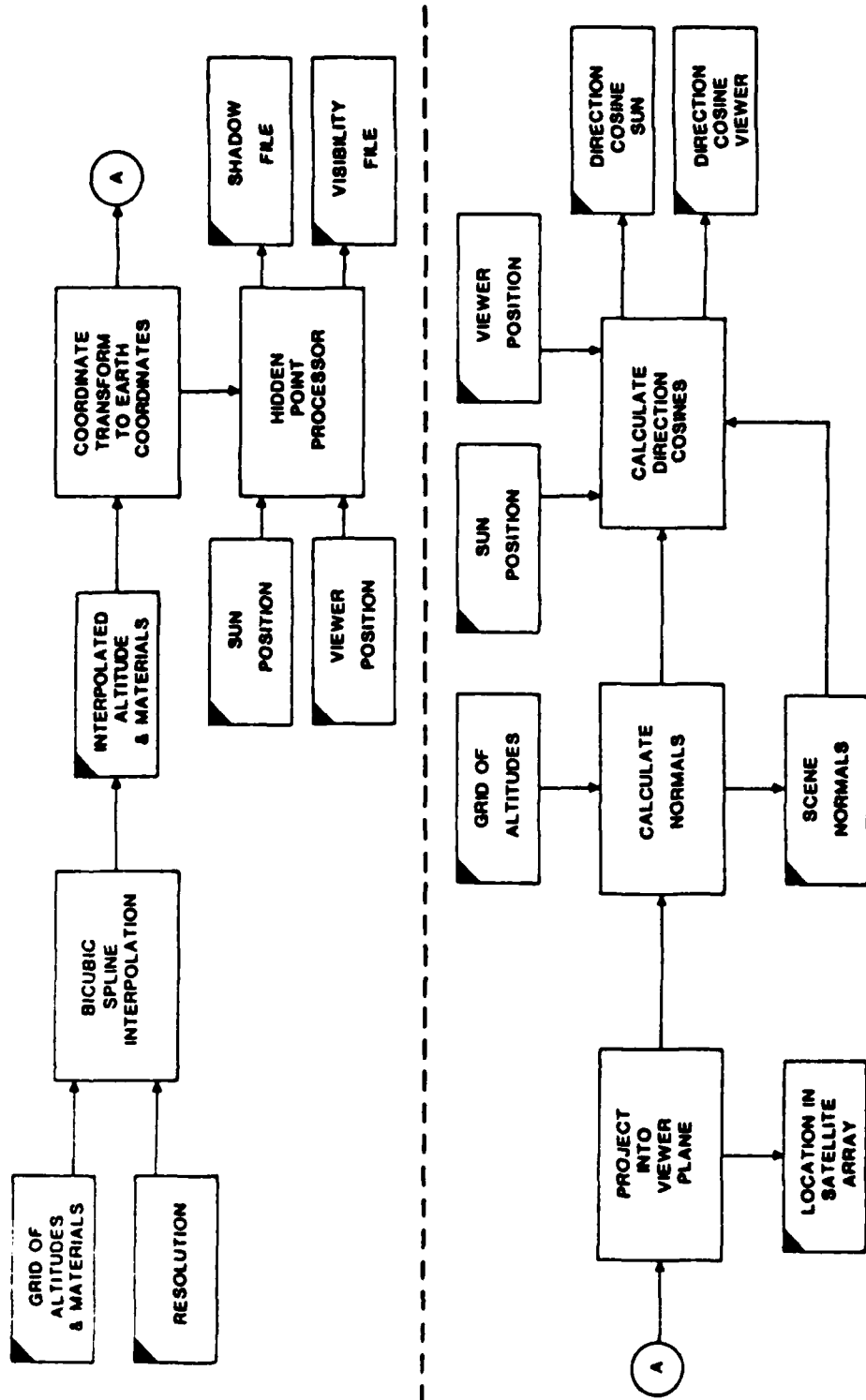
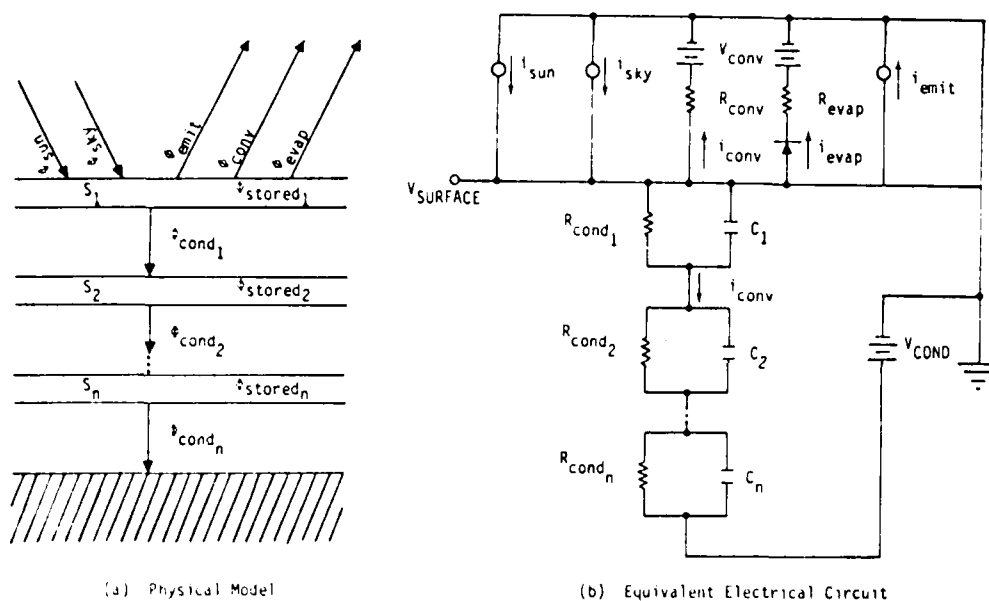


Figure 11. Geometric Module

3.3 Heat Transfer

Surface temperature is determined by the energy fluxes and thermal properties of the surface. The fluxes considered in the model are those resulting from solar irradiance, sky irradiance, convection to the air, self-emitted radiation, latent heat flux due to evaporation of surface moisture,* and the distributed flux through the material to a substrate. The heat balance solution of the dynamic surface temperature employs two simplifying assumptions. These are that the lateral heat flux at the surface is zero, and that the distributed heat flux to the substrate can be calculated using n discrete layers, the lowest of which is adjacent to a diurnally constant subsurface. The result and physical model and its equivalent electrical circuit are given in Figure 12.



FLUX DEFINITION

i_{sun}	= solar irradiance	i_{evap}	= surface evaporation
i_{sky}	= sky irradiance	i_{stored}	= layer stored
i_{emit}	= emission	i_{conv}	= air convection
		i_{cond}	= substrate conduction

Figure 12. Surface Temperature Heat Balance Model.

* For GENESIS I heat transfer due to evaporation is neglected, i.e., $i_{\text{evap}} = 0$.

The heat balance equation for the physical model is

$$\phi_{\text{sun}} + \phi_{\text{sky}} + \phi_{\text{stored}} = \phi_{\text{conv}} + \phi_{\text{evap}} + \phi_{\text{emit}} + \phi_{\text{cond}} \quad (1)$$

All fluxes are in units of W/m^2 and all vary with time. Each of these fluxes is expressed as follows.

The solar irradiance flux, ϕ_{sun} , is calculated by

$$\phi_{\text{sun}} = \alpha(s) E_{\text{sun}}(h, t) \cos \zeta(t) \quad (2)$$

where

$\alpha(s)$ is the effective solar absorptance,

$\zeta(t)$ is the time dependent angle between the vector to the sun and the surface normal vector, and

$E_{\text{sun}}(h, t)$ is the time dependent total solar irradiance at the surface.

The solar irradiance at the surface is given by

$$E_{\text{sun}}(h, t) = E_{\text{sun}, \psi_0}(h) \cdot f(\psi(t)) \quad (3)$$

where $E_{\text{sun}, \psi_0}(h)$ is the zenith total solar irradiance as a function of surface altitude, h , and $f(\psi(t))$ is a factor to correct for increasing atmospheric attenuation with increasing time variant solar zenith angle $\psi(t)$.

The sky irradiance flux, ϕ_{sky} , is computed from the Idso-Jackson formula

$$\phi_{\text{sky}} = \alpha(L) \sigma T_a^4 \left\{ 1 - .261 \exp \left[-7.77 \times 10^4 (273 - T_a)^2 \right] \right\} \quad (4)$$

where

σ is the Stephan-Boltzmann constant, $5.6687 \times 10^{-8} \text{ W/m}^2 \cdot ^\circ\text{K}$,

T_a is the ambient air temperature, and

$\alpha(L)$ is the effective thermal absorptance.

The convective flux to the atmosphere is computed by

$$\phi_{\text{conv}} = \rho c D W (T - T_a) \quad (5)$$

where

ρ is the ambient air density,

c is the specific heat of dry air,

D is the drag coefficient, empirically determined from ground truth data ranging from 0.002 to 0.01 depending upon the material,

W is the wind speed factor, equal to $1+V_w$ where V_w is the wind speed in m/sec, and

T is the surface temperature.

The latent heat flux is computed by

$$\phi_{\text{evap}} = 0.622 \rho D W e (v - v_a) / P_a \quad (6)$$

where

e is the latent heat of evaporation,

v is the water vapor pressure at the surface,

v_a is the water vapor pressure of the air, and

P_a is the atmospheric pressure.

If v_a is larger than v, ϕ_{evap} is set equal to zero.

The emitted flux is computed by

$$\phi_{\text{emit}} = \epsilon(L) \sigma T^4 \quad (7)$$

where $\epsilon(L)$ is the effective thermal emittance, set equal to $\alpha(L)$ in Equation (4).

The conductance flux to the substrate is computed by

$$\phi_{\text{cond}} = g (T - T_s)$$

where g is the conductance to the substrate, equal to $\ell_s \cdot K$ where ℓ_s is the depth at which the soil is diurnally constant and K_s is the soil conductivity, and T_s is the substrate temperature.

The stored flux in the surface layer is computed by

$$\phi_{\text{stored}} = \ell_o C [T(t+\Delta t) - T(t)] / \Delta t \quad (8)$$

where

ℓ_o is the layer thickness,

C is the heat capacity of the surface material, and

ΔT is the time increment.

The solution for the surface temperature T is achieved using an interactive method wherein the surface temperature is initially chosen as the ambient air temperature at midnight, and the heat balance equation is iteratively evaluated in time increments Δt (usually set equal to 30 minutes). This iteration is continued until successive diurnal cycles match, commonly occurring within three days.

This procedure is used to produce a data base for selected materials within the scene. The data base consists of temperature and four independent variables. All independent variables are varied over a sufficient range so as to bracket all conditions that may be encountered in the scene. These independent variables are:

1. Peak solar irradiance,
2. Air-surface convective flux,
3. Substrate-surface conductive flux, and
4. Time.

The data base is compressed using a technique by which only the j most informative time points are retained of the i that were calculated. This results in a significant reduction in size of the data base (i usually 48, j/i usually 1/6) with little reduction in accuracy. The stored data base consists of four values of solar irradiances, four values of convective flux, three values of conductive flux and eight values of solar elevation angle (radians).

The heat transfer module contains data for 9 materials of the 14 total materials within GENESSIS I (see Appendix 2). The 14 materials are:

<u>GENESSIS Material Numbers</u>	<u>Material</u>
1*	Water
2*	Forest (Broadleaf)
3	Irrigated Low Vegetation
4	Scrub
5	Urban Commercial
6	Sand
7*	Ice
8	Rock
9	Soil
10	Grass
11*	Clouds
12	Asphalt
13	Urban Residential
14*	Forest (Pine)

* Heat transfer calculations are not performed on materials 1, 2, 7, 11 and 14.

Surface temperatures for the 5 remaining materials (i.e., 1, 2, 7, 11 and 14) are set equal to the local ambient air temperature.* Ambient air temperature varies with altitude and is computed from the user specified sea level air temperature and the atmospheric lapse rate. The lapse rate is approximately linear for each of the six standard model atmospheres between 0-10 km. The least-squares lapse rates used by GENESSIS I are given in Figures 13-18.

To perform a GENESSIS execution the user must specify the local air temperature and the subsoil temperature. Monthly mean temperatures are good first-order approximations to the subsoil temperature. These data are given in Tables 1-4 for each of the five generic scenes provided with GENESSIS I.

3.4 Radiance Module

The radiance module computes observer apparent pixel radiances from the viewer-perspective shadow files created by the geometric module. If it is visible, an apparent radiance is computed for each of the grid points generated by the geometric modules' bi-cubic spline fit to the scene data. Pixel radiances are computed from these individually calculated grid point radiances. The apparent radiance of a specific grid point is composed of four terms combined additively. These include reflected solar, thermal emission, reflected skyshine and path radiance.

3.4.1 Reflected Solar

The apparent reflected solar component is

$$N_{\text{solar}} = \rho_{\text{solar}} \phi(h) \cos \theta$$

where

ρ = surface in-band diffuse reflectance (bi-directional reflectance for clouds),

$\phi(h)_{\text{solar}}$ = computed fit to apparent reflected solar versus altitude (supplied by atmospheric module),

h = surface altitude in km, and

θ = local sun zenith angle (the angle between the vector to the sun and the surface normal).

* For ice, the temperature cannot exceed 0°C.

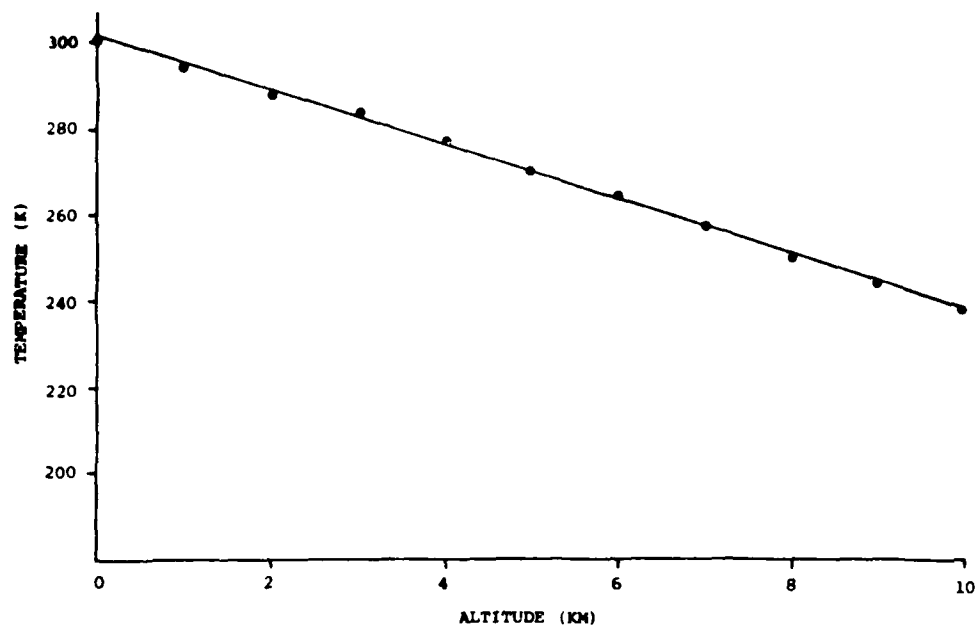


Figure 13. Tropical Model Atmosphere Lapse Rate

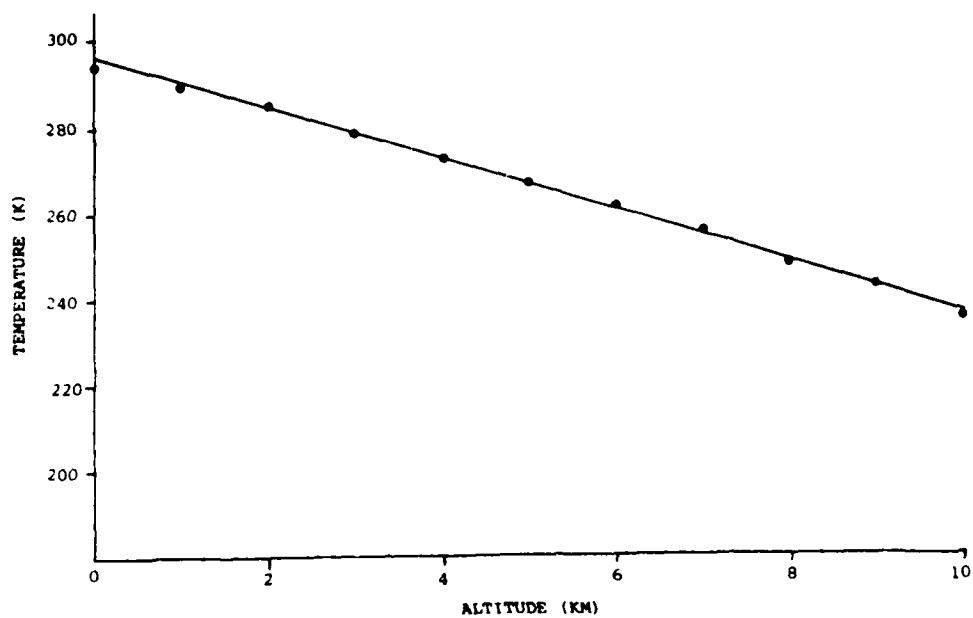


Figure 14. Midlatitude Summer Model Atmosphere Lapse Rate

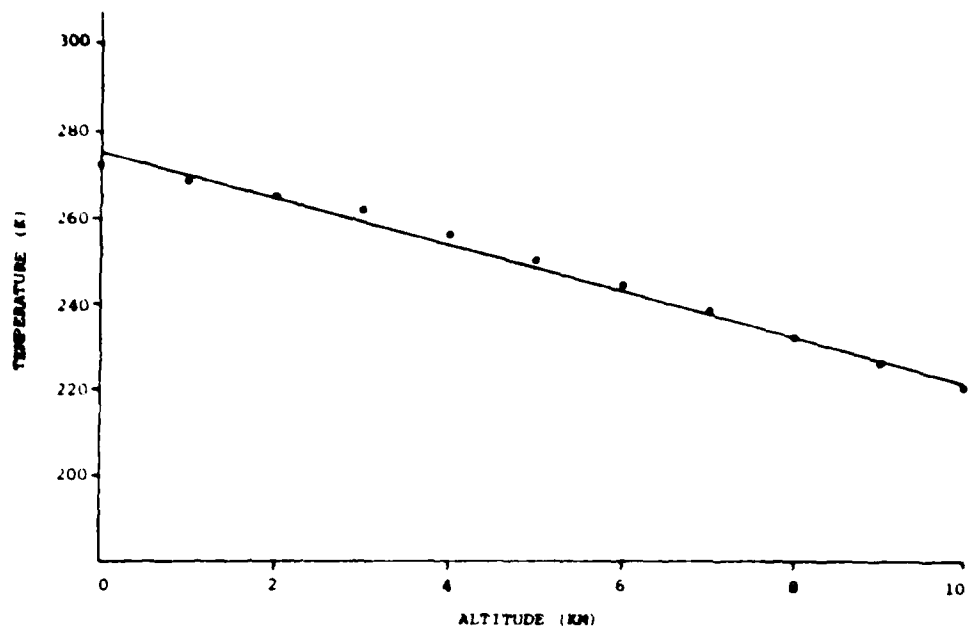


Figure 15. Midlatitude Winter Model Atmosphere Lapse Rate

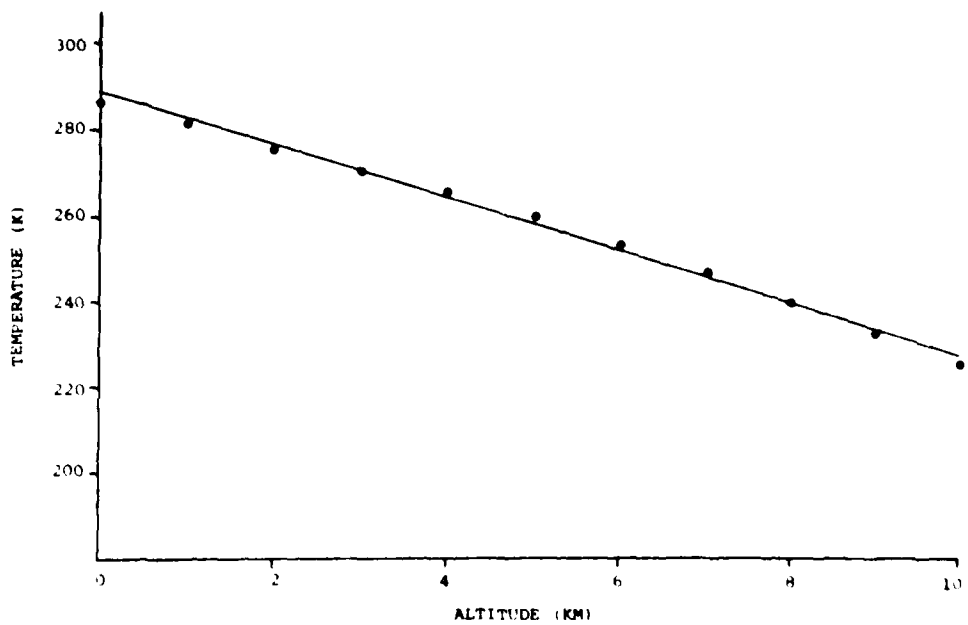


Figure 16. Subarctic Summer Model Atmosphere Lapse Rate

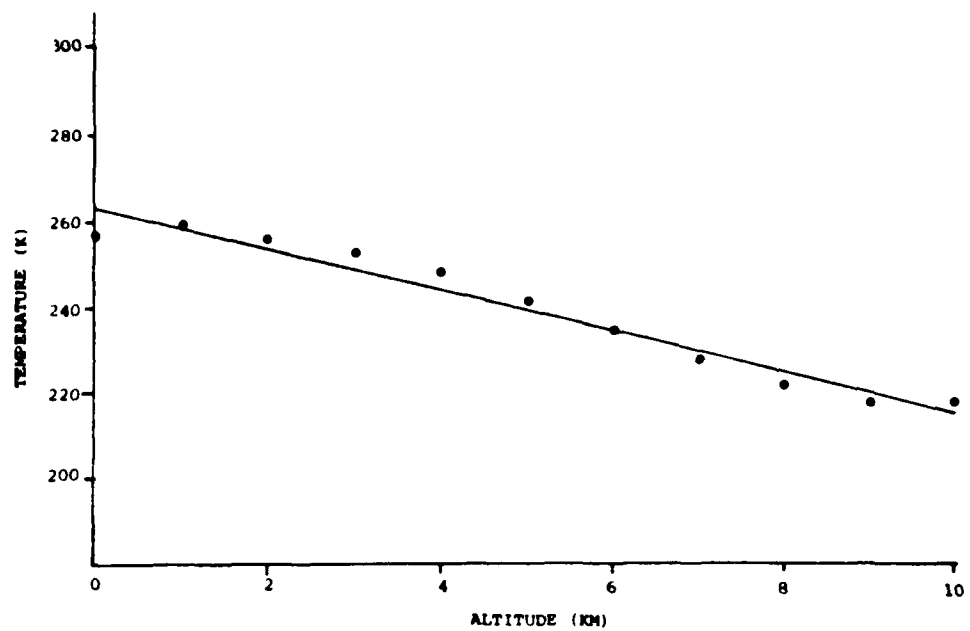


Figure 17. Subarctic Winter Model Atmosphere Lapse Rate

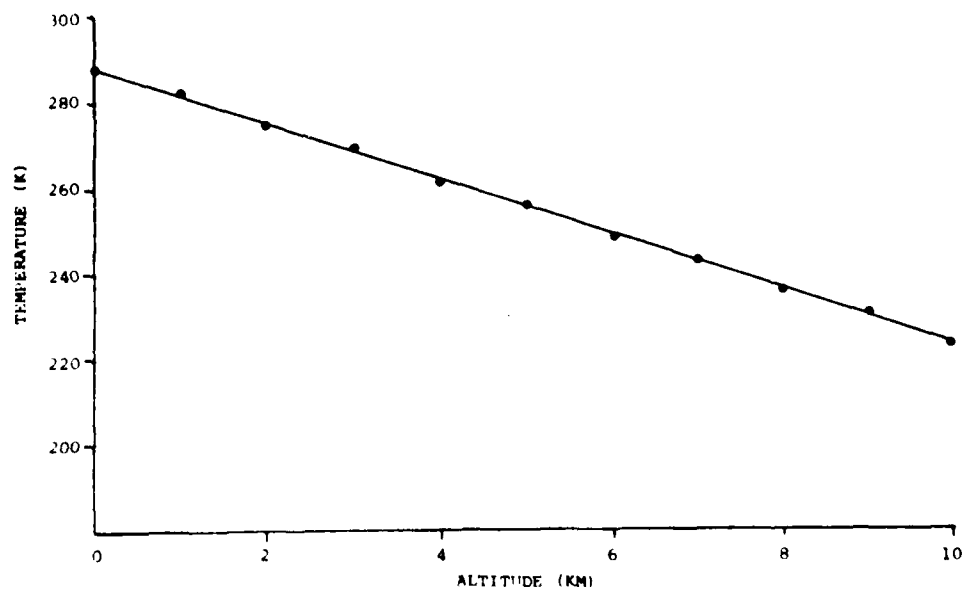


Figure 18. U.S. Standard 76 Model Atmosphere Lapse Rate

Table 1. Sea Level Air Temperature Data for
Brooks Range Scene.

Month	Temp (K)	Variance
1	260.5	33.9
2	260.2	36.0
3	262.7	41.6
4	266.2	38.2
5	270.7	31.9
6	275.2	23.9
7	277.8	22.2
8	276.9	21.8
9	274.2	21.2
10	269.6	27.0
11	265.4	30.8
12	262.6	30.0

Table 2. Sea Level Air Temperature Data for
Arctic Tundra Scene.

Month	Temp (K)	Variance
1	258.4	54.0
2	260.5	54.9
3	268.5	39.8
4	276.4	52.3
5	283.5	46.4
6	288.9	39.6
7	292.5	28.4
8	290.1	29.8
9	284.6	38.8
10	276.2	40.0
11	268.0	48.5
12	262.8	46.4

Table 3. Sea Level Air Temperature Data for
Central Europe Scene.

Month	Temp (K)	Variance
1	278.2	20.5
2	277.7	18.7
3	279.5	17.8
4	280.9	16.2
5	283.3	14.2
6	286.0	13.2
7	287.9	12.3
8	287.9	11.3
9	286.4	11.7
10	284.3	14.2
11	280.4	18.6
12	278.9	17.2

Table 4. Sea Level Air Temperature Data for
Middle East and California Coast Scenes.

Month	Temp (K)	Variance
1	286.6	37.1
2	287.6	39.3
3	290.3	34.7
4	293.1	38.1
5	296.8	35.6
6	298.9	33.6
7	299.7	33.4
8	299.6	33.4
9	298.0	42.5
10	295.5	39.5
11	291.7	39.2
12	287.2	37.4

3.4.2 Thermal Emission

The thermal emission component is given by

$$N_{\text{thermal}} = \epsilon \tau(h) \int_{\lambda_1}^{\lambda_2} N(\lambda, T_s) d\lambda$$

where

ϵ = surface emissivity,

ρ = surface in-band diffuse reflectance $(1-\epsilon)$,

$\tau(h)$ = computed fit to path transmission versus altitude (supplied by the atmospheric module),

h = surface altitude in km,

λ_1, λ_2 = beginning and ending band wavelengths in μm ,

$N(\lambda, T_s)$ = Planck function, and

T_s = equilibrium surface temperature in Kelvins (supplied by the heat transfer module).

3.4.3 Reflected Skyshine

The apparent reflected skyshine component is given by

$$N_{\text{sky}} = \rho_{\text{sky}} \phi_{\text{sky}}(h)$$

where

ρ = surface in-band diffuse reflectance,

$\phi_{\text{sky}}(h)$ = computed fit to apparent reflected skyshine versus altitude (supplied by the atmospheric module), and

h = surface altitude in km.

3.4.4 Path Radiance

Path radiance is given by

$$N_{\text{path}} = \phi_{\text{path}}(h)$$

where

$\phi(h)$ = computed fit to path radiance versus altitude (supplied by the path atmospheric module), and

h = surface altitude in km.

The total apparent surface radiance returned by the radiance module for a single grid point is

$$N(i) = N_{\text{sol}}(i) + N_{\text{sky}}(i) + N_{\text{emis}}(i) + N_{\text{path}}(i)$$

where

N = total apparent grid point radiance ($\text{w/cm}^2/\text{sr}$),

N_{sol} = apparent reflected solar radiance ($\text{w/cm}^2/\text{sr}$),

N_{sky} = apparent reflected skyshine radiance ($\text{w/cm}^2/\text{sr}$),

N_{emis} = apparent thermal radiance ($\text{w/cm}^2/\text{sr}$), and

N_{path} = observer's path radiance ($\text{w/cm}^2/\text{sr}$) per the i^{th} grid point.

Two additional calculations are made by the radiance module. These are the total (over all wavelengths) solar and skyshine irradiances required by the heat transfer module.

The total surface solar irradiance was approximated utilizing LOWTRAN 5 path transmissions computed spectrally at 20 cm^{-1} resolution in the 0.25 to $4.0 \mu\text{m}$ region (nearly 99% of the sun's total exoatmospheric irradiance is emitted between 0.25 and $4.0 \mu\text{m}$) and a blackbody the size, distance and effective temperature of the sun. Exoatmospheric irradiance is attenuated spectrally and integrated over wavelength to yield the total surface solar irradiance.

Total diffuse sky irradiance is computed from a pressure compensated Idso-Jackson formulation.

Functional relations between solar and diffuse sky irradiance and altitude are computed off-line and are stored as data for each of the six standard atmospheres. The radiance module is diagrammed in Figure 19. Figures 20, 21 illustrate the functional relation between solar and diffuse sky irradiances and altitude.

Diffuse reflectance data for 11 of the 14 materials are given in Table 5. For any user-specified spectral band an average value is calculated by GENESSIS. Reflectance data for urban (commercial and residential) are composites of asphalt, irrigated low vegetation and forest. Reflectance data for clouds are bidirectional data and are given in Appendix 2.

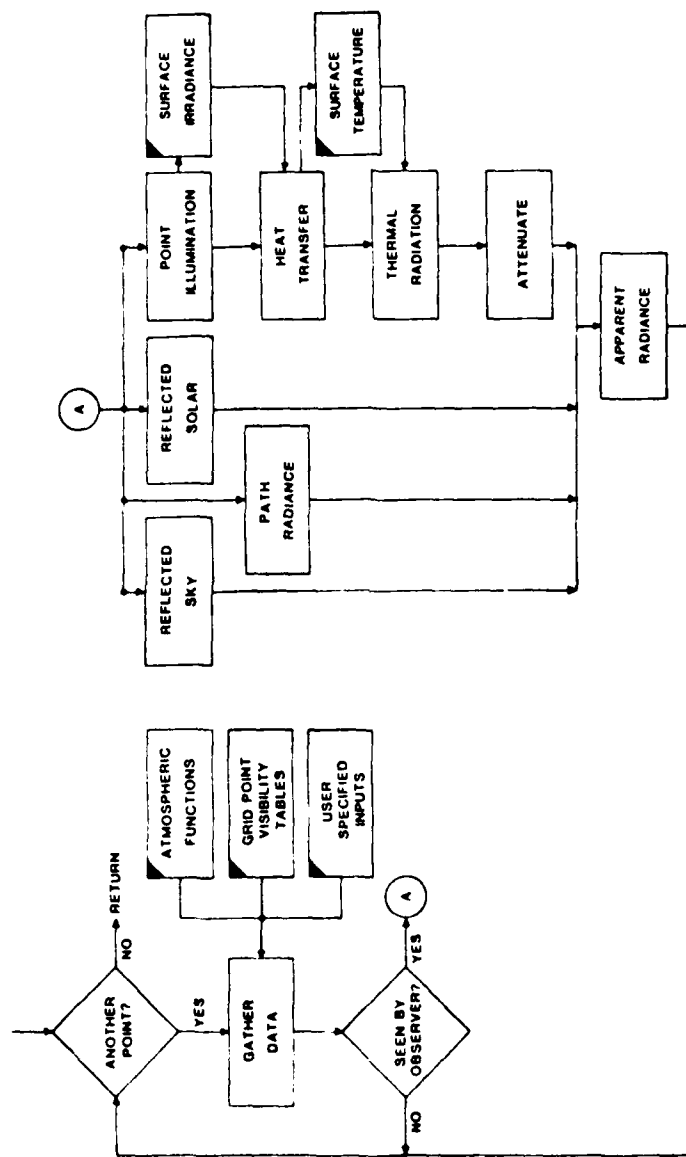


Figure 19. Radiance Module

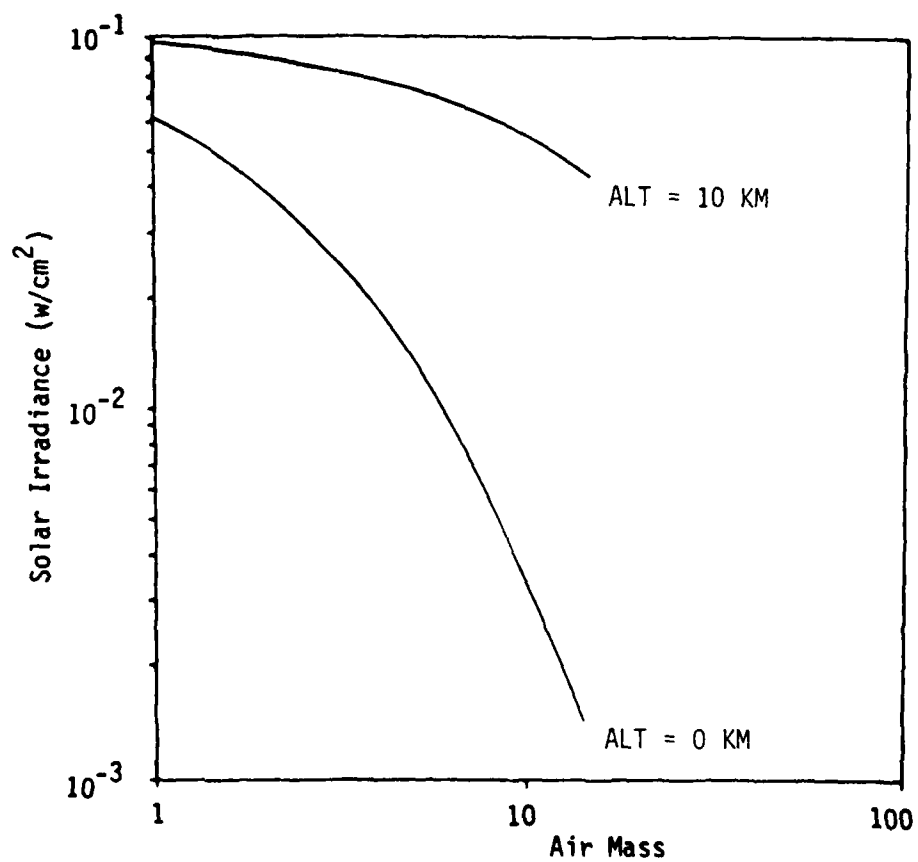


Figure 20. Solar Irradiance Versus Air Mass for Standard Atmosphere Computed at 20 cm⁻¹ Resolution

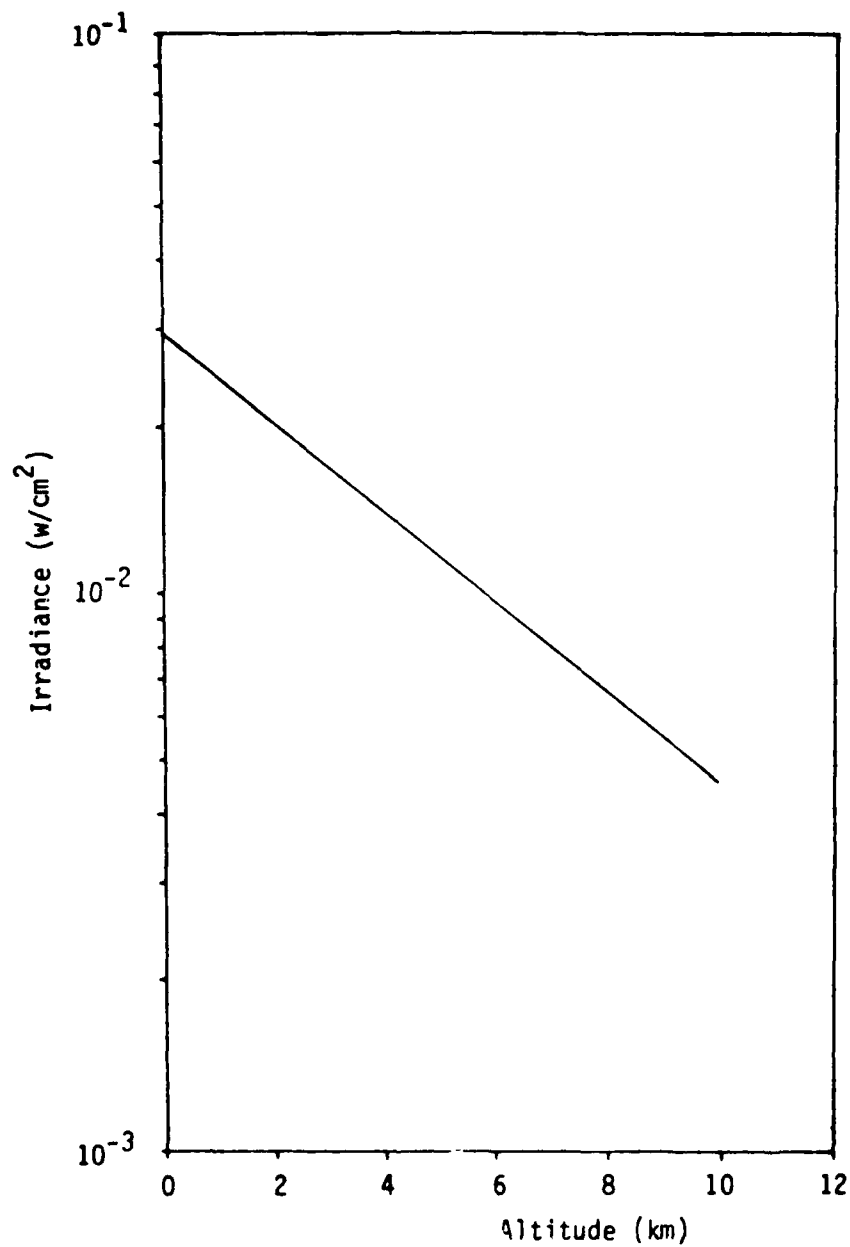


Figure 21. Pressure Compensated Idso-Jackson Total Diffuse Sky Irradiance Versus Altitude for U.S. Standard Atmosphere

Table 5. Spectral Reflectance of Terrestrial Materials (%)

JENNESS NUMBER	MATERIAL	WAVELENGTH (μm)																				
		2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	11.0	12.0	13.0	14.0	15.0
1	WATER ¹	1	3	2.5	2	1.9	1.8	1.5	1.2	2	1.8	1.6	1.7	1.6	1.5	1.3	1.0	0.8	1.2	2.5	3.5	4.5
2	FOREST (BROOKFIELD) ²	10	7	10	10	12	13	15	8	9	8	8	8	8	10	10	9	8	8	7	8	10
3	VEGETATION ² (LOW Irrigated)	2	2	2	3	4	3	2	2	2	2	2	2	2	2	2	3	4	3	2	1	1
4	SCRUB ³	28	4	10	13	17	17	13	5	4	4	3	2	2	2	2	1	1	2	5	5	2
6	SAND ¹	50	30	55	35	15	5	13	10	10	10	10	10	10	10	10	9	8	2	2	2	2
7	ICE ⁴	1	5.0	3.0	2	1.5	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.7	2	4	5.5	5.0
8	ROCK ⁵	5	10	20	12	18	7	5	7	8	5	4	10	11	13	14	12	5	3	2	2	2
9	SOIL ²	30	3	8	15	14	13	10	7	5	4	3	2	3	4	5	4	3	2	2	1	1
10	GRASS (OPY MEADOW) ²	35	8	11	20	25	30	25	9	10	6	4	4	5	6	4	10	15	15	13	10	9
12	ASPHALT ¹	40	15	8	25	40	50	40	10	7	10	10	10	10	10	10	10	10	10	10	10	10
14	FOREST (FINE) ¹	3	2	3	5	10	9	10	3	3	3	2	2	2	2	2	2	2	2	2	1	1

REFERENCES

1. The Infrared Handbook, Environmental Research Institute of Michigan, Ann Arbor, MI, 1978.
2. Target Signature Analysis Center: Data Compilation, Infrared and Optical Sensor Laboratory, University of Michigan, Ann Arbor, MI, 1967.
3. The NASA Earth Resources Spectral Information System: Data Compilation, Infrared and Optical Sensor Laboratory, University of Michigan, Ann Arbor, MI, 1971.
4. Infrared Optical Properties of Water and Ice, International Journal of the Solar System, Vol. 8, 1968.
5. Infrared Reflectance Spectrum of Igneous Rocks, Journal of the Optical Society of America, Vol. 56, No. 5, 1966.

3.5 Imaging

A mean pixel radiance is computed for each pixel in the observer's image plane from the weighted sum of grid point apparent radiances projected into that pixel. That is,

$$\bar{N}_j = \frac{\sum_{i=1}^n W_i N_i}{\sum_{i=1}^n W_i}$$

where

$\bar{N}_j$ = mean apparent radiance of pixel j ,

n = number of radiance points projected into pixel j ,

W_i = weighting factor (equal $\cos \theta_i$),

θ_i = angle between surface normal and vector to sun, and

N_i = apparent radiance of grid point, and

i = denotes the individual grid points seen by the j^{th} pixel.

The geometric module supplies both surface normal and projected grid point position in the observer's image plane. This produces an $N \times M$ viewer-perspective pixel apparent radiance map. The image module is diagrammed in Figure 22.

3.6 Code Structure Diagrams

Structure diagrams for the geometric, atmospheric and radiance modules are given in Figures 23-25. These diagrams depict the relationship between code subroutines and their hierarchy.

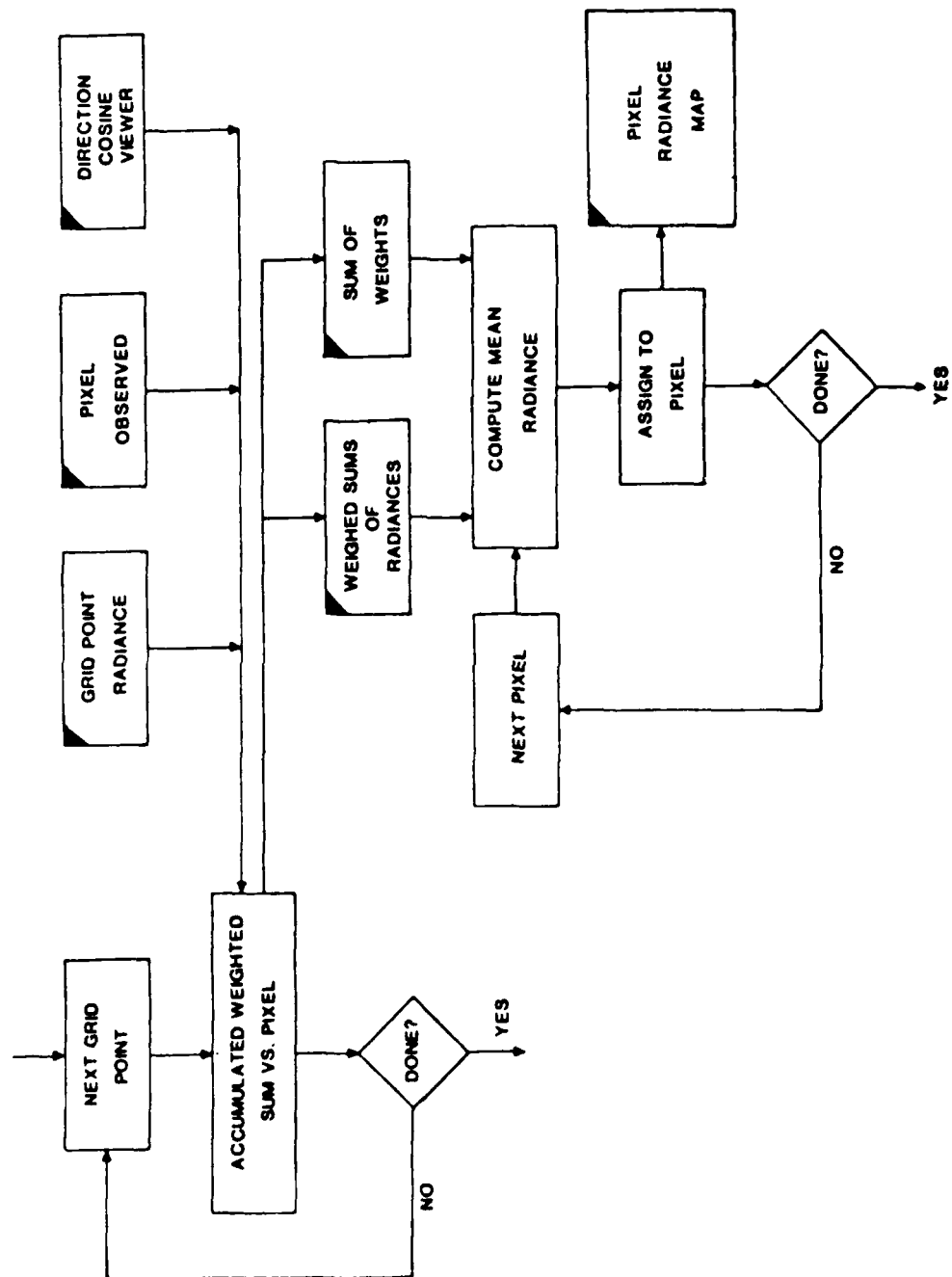


Figure 22. Image Module

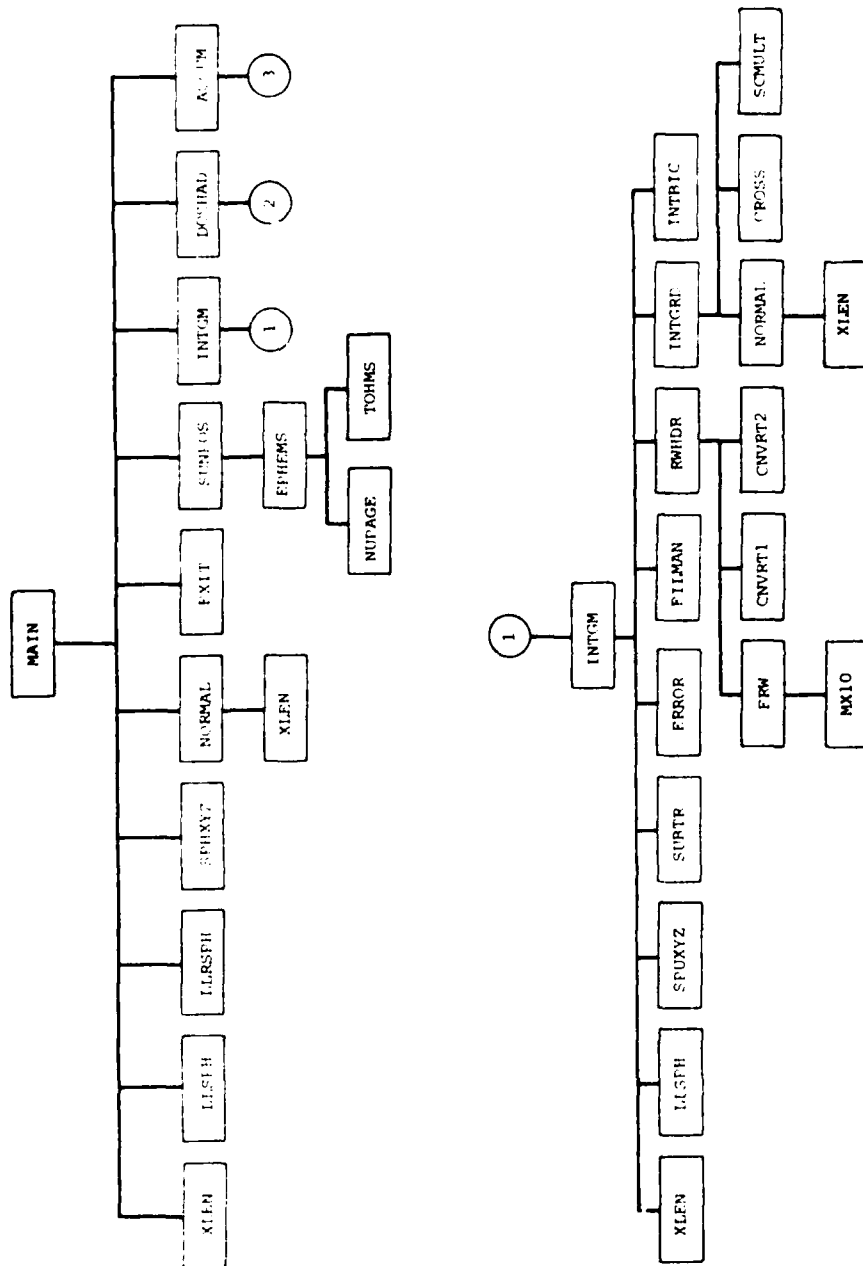


Figure 23. Structure Diagram

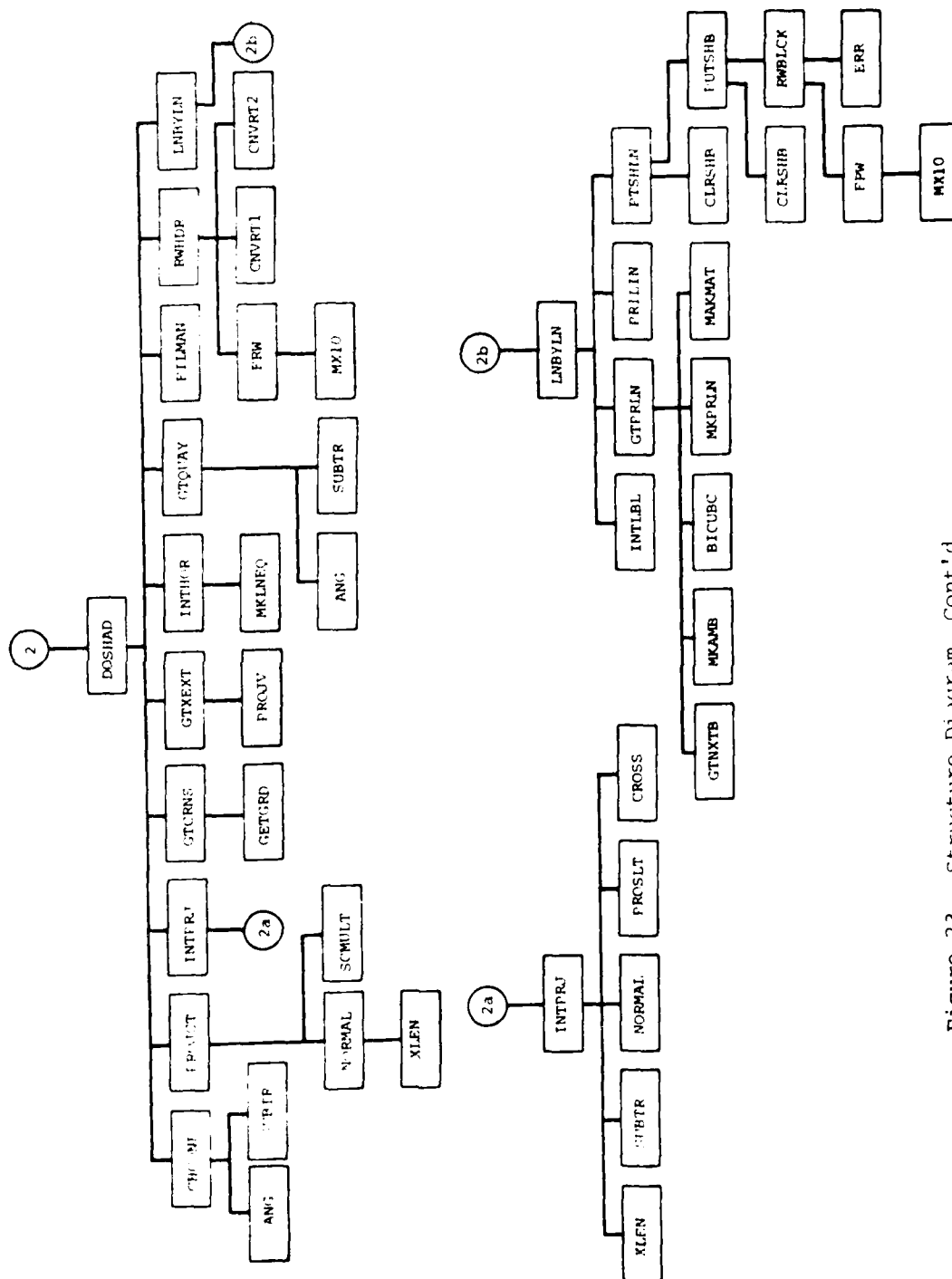


Figure 23. Structure Diagram, Cont'd.

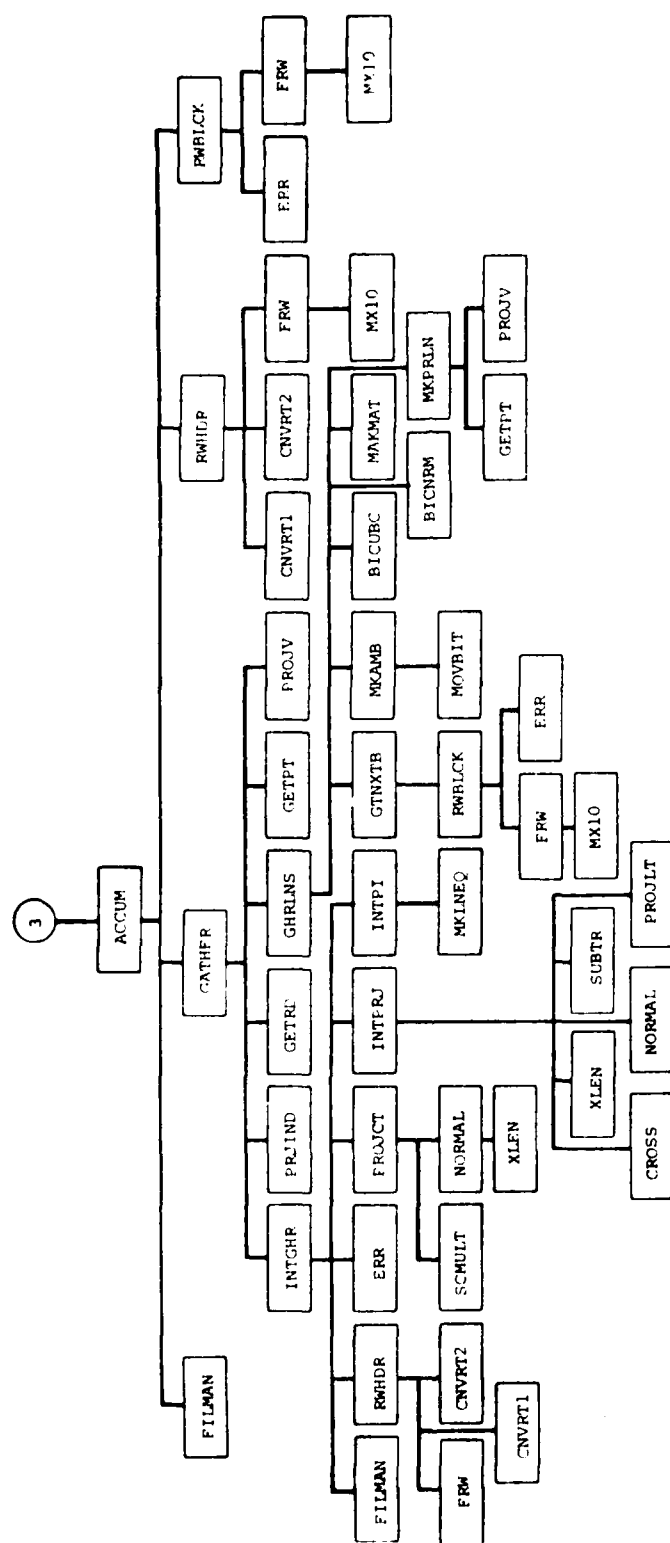
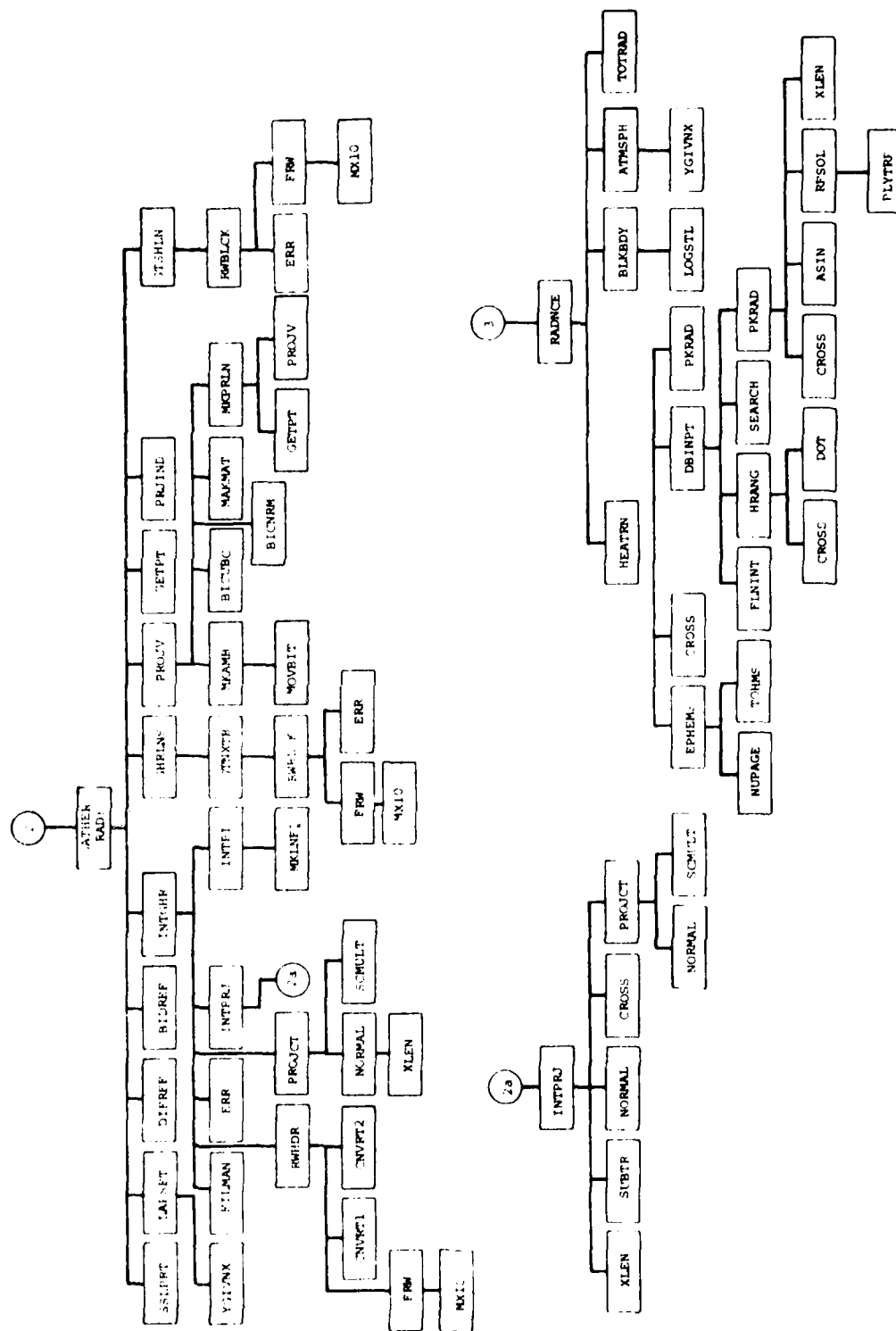


Figure 23. Structure Diagram, Cont'd.



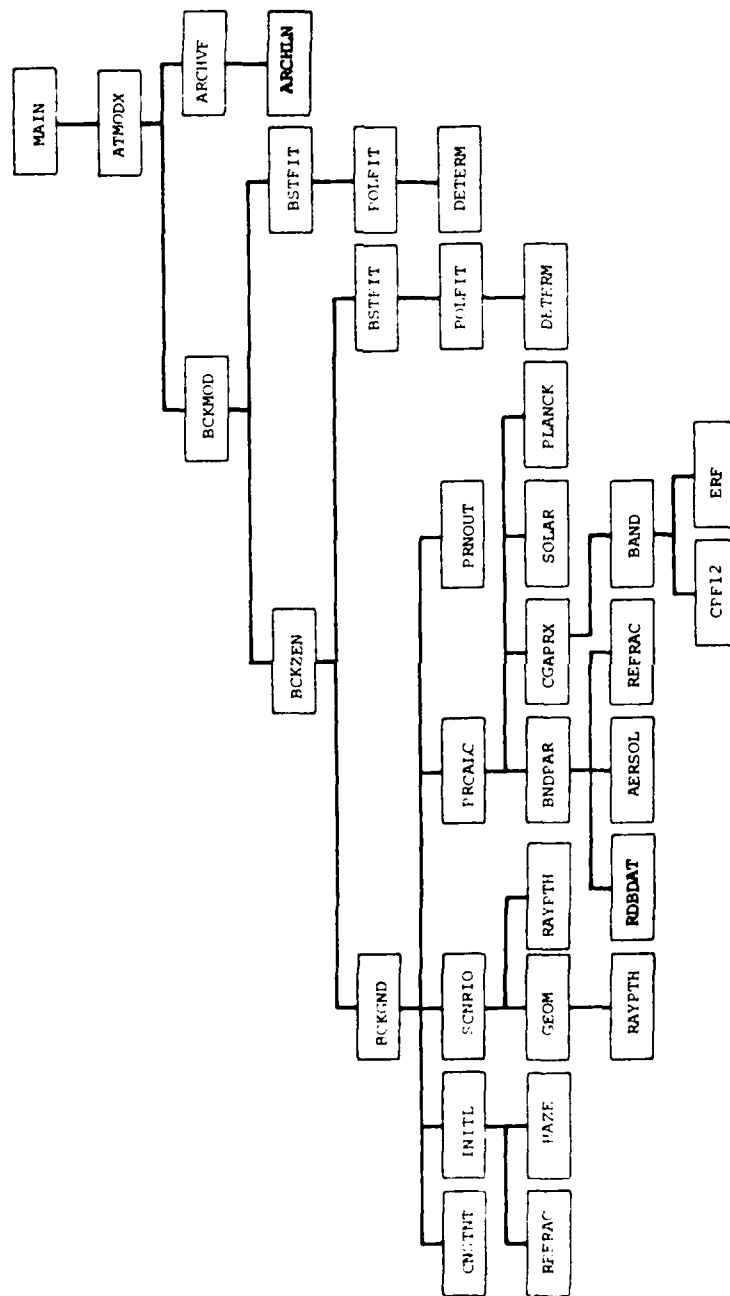


Figure 25. Atmospheric Module Structure Diagram

4.0 SCENE DATA BASES

4.1 Overview

There are five terrain data bases. Each was extracted from Defense Mapping Agency (DMA) data. The five scenes are: the California coast, the Brooks Range Mountains of Alaska, arctic tundra, Middle East, and Central Europe. All scenes were registered with Landsat data to produce complete representation of the ground cover for each point.

In addition to the five ground scenes, two cloud scenes are included. These represent a low and high altitude cloud, both with a minimum altitude of 1100 meters.

Each scene represents an area approximately forty kilometers square. DMA data is recorded at uniform angular resolution; scenes at different latitudes therefore have different spatial resolution.

4.2 File Structure

Each scene is composed of two parts: the header and the data.

Header. The header is 1024 16-bit words long. It contains the following information about the scene: the number of columns and number of rows of data, the scene center (in longitude and latitude), the scene center in X,Y,Z coordinates, the altitude scaling factors, and the spacing in kilometers between the data points in the X and Y direction. All floating-point information has been converted to an integer representation and is reconstructed by the software.

Data. The data points directly follow the header. There are (# columns) times (# rows) data points in each scene. Each data point is a 16-bit integer (binary) value and has two parts: the lower twelve bits represent the altitude of that point and the upper (left) four bits represent the material type assigned to that point. The scene is written in a row-wise format. The first row is the northernmost row.

5.0 SOFTWARE LIMITATIONS, MODEL CONSTRAINTS AND PRECAUTIONS

The following is a list of limitations, constraints, and precautions which the GENESIS user may find useful.

1. Input scene data base is currently limited to approximately 512 x 512 grid points because of computer size restrictions.
2. Output 2-D radiance map is limited to 512 x 512 pixels.
3. Data base currently limited to 14 material types.
4. Scene and/or cloud altitudes limited to 0-10 km.
5. Observer/solar zenith angles limited to 0-86 degrees due to LOWTRAN anomalies at large zenith angles.
6. Model atmospheres limited to the six standard AFGL models.
7. The atmospheric, geometric and radiance modules have some inputs in common. These must be self consistent for any single run.
8. Cloud scene shadowing is currently not handled. Cloud/scene radiance maps must be overlaid to produce a scene which contains clouds. Cloud image pixels which do not contain cloud are assigned zero radiance to facilitate this.
9. Calculations are limited to 2.5-13.0 μm .
10. Scene data bases currently limited to the five generic ground scenes and two generic cloud scenes supplied.
11. The image module currently weights path radiance which should be an unweighted component of the apparent radiance. The error introduced is small. This will be corrected in Phase II.
12. Surface level atmospheric parameters are applied uniformly over the scene. They are not spatially variable.

6.0 USER SPECIFIED INPUTS

6.1 Atmospheric Module

Card 1) IATM, ALT, WLB, WLE (I3, 3F10.3)

IATM - Standard LOWTRAN Model Atmosphere.

- 1 - Tropical
- 2 - Midlatitude Summer
- 3 - Midlatitude Winter
- 4 - Subarctic Summer
- 5 - Subarctic Winter
- 6 - U. S. Standard 76

ALT - Observer altitude in km.

WLB, WLE - Beginning and ending bandpass
wavelengths in microns.

Card 2) IAERO1, IAERO2, IHAZE, IUPPER, M1, M2, M3, VIS (7I3, F10.3)

IAERO1 - Selects the boundary layer
(0-2 km) aerosol model.

- 0, 1 - Rural
- 2 - Urban
- 3 - Maritime
- 4 - Tropospheric
- 5 - Advection Fog (default vis < 0.20)
- 6 - Radiation Fog (default 0.20 < vis < 1.00)

Note: If 1 < vis < 2, the light fog option
is used with IAERO1.

IAERO2 - Selects the stratospheric (~10-35 km)
aerosol model.

- 0, 1 - Background
- 2 - Aged Volcanic
- 3 - Fresh Volcanic
- 4 - Meteoric Dust

IHAZE - Selects the upper atmospheric
(2-100 km) haze model.

- 0, 1 - Background
- 2 - Moderate Volcanic
- 3 - High Volcanic
- 4 - Extreme Volcanic

- IUPPER - Allows modification of haze model in upper atmosphere (>35 km).
- 0, 1 - Normal (model selected by IHAZE unchanged)
 - 2 - Extreme Upper (selects extreme upper atmospheric haze model)
- M1, M2, M3 - The parameters M1, M2 and M3 can each take integer values between 0 and 6 and are used to modify or supplement the altitude profiles of temperature and pressure, water vapor, and ozone respectively, for any given atmospheric model specified by IATM.
- M1 = 1 selects the TROPICAL temperature and pressure altitude profiles.
- = 2 selects the MIDLATITUDE SUMMER temperature and pressure altitude profiles.
- = 6 selects the 1962 U.S. STANDARD temperature and pressure altitude profiles.
- M2 = 1 selects the TROPICAL water vapor altitude profile.
- = 2 selects the MIDLATITUDE SUMMER water vapor altitude profile.
- = 6 selects the 1962 U.S. STANDARD water vapor altitude profile.
- M3 = 1 selects the TROPICAL ozone altitude profile.
- = 2 selects the MIDLATITUDE SUMMER ozone altitude profile.
- = 6 selects the 1962 U.S. STANDARD ozone altitude profile.
- For most applications, M1=M2=M3=0; the profiles selected by IATM are unaltered.
- VIS - Meteorological range km. Override for the boundary layer haze model.

See Figure 26 for details of the aerosol models used.

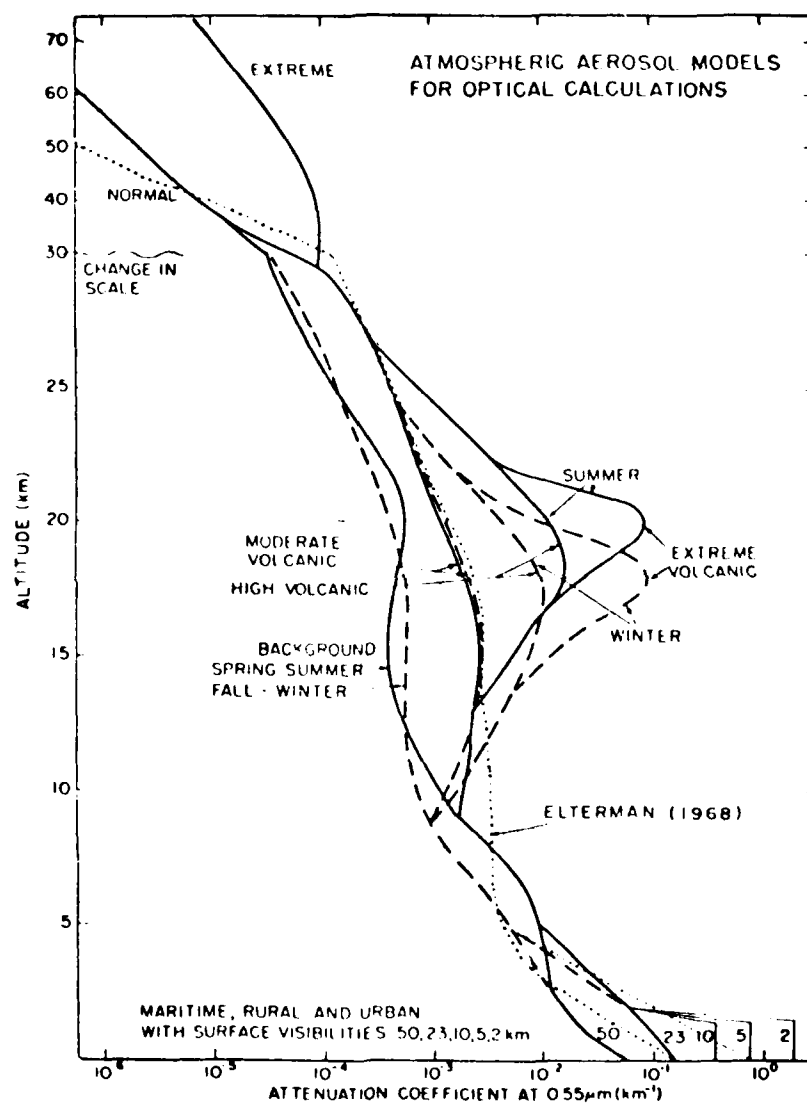


Figure 26. Atmospheric Aerosol Models Used By the Atmospheric Module

FILE UNITS

Fortran Unit	Read, Write or Read/Write	ASCII or Binary	File
5	W	A	Output data base. Contains coefficients of polynomial curve fits to atmospheric values.
6	W	A	ASCII output file. Run time diagnostics of curve fitting process.
7	R	A	User specified input file.
10	R	B	Atmospheric data base File 1.
11	R	B	Atmospheric data base File 2. This is a temporary work file.

6.2 Geometric Module

Card 1) (ISW(I), I=1, 4C) (40I2)

ISW - Array of switches for debugging purposes.
(0 - Off, 1 - On)

Card 2) DBG (A1) - Debug switch (ASCII 'T' or 'F').

Card 3) CLDMIN (F7.3) - Minimum altitude of clouds in cloud file (km).

Card 4) (SCXUSR(I), I=1,3) (3E14.6) - User Specified Scene Center.

SCXUSR(1) - Altitude (km).
SCXUSR(2) - Longitude: (DEG) - West, + East
SCXUSR(3) - Latitude: (DEG) + North, - South

Card 5) IDAY, IMONTH, IYEAR, TIME (3I5, F8.2)

IDAY, IMONTH, IYEAR - The day, month and year of the calculation. Enter as MM, DD, YYYY.
TIME - Time of run, GMT, (HHMM.SS).

Card 6) (OBSRLL(I), I=1,3) (3E14.6) - Observer position.

OBSRLL(1) - Altitude (km)
OBSRLL(2) - Longitude: (DEG) - West, + East
OBSRLL(3) - Latitude: (DEG) - South, + North

Card 7) NCOLS, NROWS (2I4)

NCOLS - Number of columns in satellite image.
NROWS - Number of rows in satellite image.

Card 8) XRESA, YRESA (2E14.6)

XRESA - Angular size of one pixel in the
satellite image, in the horizontal
direction (radians).
YRESA - Angular size of one pixel in the
satellite image, in the vertical
direction (radians).

FILE UNITS

Fortran Unit	Read, Write or Read/Write	ASCII or Binary	File
5	R	B	Scene data base.
6	W	B	Pseudo radiance used to display visible image produced.
11	W	B	Shadow file.
12	W	B	Visibility file.
13	R	A	User specified input list.
14	W	A	ASCII echo of inputs list.

6.3 Radiance Module

Card 1) IATM, IMONTH, IDAY, IYEAR, TIME (4I5, F10.2)

IATM - Standard LOWTRAN Model Atmosphere.
1 - Tropical
2 - Midlatitude Summer
3 - Midlatitude Winter
4 - Subarctic Summer

- 5 - Subarctic Winter
- 6 - U.S. Standard 76

The atmosphere selected must be the same as that in the atmospheric data base file selected.

- IMONTH, IDAY, IYEAR - The month, day and year of the calculation. Enter as MM, DD, YYYY.
- TIME - Time in hours (GMT) of calculation (24 hour clock, HHMM.SS).

Card 2) WLB, WLE, ALT, LONG, LAT (5F10.2)

- WLB, WLE - Beginning and ending bandpass wavelengths in microns. These inputs must be the same as those in the atmospheric data base file selected.
- ALT - Observer altitude in km.
- LONG, LAT - Longitude and latitude of observer's NADIR point (sub-satellite point) in degrees.

 Longitude: - West, + East
 Latitude: - South, + North

Card 3) SCNALT, SCNLNG, SCNLAT (5F10.2)

- SCNALT - Scene stare point (scene center) altitude in km.
 - SCNLNG, SCNLAT - Scene stare point (scene center) longitude and latitude in degrees.

 Longitude: - West, + East
 Latitude: - South, + North
- These values override the default values read from the scene header.

Card 4) NCOL, NROW (2I5)

- NCOL, NROW - Number of columns and rows in observer's apparent radiance pixel map. These are used to determine the scene F.O.V. extent (see Card 6 below).

Card 5) TAIR, TSSL (5F10.2)

- TAIR - Sea level air temperature in degrees K. This is a 24 hr. diurnal average air temperature.
- TSSL - Temperature of the sub-soil layer. The temperature of that layer of sub-soil which does not vary with the diurnal cycle of air temperature. In general, the mean monthly air temperature is a good first approximation to the sub-soil temperature (see pgs. 24-25).

Card 6) XRES, YRES (5F10.2)

- XRES, YRES - The angular extent of one pixel in the observer's field of view in radians in the X (vertical) and Y (horizontal) directions. The total field of view is then $NCOL * XRES$ by $NROW * YRES$.

FILE UNITS

Fortran Unit	Read, Write or Read/Write	ASCII or Binary	File
5	R	A	User input file.
6	W	A	ASCII output file. Run time diagnostics and statistics are written here.
7	R	A	Atmospheric data base file generated by the atmospheric module.
8	R	A	Heat transfer data base.
9	R	A	Monte Carlo cloud bi-directional reflectance data.
11	R	A	Spectral material diffuse reflectance data.
12	R	B	Scene data base.
13	R	B	Shadow file generated by geometric module.
14	R	B	Visibility file generated by geometric module.
17	W	B	Pixel apparent radiance file.

APPENDIX 1

Solar Ephemeris Module User Manual

APPENDIX 1

A detailed description of the algorithm is given here, extracted verbatim* from W. Wilson, "Solar Ephemeris Algorithm," University of California Visibility Laboratory, La Jolla, CA, July 1980.

This section describes the algorithm itself in terms of its logical flow and various equations and tables used.

All values computed are in degrees and fractions of degrees. For printing purposes, many times values are first converted to the form $xx^{\circ}xx'xx''$ or $xx^{\circ}xx'xx''$. The function routine which does this is called TOHMS.

3.1. STEPS

STEP 1 Compute $p23 = T$, fraction of century from 1900 JAN 0^d 12^h ET

This routine first computes the number of days since 1900 JAN 0^d 12^h ET. The algorithm used yields a value of 694038.5 for this date. Thus, this value is subtracted to yield the actual number of days. Because the algorithm does not take proper account of the leap year century years (i.e. 1800, 1900) additional days need to be added for these and preceding years. To the number of whole days the standard local time (in days) and the observer's longitude is added to get the correct time; $p22 = d$ since 1900 JAN 0^d 12^h ET. This is then divided by 36525, the number of days in a century, to obtain the fraction of century, $p23$. Thus,

$$p23 = T = \frac{p22}{36525} \quad (28)$$

* Used with permission.

STEP 2(a) Compute the mean longitude of sun referenced to mean equinox of date - $p24 = L$

$$p24 = L = 279.69668 + 0.9856473354 \cdot p22 + 3.03 \cdot 10^{-4} \cdot p23^2 \quad (29)$$

Note that all values are converted to the range of 0-360° by using the function $\text{mod}(x, 360)$, which is defined as the remainder of the division $\frac{x}{360}$.

STEP 2(b) Mean anomaly of sun - $p25 = M$.

$$p25 = M = 358.47583 + 0.9856002670 \cdot p22 - 0.00015 \cdot p23^2 - 3 \cdot 10^{-6} \cdot p23^3 \quad (30)$$

STEP 2(c) Eccentricity - $p26 = e$

$$p26 = e = 0.01675104 - 4.18 \cdot 10^{-5} \cdot p23 - 1.26 \cdot 10^{-7} \cdot p23^2 \quad (31)$$

STEP 3 Compute eccentric anomaly - $p13 = E$ from

$$M = E - e \cdot \sin E, \quad (32)$$

or

$$p25 = p13 - p26 \cdot \sin(p13).$$

This transcendental equation is solved for $p13$ by successive approximation. When the change in $p13$ is smaller than 10^{-8} , iteration is stopped.

STEP 4 Compute true anomaly - $p27 = V$ from

$$V = 2 \cdot \tan^{-1} \left[\frac{\sqrt{1+e}}{\sqrt{1-e}} \tan \left(\frac{E}{2} \right) \right], \quad (33)$$

if

$$\text{sign}(V) \neq \text{sign}(E); \text{ Then } V = V + 180^\circ, \quad (34)$$

$$\begin{aligned} & \text{if} \\ & V < 0, \text{ Then } V = V + 360^\circ, \end{aligned} \quad (35)$$

or

$$p27 = 2 \cdot \tan^{-1} \left[\frac{\sqrt{1+p26}}{\sqrt{1-p26}} \tan \left(\frac{p13}{2} \right) \right].$$

or if

$$\text{sign}(p27) \neq \text{sign}(p13), \text{ Then } p27 = p27 + 180^\circ.$$

or if

$$p27 < 0, \text{ Then } p27 = p27 + 360^\circ.$$

STEP 5(a) Compute radius vector - R

$$R = 1.0 - e \cdot \cos(E), \quad (36)$$

or

$$R = 1.0 - p26 \cdot \cos(p13)$$

STEP 5(b) Compute aberration - $p29 = \Delta\lambda_4$

$$p29 = \Delta\lambda_4 = \frac{-20''.47}{R} \cdot \frac{1^\circ}{3600''}. \quad (37)$$

STEP 5(c) Compute mean obliquity - $p43 = \epsilon_m$

$$p43 = \epsilon_m = 23^\circ 45' 22.94'' - 0''.0130125 \cdot p23 - 1''.64 \cdot 10^{-6} \cdot p23 + 5''.03 \cdot 10^{-7} \cdot p23^3. \quad (38)$$

STEP 5(d) Compute mean ascension - $p45 = \alpha_m$

$$p45 = \alpha_m = 279.6909832 + 0''.98564734 \cdot p22 + 3''.8708 \cdot 10^{-4} \cdot p23^2. \quad (39)$$

STEP 6 In this step all perturbations due to the moon are computed.

The variable $p8$ controls the degree of approximation of the algorithm. If $p8 < 2$, the perturbations due to the moon are included in the algorithm.

These require the initial computation of four quantities which are:

moon's mean anomaly - $p28 = l$
 moon's mean elongation - $p30 = D$
 moon's longitude of ascending node - $p31 = \Omega$
 moon's mean longitude - $p32 = \gamma$.

Note that $D = \gamma - L$ where L = mean longitude of sun.

$$p28 = l = 296^\circ.104608 + 1325 \cdot 360^\circ \cdot p23 + 198^\circ.8491083 \cdot p23 \\ + 0^\circ.00919167p23^2 + 1^\circ.4388 \cdot 10^{-5} \cdot p23^3 \quad (40)$$

$$p30 = D = 350^\circ.737486 + 1236 \cdot 360^\circ \cdot p23 + 307^\circ.1142167 \cdot p23 \\ - 1^\circ.436 \cdot 10^{-3} \cdot p23^2 \quad (41)$$

$$p31 = \Omega = 259^\circ.183275 - 5 \cdot 360^\circ \cdot p23 - 134^\circ.14200 \cdot p23 \\ + 2^\circ.0778 \cdot 10^{-3} \cdot p23^2 \quad (42)$$

$$p32 = \gamma = 270^\circ.434164 + 1336 \cdot 360^\circ \cdot p23 + 370^\circ.8831417 \cdot p23 \\ - 1^\circ.1333 \times 10^{-3} \cdot p23^2 \quad (43)$$

The perturbation of the earth's orbit due to the mass of the moon is $p33 = \Delta\lambda$,

$$\text{where } p33 = 6''.454 \sin D \\ + 0''.013 \sin 3D \\ + 0''.177 \sin (D+l) \\ - 0''.424 \sin (D-l) \\ + 0''.039 \sin (3D-l) \\ - 0''.064 \sin (D+M) \\ + 0''.172 \sin (D-M) \quad (44)$$

Note that $D = p30$, $l = p28$, $M = p25$.

The moon also causes nutation of the solar longitude, $\Delta\psi$, and obliquity of the ecliptic, $\Delta\epsilon$. As mentioned earlier, this nutation is in terms of a power series with up to 60 terms. Table 3 has a listing

Table 3.

Series Terms for Nutation

Period (days)	Argument Multiple of					Longitude Coefficient of		Obliquity Coefficient of	
	I	M	F	D	Ω	sine argument		cosine argument	
6798					+1	-172327	-173.7T	+92100	+9.1T
3399					+2	+ 2088	+ 0.2T	- 904	+0.4T
1305	-2		+2		+1	+ 45		- 24	
1095	+2		-2			+ 10			
6786		-2	+2	-2	+1	- 4		+ 2	
1616	-2		+2		+2	- 3		+ 2	
3233	+1	-1		-1		- 2			
183			+2	-2	+2	-12729	- 1.3T	+5522	-2.9T
365		+1				+1261	- 3.1T		
122		+1	+2	-2	+2	- 497	+ 1.2T	+ 216	-0.6T
365		-1	+2	-2	+2	+ 214	- 0.5T	- 93	+0.3T
178			+2	-2	+1	+ 124	+ 0.1T	- 66	
206	+2			-2		+ 45			
173			+2	-2		- 21			
183		+2				+ 16	- 0.1T		
386		+1			+1	- 15		+ 8	
91		+2	+2	-2	+2	- 15	+ 0.1T	+ 7	
347		-1			+1	- 10		+ 5	
200	-2			+2	+1	- 5		+ 3	
347		-1	+2	-1	+1	- 5		+ 3	
212	+2			-2	+1	+ 4		- 2	
120		+1	+2	-2	+1	+ 3		- 2	
412	+1			-1		- 3			
13.7			+2		+2	- 2037	- 0.2T	+ 804	
27.6	+1					+ 675	+ 0.1T		
13.6			+2		+1	- 342	- 0.4T	+ 183	
9.1	+1		+2		+2	- 261		+ 113	-0.1T
31.8	+1			-2		- 149			
27.1	-1		+2		+2	+ 114		- 50	
14.8				+2		+ 60			
27.7	+1				+1	+ 58		- 31	
27.4	-1				+1	- 57		+ 30	
9.6	-1		+2	+2	+2	- 52		+ 22	
9.1	+1		+2		+1	- 44		+ 23	
7.1			+2	+2	+2	- 32		+ 14	
13.8	+2					+ 28			
23.9	+1		+2	-2	+2	+ 26		- 11	
6.9	+2		+2		+2	- 26		+ 11	
13.6			+2			+ 25			
27.0	-1		+2		+1	+ 19		- 10	
32.0	-1			+2	+1	+ 14		- 7	
31.7	+1			-2	+1	- 13		+ 7	
9.5	-1		+2	+2	+1	- 9		+ 5	
34.8	+1	+1		-2		- 7			
13.2		+1	+2		+2	+ 7		- 3	
9.6	+1			+2		+ 6			
14.8				+2	+1	- 6		+ 3	
14.2		-1	+2		+2	- 6		+ 3	
5.6	+1		+2	+2	+2	- 6		+ 3	
12.8	+2		+2	-2	+2	+ 6		- 2	
14.7				-2	+1	- 5		+ 3	
7.1			+2	+2	+1	- 5		+ 3	
23.9	+1		+2	-2	+1	+ 5		- 3	
29.5				+1		- 4			
15.4		+1		-2		- 4			
29.8	+1	-1				+ 4			
26.9	+1		-2			+ 4			
6.9	+2		+2		+1	- 4		+ 2	
9.1	+1		+2			+ 3			
25.6	+1	+1				- 3			
9.4	+1	-1	+2		+2	- 3			
13.7	-2				+1	- 2			
32.6	-1		+2	-2	+1	- 2			
13.8	+2				+1	+ 2			
9.8	-1	-1	+2	+2	+2	- 2			
7.2		-1	+2	+2	+2	- 2			
27.8	+1				+2	- 2			
8.9	+1	+1	+2		+2	+ 2			
5.5	+3		+2		+2	- 2			

Note: T is the fraction of century coefficient defined in the text

of the terms of this power series. The form of each term in the series is

$$S \cdot \sin(al + bM + cF + dD + e\Omega) \quad (45)$$

for nutation in longitude, and

$$S \cdot \cos(al + bM + cF + dD + e\Omega) \quad (46)$$

for obliquity, where $F = L - \Omega$.

The algorithm as presently implemented uses only 5 terms for longitude and 4 terms for obliquity. If a higher degree of accuracy is desired more terms may be added. The terms presently used are in bold face in Table 3.

The nutation in longitude is $p34 = \Delta\psi$.

The nutation in obliquity is $p35 = \Delta\epsilon$.

The moon also has a perturbation effect on the solar latitude. For the accuracy of the present algorithm, this effect is negligible. For illustrative purposes, however, the perturbation effect is computed in the event higher degrees of accuracy are required.

The moon's mean argument of latitude, $p63$, is first computed by

$$p63 = 11^\circ.250889 + 1342 \cdot 360^\circ \cdot p23 + 82^\circ.02515 \cdot p23 \\ + 0^\circ.003211 \cdot p23^2 \quad (47)$$

Then the perturbation of latitude due to the moon is

$$\Delta\beta = 0''.576 \sin(p63) \\ + 0''.016 \sin(p63 + l) \\ - 0''.047 \sin(p63 - l) \\ + 0''.021 \sin(p63 - 2(l - \Omega)) \quad (48)$$

STEP 7 In this step perturbations due to the planets are computed. The variable $p8$ again controls the degree of approximation. If $p8 < 1$, the planetary perturbations are included.

The inequalities of the long period in the mean longitude, δL , caused by the planetary masses are computed from

$$p36 = \delta L = 0''.266 \sin(31.8^\circ + 119^\circ \cdot p23) \\ + (1''.882 - 0''.016 \cdot p23) \sin(57^\circ.24 + 150^\circ.27 \cdot p23) \\ + 0''.202 \sin(315^\circ.0 + 893^\circ.3 \cdot p23) \\ + 1''.089 \cdot p23^2 \\ + 6''.4 \sin(231^\circ.19 + 20^\circ.2 \cdot p23) \quad (49)$$

The other perturbations due to the planets all require the mean anomalies of each planet which are as follows:

VENUS:

$$p_{37} = 212^{\circ}.603222 + 162 \cdot 360^{\circ} \cdot p_{23} + 197^{\circ}.803875 \cdot p_{23} + 1^{\circ}.286 \cdot 10^{-3} \cdot p_{23}^2 \quad (50)$$

MARS:

$$p_{38} = 319^{\circ}.529022 + 53 \cdot 360^{\circ} \cdot p_{23} + 59^{\circ}.8592194 \cdot p_{23} + 1^{\circ}.8083 \cdot 10^{-4} \cdot p_{23}^2 \quad (51)$$

JUPITER:

$$p_{39} = 225^{\circ}.3225 + 8 \cdot 360^{\circ} \cdot p_{23} + 154^{\circ}.583 \cdot p_{23} \quad (52)$$

SATURN:

$$p_{40} = 175^{\circ}.613 + 3 \cdot 360^{\circ} \cdot p_{23} + 141^{\circ}.794 \cdot p_{23} \quad (53)$$

The perturbations due to each planet may be computed by using the mean anomalies and the coefficients from Tables 4-7. The coefficients in Tables 4-7 are given in the form of j , i , S , and K . A single term has the form

$$S \cdot \cos(K - jg' - iM) , \quad (54)$$

where g' is the mean anomaly of the planet and M the mean anomaly of the sun.

Only the coefficients in bold face in the tables are used in the present algorithm. These coefficients account for most of the perturbations in longitude. Further discussion of this point is made later.

The perturbation of latitude by the planets is also negligible for the present purposes. However, if needed, a type of latitude correction may be made similar to the longitude correction. Table 8 gives the required coefficients.

Table 4.
Perturbations by VENUS

J	I	S	K
-1	+0	075	296.6
	1	4.838	299.6.1
	2	074	207.9
	3	009	249
-2	+0	003	162
	1	116	148.9
	2	5.526	148.18.8
	3	2.497	315.56.6
	4	044	311.4
-3	+2	013	176
	3	.666	177.71
	4	1.559	345.15.2
	5	1.024	318.15
	6	017	315
-4	+3	003	198
	4	210	206.2
	5	144	195.4
	6	152	343.8
	7	006	322
-5	+5	084	235.6
	6	037	221.8
	7	123	195.3
	8	154	359.6
-6	+6	038	264.1
	7	014	253
	8	010	230
	9	014	12
-7	+7	020	294
	8	006	279
	9	003	288
-8	+8	011	322
	12	041	259.2
	14	032	48.8
-9	+9	006	351
-10	+10	003	18

Table 6.
Perturbations by JUPITER

J	I	S	K
+1	-3	003	198
	-2	161	198.6
	-1	7.208	179.31.9
	0	2.608	243.13.8
	+1	073	276.3
+2	-3	069	80.8
	-2	2.731	87.8.7
	-1	1.610	189.29.6
	0	073	252.6
+3	-4	005	158
	-3	164	170.5
	-2	.556	82.65
	-1	210	98.5
+4	-4	016	259
	-3	044	168.2
	-2	080	77.7
	-1	021	93
+5	-4	005	259
	-3	007	164
	-2	.079	71

Table 5.
Perturbations by MARS

J	I	S	K
+1	-2	006	218
	-1	.273	217.7
	0	048	260.3
+2	-3	041	346.0
	-2	2.843	343.53.3
	-1	1.770	288.24.1
	0	028	148
+3	-4	004	284
	-3	129	294.2
	-2	.425	338.88
	-1	008	7
+4	-4	034	71.0
	-3	.588	185.18
	-2	.585	344.86
	-1	009	325
+5	-5	007	172
	-4	085	54.6
	-3	204	100.8
	-2	003	18
+6	-5	020	186
	-4	154	227.4
	-3	101	96.3
+7	-6	006	301
	-5	049	176.5
	-4	106	222.7
+8	-7	003	72
	-6	010	307
	-5	052	348.9
	-4	021	215.2
+9	-7	004	57
	-6	028	298
	-5	062	346.0
+10	-7	005	68
	-6	019	111
	-5	005	338
+11	-7	017	59
	-6	044	105.9
+12	-7	006	232
+13	-8	013	184
	-7	.045	227.8
+15	-9	021	309
+17	-10	004	243
	-9	026	113

Table 7.
Perturbations by SATURN

J	I	S	K
+1	-2	011	105
	-1	.419	188.58
	0	320	269.46
	+1	008	270
+2	-2	108	290.6
	-1	112	293.6
	0	017	277
+3	-2	021	289
	-1	017	291
+4	-2	001	288

Table 8.
Latitude Perturbations by VENUS

J	I	S	K
-1	+0	029	145
	1	005	323
	2	.893	93.7
	3	007	262
-2	+1	023	173
	2	.012	149
	3	.867	123.0
	4	014	111
-3	+2	014	201
	3	008	187
	4	.210	151.8
	5	007	153
	6	004	296
-4	+3	.006	232
	5	031	1.8
	6	012	180
-5	+6	009	27
	7	019	18
-6	+5	006	288
	7	004	57
	8	004	57
-8	+12	010	61

Latitude Perturbations by MARS

J	I	S	K
		-	-
+2	-2	008	90
	0	008	346
+4	-3	007	188

Latitude Perturbations by JUPITER

J	I	S	K
		-	-
+1	-2	007	180
	-1	017	273
	0	016	180
	+1	023	268
+2	-1	.164	245.5
+3	-2	006	171
	-1	018	267

Latitude Perturbations by SATURN

J	I	S	K
		-	-
+1	-1	006	260
	+1	006	280

STEP 8(a) Computation of precession - $p42$

The precession is defined as the distance the equinox has moved from the beginning of the year. The rate of precession, p , is

$$p = 50''.2564 + 0''.0222 \cdot p23 . \quad (55)$$

Thus the precession is,

$$p42 = p \cdot (\text{time since beginning of year}) . \quad (56)$$

STEP 8(b) Computation of apparent (true) longitude - $p41 = \lambda$

The apparent longitude of the sun is the solar longitude measured from the mean equinox of date apparent at the earth's surface, ignoring refraction. Thus

$$\lambda = (V - M) + L + \Delta\lambda_1 + \delta L + \Delta\lambda + \Delta\psi , \quad (57)$$

or

$$p41 = (p27 - p25) + p24 + p29 + p33 + p36 + p34 .$$

STEP 8(c) Computation of obliquity $p75 = \epsilon$

$$\epsilon = \epsilon_m + \Delta\epsilon . \quad (58)$$

or

$$p75 = p43 + p35 .$$

STEP 8(d) Computation of apparent right ascension - $p44 = \alpha$

From equation 5)

$$\alpha = \tan^{-1}(\tan\lambda \cdot \cos\epsilon) , \quad (59)$$

if

$$\text{sign } \alpha \neq \text{sign } \lambda ; \text{ the } \alpha = \alpha + 180^\circ , \quad (60)$$

if

$$\alpha < 0 \text{ Then } \alpha = \alpha + 360^\circ ,$$

or

$$p44 = \tan^{-1}(\tan(p41) \cdot \cos(p43)) ,$$

if

$$\text{sign}(p44) \neq \text{sign}(p41) . \text{ Then } p44 = p44 + 180^\circ .$$

or if

$$p44 < 0 \text{ Then } p44 = p44 + 360^\circ.$$

STEP 8(e) Computation of equation of time - $p46 = Eq. T.$

$$Eq. T = \alpha_m - \alpha. \quad (61)$$

if

$$Eq. T > 180^\circ; \text{ Then } Eq. T = Eq. T - 360^\circ, \quad (62)$$

or

$$p46 = p45 - p44.$$

or if

$$p46 > 180^\circ; \text{ Then } p46 = p46 - 360^\circ.$$

STEP 8(f) Computation of hour angle - $p48 = h_m$

From Eq. (26)

$$p48 = p21 \cdot 360 + 15 \cdot \text{int} \left(\frac{7.5 + p20}{15} \right) \cdot \text{sign}(p2) - p20 - 180 \quad (63)$$

where $p21$ = local standard time in fractions of days

$p20$ = absolute value of longitude

$p2$ = longitude.

STEP 8(g) Computation of local apparent hour angle - $p49 = h_s$

$$h_s = Eq. T + h_m \quad (64)$$

or

$$p49 = p46 + p48$$

STEP 8(h) Computation of declination - $p47 = \delta_s$ from Eq. (1)

$$\delta_s = \sin^{-1} \left[\cos \beta \sin \lambda \sin \epsilon + \sin \beta \cos \epsilon \right]. \quad (65)$$

or

$$p47 = \sin^{-1} \left[\cos(p60) \sin(p41) \sin(p75) + \sin(p60) \cos(p75) \right] .$$

STEP 8(i) Computation of zenith angle - Z from Eq. (7)

$$Z = \cos^{-1} \left[\sin \delta_s \sin \phi + \cos \delta_s \cos \phi \cos h_s \right] , \quad (66)$$

or

$$Z = \cos^{-1} \left[\sin(p47) \sin(p19) + \cos(p47) \cos(p19) \cos(p49) \right] ,$$

where $p19$ = latitude of observer.

STEP 8(j) Computation of azimuth - A from Eq. (8)

$$A = \cos^{-1} \left[\frac{\sin \delta_s \cos \phi - \cos \delta_s \sin \phi \cos h_s}{\sin Z} \right] \quad (67)$$

if

$$\text{sign} \left[\frac{-\cos \delta_s \sin h_s}{\sin Z} \right] \neq \text{sign}(A); \text{ Then } A = 360 - A , \quad (68)$$

or

$$A = \cos^{-1} \left[\frac{\sin(p47) \cos(p19) - \cos(p47) \sin(p19) \cos(p49)}{\sin Z} \right] ,$$

or if

$$\text{sign} \left[\frac{-\cos(p47) \sin(p49)}{\sin Z} \right] \neq \text{sign}(A); \text{ Then } A = 360 - A .$$

The longitude tabulated in the Nautical Almanac is the apparent longitude minus the sum of the aberration and the nutation of longitude. Therefore, the tabulated quantity is

$$\lambda = (\Delta \lambda_A + \Delta \psi) , \quad (69)$$

or

$$p41 = (p29 + p34) .$$

3.2. ALGORITHM ACCURACY

The accuracy of the solar ephemeris algorithm depends ultimately on the number of terms used for the perturbation effects. In order to give some insight into the degree of accuracy achievable, this section will explore the effect of the various component parts on the final result.

For our specific requirements, the value of major concern is the apparent zenith angle Z . This value, computed from Eq. (7), is a function of declination δ , observer latitude ϕ and solar hour angle h . Thus

$$\cos Z = \sin \delta \sin \phi + \cos \delta \cos \phi \cos h. \quad (70)$$

We also know

$$h_s = h_m + Eq. T = h_m + \alpha_m - \alpha, \quad (71)$$

or, combining known quantities,

$$h_s = LMT - \alpha - \Lambda + C. \quad (72)$$

Thus taking derivatives and assuming the maximum possible error for each component, one obtains

$$\Delta Z \approx \Delta \delta + \Delta \alpha + \Delta LMT + \Delta \Lambda + \Delta \phi. \quad (73)$$

It should be noted that the maximum possible error will not occur simultaneously for each of the components. Thus the maximum error $\Delta \Lambda$ will occur when $\phi=0$, while the maximum error $\Delta \delta$ will occur when $\phi=0$, $\delta_s=0$ but $h_s = 0^\circ$ or 90° . By doing the analysis in this manner however, the relative importance of each component is illustrated.

The present requirements for the algorithm have been to compute ΔZ to within $0^\circ.1$ or $6'$. If this error is then divided proportionally among the five components, each must have maximum errors of $0^\circ.02$ or $72''$.

3.2.1. Latitude and Longitude

Since $0^\circ.02$ of latitude is 1.2 nautical miles, this fixes the required latitude determination. A longitude increment of $0^\circ.02$, in terms of surface distance is given by

$$\frac{0^\circ.02}{\cos \phi}. \quad (74)$$

However, the maximum error $\Delta \Lambda$ is proportional to $\cos \phi$, so that again a determination of Λ to within 1.2 nautical miles will give the requisite accuracy.

3.2.2. Time

A change in arc degrees of $0^\circ.02$ in zenith angle is equivalent to 4.8 seconds of time. Again, this is proportional to $\cos \phi$, so that at higher latitudes this requirement is relaxed.

3.2.3. Declination

Declination is computed using Eq. (4). Thus,

$$\sin \delta_s = \sin \lambda \cdot \sin \epsilon. \quad (75)$$

and therefore

$$\Delta\delta_s = \left(\frac{\sin\lambda \cos\epsilon}{\cos\delta_s} \right) \Delta\epsilon + \left(\frac{\cos\lambda \sin\epsilon}{\cos\delta_s} \right) \Delta\lambda. \quad (76)$$

Since ϵ , the obliquity is on the order of $23^\circ.5$, the maximum error for $\Delta\epsilon + \Delta\lambda$ is on the order of

$$\Delta\delta_s = \Delta\epsilon + 0.4x\Delta\lambda. \quad (77)$$

For $\Delta\delta_s = 0^\circ.02$, and dividing maximum error proportionally

$$\Delta\epsilon = 36'' \quad (78)$$

and

$$\Delta\lambda = 90'' = 1' 30''.$$

3.2.4. Right Ascension

From Eq. (5), right ascension α is computed as

$$\tan\alpha = \tan\lambda \cdot \cos\epsilon, \quad (79)$$

or

$$\Delta\alpha = \frac{\sec^2\lambda \cos\epsilon}{\sec^2\alpha} \cdot \Delta\lambda + \frac{\tan\lambda \sin\epsilon}{\sec^2\alpha} \cdot \Delta\epsilon. \quad (80)$$

Putting in values for maximum error, the relationship

$$\Delta\alpha = \Delta\lambda + 0.7 \cdot \Delta\epsilon \quad (81)$$

is obtained.

For $\Delta\alpha = 0^\circ.02$ and dividing the maximum error proportionally,

$$\Delta\epsilon = 90'' = 1' 30'' \quad (82)$$

and

$$\Delta\lambda = 36''.$$

3.2.5. Obliquity and Solar Longitude

The analysis of errors due to declination and right ascension shows that in general for $\Delta Z = 0^\circ.1$, the error in obliquity $\Delta\epsilon$ should be less than $36''$. This is also true for the error in solar longitude $\Delta\lambda$.

The major source of error in obliquity is the inclusion of the nutation of obliquity $\Delta\epsilon$. Addition of all of the coefficients for nutation of obliquity found in Table 3 gives the sum $10''.04$. If the four highest terms are summed the value $9''.94$ is obtained.

Thus the maximum possible error in obliquity is not $36''$ but on the order of $10''$. If the four largest terms for nutation of obliquity are used this reduces the maximum error to $0''.1$. Therefore the maximum error for longitude $\Delta\lambda$ may be increased to $62''$ or $72''$.

The errors in the computation of longitude are listed in Table 9 along with the corrections used in the present algorithm. The errors are computed by adding the coefficients given in Tables 3 and 4.

Table 9.

	All Corrections	Algorithm Corrections	# of Terms
Nutation of Long $\Delta\psi$	19" 36	19" 03	5
Moon perturbation of long $\Delta\lambda_m$	7" 34	7" 34	7
Inequalities of Long Period δL	9" 84	9" 84	5
Perturbations of Planets			
VENUS	17" 57	16" 11	6
MARS	7" 02	5" 00	6
JUPITER	15" 65	14" 71	5
SATURN	1" 04	0" 74	2
TOTAL	77" 82	73" 37	

It can be seen from Table 9 that the maximum error $\Delta\lambda$ is about 78". This is just 16" higher than the maximum allowable error of 62" from $\Delta Z = 0^\circ.1$. Since this is the maximum allowable error, the computation of λ without any nutation and perturbation corrections should allow Z to be computed to within $0^\circ.1$ under most conditions.

The addition of the nutation terms in the obliquity and longitude calculations using only those 9 terms used in the present algorithm will reduce the maximum allowable error in longitude to 49" which is well within the requirement.

The use of all the terms for nutation and perturbations in the present algorithm reduces the error in longitude computation on the order of 4".5. This degree of accuracy is far greater than is needed for most applications. Their inclusion has been merely an illustration of the technique required for a highly accurate solar ephemeris.

3.2.6. Sample Results

To show the accuracy of the algorithm, the ephemeris for four days have been computed and tabulated below. They are:

- Table 10 1786 MAY 3, 17^h 30^m GMT
- Table 11 1960 MAR 1, 0^h GMT
- Table 12 1979 JAN 1, 0^h GMT
- Table 13 1979 JUL 1, 0^h GMT

The first date was chosen because Newcomb used this date as an example as to how to use the "tables". The second date is used in the *Supplement* as an example, and the last two are merely illustrative of the accuracy for the year 1979.

For each date the computations have been made for the approximations noted in the sections above. The first uses the full algorithm, the second excludes planetary effects, while the third excludes lunar and planetary effects.

Table 10. 1786 MAY 4 5^h30^m GMT

	Nautical Almanac	Algorithm Full	Algorithm no planetary effects	Algorithm no lunar effects
Longitude for Mean Equinox of Date	43° 50' 49" 5	43° 50' 51" 7	43° 50' 51" 3	43° 50' 54" 6
Reduction to Apparent Longitude	-6" 02	-6" 11	-6" 11	-20" 28
Latitude for ecliptic of Date	-	-0" 01	0" 02	-
Precession in Longitude from 1786.0 to Date	17" 06	17" 22	17" 22	17" 22
Nutation in Longitude	14" 26	14" 17	14" 17	-
Nutation in Obliquity	4" 13	4" 30	4" 30	-
Obliquity of Ecliptic	25° 28' 05" 8	23° 28' 05" 8	23° 28' 05" 8	23° 28' 01" 5
Apparent Right Ascension	-	2 ^h 45 ^m 31 ^s 6	2 ^h 45 ^m 20 ^s 1	2 ^h 45 ^m 31 ^s 0
Apparent Declination	-	16° 00' 50" 0	16° 00' 51" 8	16° 00' 43" 9
Radius Vector	1.0093	1.0093	1.0093	1.0093
ET of Ephemeris Transit	-	11 ^h 50 ^m 30 ^s 3	11 ^h 50 ^m 30 ^s 6	11 ^h 56 ^m 29 ^s 6

*Note that previous to 1925 GMT was measured from Greenwich noon. Thus Newcomb computed ephemeris for 1786 May 3 17^h30^m GMT

Table 11. 1960 MARCH 7 0^h GMT

	Nautical Almanac	Algorithm Full	Algorithm no planetary effects	Algorithm no lunar effects
Longitude for Mean Equinox of Date	346° 26' 23" 5	346° 26' 24" 3	346° 26' 04" 5	346° 26' 01" 9
Reduction to Apparent Longitude	-21" 37	-21" 45	-21" 45	-20" 62
Latitude for ecliptic of Date	-0" 65	-0" 61	-0" 57	-
Precession in Longitude from 1960.0 to Date	9" 04	9" 01	9" 01	9" 01
Nutation in Longitude	-0" 74	-0" 82	-0" 82	-
Nutation in Obliquity	-8" 84	-8" 89	-8" 89	-
Obliquity of Ecliptic	23° 26' 31" 2	23° 26' 31" 2	23° 26' 31" 2	23° 26' 40" 0
Apparent Right Ascension	23 ^h 10 ^m 04 ^s 1	23 ^h 10 ^m 04 ^s 1	23 ^h 10 ^m 02 ^s 9	23 ^h 10 ^m 02 ^s 9
Apparent Declination	-5° 21' 16" 3	-5° 21' 16" 0	-5° 21' 23" 7	-5° 21' 25" 7
Radius Vector	9925	9925	9925	9925
ET of Ephemeris Transit	12 ^h 11 ^m 05 ^s 8	12 ^h 11 ^m 05 ^s 7	12 ^h 11 ^m 04 ^s 5	12 ^h 11 ^m 04 ^s 5

Table 12. 1979 JAN 1 0^h GMT

	Nautical Almanac	Algorithm Full	Algorithm no planetary effects	Algorithm no lunar effects
Longitude for Mean Equinox of Date	279° 58' 14" 90	279° 58' 16" 3	279° 58' 16" 7	279° 58' 18" 6
Reduction to Apparent Longitude	-22" 86	-22" 88	-22" 88	-20" 82
Latitude for ecliptic of Date	0" 60	0" 21	0" 38	-
Precession in Longitude from 1979.0 to Date	+0" 007	-0" 03	-0" 03	-0" 03
Nutation in Longitude	-2" 047	2" 059	2" 059	-
Nutation in Obliquity	-9" 743	9" 724	9" 724	-
Obliquity of Ecliptic	23° 20' 21" 467	23° 26' 21" 5	23° 26' 21" 5	23° 26' 31" 3
Apparent Right Ascension	18 ^h 43 ^m 21 ^s 66	18 ^h 43 ^m 21 ^s 76	18 ^h 43 ^m 21 ^s 8	18 ^h 43 ^m 22" 1
Apparent Declination	-23° 03' 53" 8	-23° 03' 54" 1	23° 03' 53" 9	-23° 04' 03" 6
Radius Vector	0.9833336	9833	9833	9833
ET of Ephemeris Transit	12 ^h 03 ^m 23 ^s 61	12 ^h 03 ^m 23 ^s 5	12 ^h 03 ^m 23 ^s 5	12 ^h 03 ^m 23 ^s 8

Table 13. 1979 JUL 1 0^h GMT

	Nautical Almanac	Algorithm Full	Algorithm no planetary effects	Algorithm no lunar effects
Longitude for Mean Equinox of Date	98° 35' 43" 40	98° 35' 43" 4	98° 35' 43" 8	98° 35' 42" 6
Reduction to Apparent Longitude	-25" 27	-25" 33	-25" 33	-20" 13
Latitude for ecliptic of Date	-4" 02	-1" 15	0" 12	-
Precession in Longitude from 1979.0 to Date	-25" 353	-24" 88	24" 88	-24" 88
Nutation in Longitude	-5" 119	5" 19	5" 19	-
Nutation in Obliquity	-9" 271	9" 25	9" 25	-
Obliquity of Ecliptic	23° 26' 21" 747	23° 26' 21" 8	23° 26' 21" 8	23° 26' 31" 0
Apparent Right Ascension	6 ^h 37 ^m 23 ^s 45	6 ^h 37 ^m 23 ^s 45	6 ^h 37 ^m 23 ^s 5	6 ^h 37 ^m 23 ^s 8
Apparent Declination	21° 09' 40" 0	21° 09' 40" 02	21° 09' 40" 1	21° 09' 48" 9
Radius Vector	1.0166814	1.0167	1.0167	1.0167
ET of Ephemeris Transit	12 ^h 01 ^m 40 ^s 67	12 ^h 01 ^m 40 ^s 2	12 ^h 01 ^m 40 ^s 1	12 ^h 01 ^m 40 ^s 6

APPENDIX 2

GENESSIS Heat Transfer and Reflectance Data Bases

Table A2-1. Heat Transfer Data Base.*

3 4	3 4	3 8	3 8	3 8	3 8	3 8	3 8	3 8
0 000	220 940	613 641	864 682	- Solar Irradiance Values				
260 00	273 00	286 00	300 00	- Convective Flux Values				
-60 00	0 00	60 00		- Conductive Flux Values				
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	Solar Elevation Angle (rad)
248 7	248 7	248 7	248 7	248 7	248 7	248 7	248 7	
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	Temperature (kelvin)
259 9	259 9	260 0	260 0	260 0	260 0	260 0	259 9	
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	
271 2	271 2	271 3	271 3	271 3	271 3	271 3	271 2	
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	
261 5	261 5	261 6	261 6	261 6	261 6	261 6	261 5	
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	
272 8	272 8	272 9	272 9	272 9	272 9	272 9	272 8	
-1 560	-1 559	-1 557	1 553	1 554	1 554	1 557	1 560	
284 2	284 2	284 2	284 2	284 2	284 2	284 2	284 2	
-1 560	-1 557	1 553	1 554	1 554	1 554	1 557	1 560	
274 5	274 5	274 5	274 5	274 5	274 5	274 5	274 5	
-1 560	-1 557	1 553	1 554	1 556	1 556	1 557	1 560	
285 8	285 8	285 8	285 8	285 8	285 8	285 8	285 8	
-1 560	-1 560	-1 559	-1 557	1 553	1 554	1 557	1 560	
297 2	297 2	297 2	297 2	297 2	297 2	297 2	297 2	
-1 560	-1 560	-1 557	1 553	1 554	1 554	1 557	1 560	
288 4	288 4	288 4	288 5	288 5	288 5	288 4	288 4	
-1 560	-1 559	-1 557	1 553	1 554	1 554	1 557	1 560	
299 8	299 8	299 8	299 8	299 8	299 8	299 8	299 8	
-1 560	-1 559	-1 559	-1 557	1 553	1 554	1 557	1 560	
311 2	311 2	311 2	311 2	311 3	311 3	311 2	311 2	
-1 445	-1 320	-1 226	-1 033	1 185	1 391	1 392	2 084	
249 3	250 1	250 8	252 3	251 2	250 4	249 7	246 2	
-1 445	-1 320	-1 226	-1 033	1 185	1 391	1 392	2 084	
260 6	261 5	262 1	263 7	262 5	261 7	261 0	257 4	
-1 445	-1 340	1 320	-1 226	-1 033	1 391	1 392	2 084	
271 9	272 6	272 8	273 5	275 1	273 1	272 4	268 5	

* See P. 19 for further explanation.

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-1 445 262 2	-1 320 263 1	-1 226 263 8	-1 033 265 3	1 185 264 2	1 299 263 3	1 392 262 7	2 084 259 0
-1 445 273 5	-1 340 274 2	-1 320 274 4	-1 226 275 1	-1 033 276 8	1 299 274 7	1 392 274 0	2 084 270 1
-1 445 284 9	-1 340 285 6	-1 320 285 8	-1 226 286 6	-1 033 288 2	1 299 286 1	1 392 285 4	2 084 281 4
-1 445 275 1	-1 340 275 8	-1 320 276 0	-1 226 276 7	-1 033 278 4	1 299 276 3	1 392 275 6	2 084 271 7
-1 445 286 5	-1 340 287 2	-1 320 287 5	-1 226 288 2	-1 033 289 9	1 299 287 7	1 392 287 0	2 084 283 0
-1 445 297 9	-1 340 298 7	-1 320 298 9	-1 226 299 6	-1 033 301 4	1 299 299 2	1 392 298 4	2 084 294 2
-1 445 289 1	-1 340 289 9	-1 320 290 1	-1 226 290 8	-1 033 292 5	1 299 290 4	1 392 289 6	2 084 285 5
-1 445 300 6	-1 340 301 3	-1 320 301 5	-1 226 302 3	-1 033 304 0	1 299 301 8	1 392 301 1	2 084 296 8
-1 445 312 0	-1 340 312 8	-1 320 313 0	-1 226 313 7	-1 033 315 5	1 299 313 3	1 392 312 5	2 084 308 1
-1 364 249 8	-1 178 251 1	-0 962 252 7	-0 510 255 5	0 879 253 4	1 090 251 9	1 274 250 6	2 607 244 4
-1 364 261 1	-1 178 262 4	-0 962 264 1	-0 510 267 0	0 879 264 9	1 090 263 3	1 274 262 0	2 607 255 5
-1 364 272 5	-1 178 273 8	-0 962 275 5	-0 510 278 5	0 879 276 3	1 090 274 7	1 274 273 3	2 607 266 6
-1 364 262 7	-1 178 264 1	-0 962 265 7	-0 510 268 6	0 879 266 5	1 090 264 9	1 274 263 6	2 607 257 1
-1 364 274 1	-1 178 275 4	-0 962 277 2	-0 510 280 1	0 879 278 0	1 090 276 3	1 274 275 0	2 607 268 1
-1 364 285 5	-1 178 286 9	-0 962 288 7	-0 510 291 7	0 879 289 5	1 090 287 8	1 274 286 4	2 607 279 3
-1 364 275 7	-1 178 277 1	-0 962 278 8	-0 510 281 8	0 879 279 6	1 090 278 0	1 274 276 6	2 607 269 7
-1 364 287 1	-1 178 288 5	-0 962 290 3	-0 510 293 3	0 879 291 1	1 090 289 4	1 274 288 0	2 607 280 9

-1 364 298 5	-1 178 300 0	-0 962 301 8	-0 510 304 9	1 090 300 9	1 274 297 5	1 500 297 7	2 607 292 0
-1 364 289 7	-1 178 291 1	-0 962 292 9	-0 510 296 0	0 879 293 7	1 090 292 1	1 274 290 6	2 607 283 4
-1 364 301 2	-1 178 302 6	-0 962 304 4	-0 510 307 6	1 090 303 6	1 274 300 1	1 500 300 3	2 607 294 6
-1 364 312 6	-1 178 314 1	-0 962 316 0	-0 510 319 2	1 090 315 1	1 274 313 6	1 500 311 8	2 607 305 8
-1 339 249 7	-1 121 251 3	-0 859 253 4	-0 033 256 8	0 756 254 3	1 018 252 4	1 236 250 7	3 109 243 4
-1 339 261 0	-1 121 262 7	-0 859 264 8	-0 033 268 3	0 756 265 7	1 018 263 0	1 236 262 1	3 109 254 4
-1 339 272 3	-1 121 274 0	-0 859 276 2	-0 033 279 8	0 756 277 2	1 018 275 2	1 236 273 4	3 109 265 5
-1 339 262 6	-1 121 264 3	-0 859 266 4	-0 033 270 0	0 756 267 3	1 018 265 4	1 236 263 7	3 109 256 0
-1 339 274 0	-1 121 275 7	-0 859 277 8	-0 033 281 5	0 756 278 8	1 018 276 0	1 236 275 0	3 109 267 1
-1 339 285 3	-1 121 287 0	-0 859 289 3	-0 033 293 0	0 756 290 2	1 018 288 2	1 236 286 4	3 109 278 1
-1 339 275 6	-1 121 277 3	-0 859 279 4	-0 033 283 1	0 756 280 4	1 018 278 4	1 236 276 7	3 109 268 6
-1 339 286 9	-1 121 288 6	-0 859 290 9	-0 033 294 6	0 756 291 9	1 018 289 8	1 236 288 0	3 109 279 7
-1 339 298 2	-1 121 300 0	-0 859 302 3	-0 033 306 1	0 756 303 3	1 018 301 2	1 236 299 4	3 109 290 7
-1 339 289 5	-1 121 291 3	-0 859 293 5	-0 033 297 2	0 756 294 5	1 018 292 4	1 236 290 6	3 109 282 2
-1 339 300 8	-1 121 302 7	-0 859 304 9	-0 033 308 8	0 756 305 9	1 018 303 8	1 236 302 0	3 109 293 3
-1 339 312 2	-1 121 314 0	-0 859 316 4	-0 033 320 3	1 018 315 2	1 236 313 4	1 498 311 1	3 109 304 3

4	4	3	8	
0 000	220 940	613 641	864 682	
260 00	273 00	286 00	300 00	
-60 00	0 00	60 00		

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260 5	261 6	262 4	264 7	263 1	262 0	261 2	257 3
-1 445	-1 320	-1 226	-1 033	1 185	1 291	1 392	2 084
271 5	272 6	273 5	275 7	274 1	273 0	272 1	268 2

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-1 445 273 3	-1 320 274 4	-1 226 275 3	-1 033 277 6	1 185 276 0	1 392 276 7	1 392 274 0	2 084 270 0
-1 445 284 4	-1 320 285 6	-1 226 286 5	-1 033 288 8	1 185 287 1	1 392 286 0	1 392 285 1	2 084 280 9
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-1 445 286 3	-1 320 287 4	-1 226 288 3	-1 033 290 7	1 185 289 0	1 392 287 9	1 392 287 0	2 084 282 8
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-1 445 289 1	-1 320 290 3	-1 226 291 2	-1 033 293 5	1 185 291 9	1 392 290 7	1 392 289 8	2 084 285 6
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-1 445 311 5	-1 320 312 7	-1 226 313 7	-1 033 316 1	1 185 314 4	1 392 313 2	1 392 312 2	2 084 307 7
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-1 364 272 1	-1 141 274 4	-0 962 276 2	-0 510 280 4	0 879 277 5	1 090 275 2	1 274 273 5	2 607 266 2
-1 364 263 0	-1 141 265 2	-0 962 266 9	-0 510 271 1	0 879 268 2	1 090 266 0	1 274 264 3	2 607 257 3
-1 364 274 0	-1 141 276 3	-0 962 278 0	-0 510 282 3	0 879 279 3	1 090 277 1	1 274 275 3	2 607 268 1
-1 364 285 1	-1 141 287 4	-0 962 289 2	-0 510 293 6	0 879 290 5	1 090 288 3	1 274 286 5	2 607 278 9
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-1 364 287 0	-1 141 289 3	-0 962 291 1	-0 510 295 4	0 879 292 4	1 090 290 1	1 274 288 3	2 607 280 7

-1 364 298 2	-1 141 300 6	-0 962 302 4	-0 510 306 8	0 879 303 7	1 090 301 4	1 274 299 6	2 607 291 6
-1 364 289 8	-1 141 292 2	-0 962 294 0	-0 510 298 3	0 879 295 3	1 090 293 0	1 274 291 2	2 607 283 5
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-1 339 260 8	-1 077 263 7	-0 859 265 9	-0 033 271 2	0 756 267 5	1 018 264 7	1 236 262 5	3 109 254 2
-1 339 271 7	-1 077 274 7	-0 859 277 0	-0 033 282 3	0 756 278 6	1 018 275 8	1 236 273 5	3 109 264 8
-1 339 262 6	-1 077 265 6	-0 859 267 8	-0 033 273 0	0 756 269 4	1 018 266 6	1 236 264 3	3 109 256 0
-1 339 273 6	-1 077 276 6	-0 859 278 8	-0 033 284 2	0 756 280 4	1 018 277 6	1 236 275 3	3 109 266 7
-1 339 284 6	-1 077 287 6	-0 859 289 9	-0 033 295 3	0 756 291 5	1 018 288 7	1 236 286 3	3 109 277 3
-1 339 275 4	-1 077 278 4	-0 859 280 7	-0 033 286 0	0 756 282 3	1 018 279 5	1 236 277 2	3 109 268 5
-1 339 286 4	-1 077 289 5	-0 859 291 7	-0 033 297 2	0 756 293 4	1 018 290 5	1 236 288 2	3 109 279 2
-1 339 297 4	-1 077 300 5	-0 859 302 8	-0 033 308 4	0 756 304 5	1 018 301 6	1 236 299 2	3 109 289 9
-1 339 289 2	-1 077 292 3	-0 859 294 6	-0 033 300 0	0 756 296 2	1 018 293 4	1 236 291 0	3 109 282 0
-1 339 300 2	-1 077 303 4	-0 859 305 7	-0 033 311 2	0 756 307 4	1 018 304 4	1 236 302 0	3 109 292 7
-1 339 311 2	-1 077 314 4	-0 859 316 7	-0 033 322 3	0 756 318 4	1 018 315 5	1 236 313 0	3 109 303 4

5	4	3	8	
0 000	270 940	613 641	864 682	
260 00	273 00	286 00	300 00	
-60 00	0 00	60 00		

-1 560 250 0	-1 560 250 0	-1 557 250 0	1 553 250 0	1 554 250 0	1 554 250 0	1 557 250 0	1 560 250 0
-1 560 259 7	-1 560 259 7	-1 557 259 7	1 553 259 7	1 554 259 7	1 554 259 7	1 557 259 7	1 560 259 7
-1 560 269 5	-1 560 269 5	-1 557 269 5	1 553 269 5	1 554 269 5	1 554 269 5	1 557 269 5	1 560 269 5
-1 560 262 6	-1 560 262 6	-1 557 262 6	1 553 262 7	1 554 262 7	1 554 262 7	1 557 262 7	1 560 262 6
-1 560 272 4	-1 560 272 4	-1 560 272 4	-1 557 272 4	1 553 272 4	1 554 272 4	1 557 272 4	1 560 272 4
-1 560 282 4	-1 559 282 4	-1 557 282 4	1 553 282 4	1 554 282 4	1 554 282 4	1 557 282 4	1 560 282 4
-1 560 275 3	-1 559 275 4	-1 559 275 4	-1 557 275 4	1 553 275 4	1 554 275 4	1 557 275 4	1 560 275 4
-1 560 285 3	-1 559 285 3	-1 559 285 3	-1 557 285 3	1 553 285 3	1 554 285 3	1 557 285 3	1 560 285 3
-1 560 295 4	-1 560 295 4	-1 557 295 4	1 553 295 4	1 554 295 4	1 554 295 4	1 557 295 4	1 560 295 4
-1 560 289 2	-1 560 289 2	-1 559 289 2	-1 557 289 2	1 553 289 2	1 554 289 2	1 557 289 2	1 560 289 2
-1 560 299 3	-1 560 299 3	-1 557 299 3	1 553 299 3	1 554 299 3	1 554 299 3	1 557 299 3	1 560 299 3
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-1 339 275	-1 077 278 4	-0 859 280 7	-0 033 286 0	0 756 282 3	1 018 279 5	1 236 277 2	3 109 268 5
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-1 339 289 2	-1 077 292 3	-0 859 294 6	-0 033 300 0	0 756 296 2	1 018 293 4	1 236 291 0	3 109 282 0
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260 4	261 7	262 7	265 6	263 6	263 6	261 2	257 5
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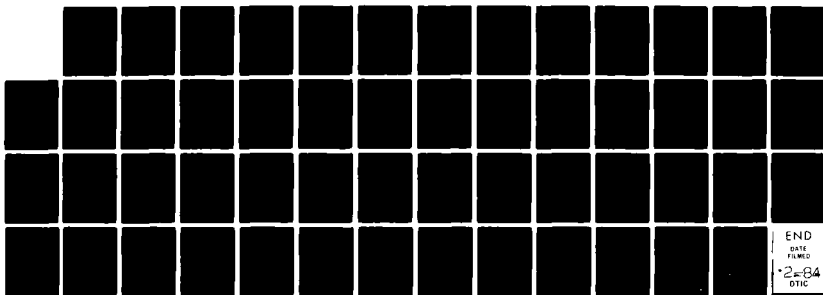
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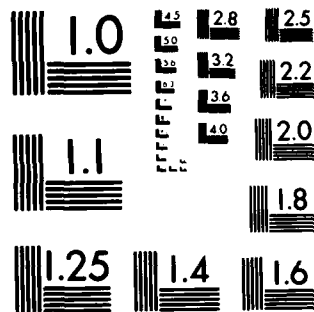
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UNCLASSIFIED

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NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

-1.445 263.3	-1.320 264.6	-1.226 265.6	-1.033 268.5	1.185 266.5	1.272 265.5	1.392 264.1	2.084 260.4
-1.445 273.1	-1.320 274.4	-1.226 275.5	-1.033 278.4	1.185 276.4	1.272 275.3	1.392 273.9	2.084 270.1
-1.445 283.1	-1.320 284.4	-1.226 285.5	-1.033 288.5	1.185 286.4	1.272 285.3	1.392 283.9	2.084 279.9
-1.445 276.1	-1.320 277.4	-1.226 278.4	-1.033 281.3	1.185 279.3	1.272 278.3	1.392 276.9	2.084 273.0
-1.445 286.0	-1.320 287.4	-1.226 288.5	-1.033 291.4	1.185 289.3	1.272 288.3	1.392 286.9	2.084 282.8
-1.445 296.2	-1.320 297.5	-1.226 298.6	-1.033 301.6	1.185 299.5	1.272 298.4	1.392 297.0	2.084 292.7
-1.445 290.0	-1.320 291.3	-1.226 292.4	-1.033 295.3	1.185 293.3	1.272 292.2	1.392 290.8	2.084 286.7
-1.445 300.1	-1.320 301.4	-1.226 302.6	-1.033 305.5	1.185 303.4	1.272 302.0	1.392 300.9	2.084 296.6
-1.445 310.2	-1.320 311.6	-1.226 312.7	-1.033 315.7	1.185 313.6	1.272 312.5	1.392 311.1	2.084 306.7
-1.364 251.4	-1.141 254.1	-0.962 256.2	-0.510 261.4	0.879 257.8	1.070 255.1	1.274 253.0	2.607 246.3
-1.364 261.1	-1.141 263.9	-0.962 266.0	-0.510 271.4	0.879 267.7	1.070 264.9	1.274 262.8	2.607 255.9
-1.364 271.0	-1.141 273.3	-0.962 276.0	-0.510 281.4	0.879 277.7	1.070 274.8	1.274 272.6	2.607 265.4
-1.364 264.1	-1.141 266.8	-0.962 268.9	-0.510 274.3	0.879 270.6	1.070 267.8	1.274 265.7	2.607 258.8
-1.364 273.9	-1.141 276.7	-0.962 278.9	-0.510 284.3	0.879 280.6	1.070 277.8	1.274 275.6	2.607 268.3
-1.364 283.9	-1.141 286.8	-0.962 289.0	-0.510 294.5	0.879 290.7	1.070 287.8	1.274 285.6	2.607 278.0
-1.364 276.8	-1.141 279.6	-0.962 281.8	-0.510 287.2	0.879 283.5	1.070 280.7	1.274 278.5	2.607 271.2
-1.364 286.8	-1.141 289.7	-0.962 291.9	-0.510 297.4	0.879 293.6	1.070 290.8	1.274 288.5	2.607 280.9

-1 364 297 0	-1 141 299 9	-0 962 302 1	-0 510 307 7	0 879 303 9	1 090 301 0	1 274 298 7	2 607 290 8
-1 364 290 8	-1 141 293 6	-0 962 295 8	-0 510 301 3	0 879 297 5	1 090 294 7	1 274 292 4	2 607 284 8
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-1 364 311 0	-1 141 314 0	-0 962 316 3	-0 510 321 9	0 879 318 0	1 090 315 1	1 274 312 8	2 607 304 6
-1 339 250 8	-1 077 254 5	-0 859 257 3	-0 033 264 1	0 756 259 4	1 018 255 0	1 236 253 0	3 109 244 8
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-1 339 270 3	-1 077 274 1	-0 859 277 0	-0 033 284 0	0 756 279 2	1 018 275 5	1 236 272 5	3 109 263 8
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-1 339 283 0	-1 077 286 9	-0 859 289 8	-0 033 296 8	0 756 292 0	1 018 288 3	1 236 285 3	3 109 276 2
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-1 339 285 9	-1 077 289 8	-0 859 292 7	-0 033 299 7	0 756 294 9	1 018 291 2	1 236 288 2	3 109 279 1
-1 339 295 8	-1 077 299 7	-0 859 302 6	-0 033 309 7	0 756 304 8	1 018 301 1	1 236 298 1	3 109 288 7
-1 339 289 8	-1 077 293 7	-0 859 296 6	-0 033 303 5	0 756 298 7	1 018 295 0	1 236 292 1	3 109 283 0
-1 339 299 7	-1 077 303 6	-0 859 306 5	-0 033 313 6	0 756 308 7	1 018 304 7	1 236 301 9	3 109 292 5
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-60.00	0.00	60.00			

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-1.560	-1.560	-1.557	1.553	1.554	1.554	1.557	1.560
259.8	259.8	259.8	259.8	259.8	259.7	259.8	259.8
-1.560	-1.560	-1.557	1.553	1.554	1.554	1.557	1.560
270.8	270.8	270.8	270.8	270.8	270.8	270.8	270.8
-1.560	-1.560	-1.557	1.553	1.554	1.554	1.557	1.560
261.7	261.7	261.7	261.7	261.7	261.7	261.7	261.7
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272.6	272.6	272.6	272.7	272.7	272.7	272.6	272.6
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283.7	283.7	283.7	283.7	283.7	283.7	283.7	283.7
-1.560	-1.560	-1.557	1.553	1.554	1.554	1.557	1.560
274.5	274.5	274.5	274.5	274.5	274.5	274.5	274.5
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285.5	285.5	285.6	285.6	285.6	285.6	285.6	285.5
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296.7	296.7	296.7	296.7	296.7	296.7	296.7	296.7
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288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
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249.5	250.6	251.4	253.6	252.1	251.0	250.2	246.5
-1.445	-1.320	-1.226	-1.033	1.185	1.171	1.392	2.084
260.5	261.6	262.4	264.7	263.1	262.0	261.2	257.3
-1.445	-1.320	-1.226	-1.033	1.185	1.171	1.392	2.084
271.5	272.6	273.5	275.7	274.1	273.0	272.1	268.2

-1.445 262.4	-1.320 263.4	-1.226 264.3	-1.033 266.5	1.185 264.9	1.271 263.8	1.392 263.0	2.084 259.2
-1.445 273.3	-1.320 274.4	-1.226 275.3	-1.033 277.6	1.185 276.0	1.271 274.9	1.392 274.0	2.084 270.0
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-1.445 311.5	-1.320 312.7	-1.226 313.7	-1.033 316.1	1.185 314.4	1.271 313.2	1.392 312.2	2.084 307.7
-1.364 250.2	-1.141 252.4	-0.962 254.0	-0.510 258.1	0.879 255.3	1.070 253.1	1.274 251.4	2.607 244.8
-1.364 261.1	-1.141 263.4	-0.962 265.1	-0.510 269.2	0.879 266.3	1.070 264.2	1.274 262.4	2.607 255.5
-1.364 272.1	-1.141 274.4	-0.962 276.2	-0.510 280.4	0.879 277.5	1.070 275.2	1.274 273.5	2.607 266.2
-1.364 263.0	-1.141 265.2	-0.962 266.9	-0.510 271.1	0.879 268.2	1.070 266.0	1.274 264.3	2.607 257.3
-1.364 274.0	-1.141 276.3	-0.962 278.0	-0.510 282.3	0.879 279.3	1.070 277.1	1.274 275.3	2.607 268.1
-1.364 285.1	-1.141 287.4	-0.962 289.2	-0.510 293.6	0.879 290.5	1.070 288.3	1.274 286.5	2.607 278.9
-1.364 275.9	-1.141 278.2	-0.962 279.9	-0.510 284.1	0.879 281.2	1.070 279.0	1.274 277.2	2.607 269.9
-1.364 287.0	-1.141 289.3	-0.962 291.1	-0.510 295.4	0.879 292.4	1.070 290.1	1.274 288.3	2.607 280.7

-1 364 298 2	-1 141 300 6	-0 962 302 4	-0 510 306 8	0 879 303 7	1 090 301 4	1 274 299 6	2 607 291 6
-1 364 289 8	-1 141 292 2	-0 962 294 0	-0 510 298 3	0 879 295 3	1 090 293 0	1 274 291 2	2 607 283 5
-1 364 301 0	-1 141 303 4	-0 962 305 2	-0 510 309 7	0 879 306 6	1 090 304 3	1 274 302 4	2 607 294 5
-1 364 312 2	-1 141 314 7	-0 962 316 5	-0 510 321 0	0 879 317 9	1 090 315 5	1 274 313 7	2 607 305 4
-1 339 249 8	-1 077 252 7	-0 859 254 9	-0 033 260 1	0 756 256 5	1 018 253 7	1 236 251 5	3 109 243 5
-1 339 260 8	-1 077 263 7	-0 859 265 9	-0 033 271 2	0 756 267 5	1 018 264 7	1 236 262 5	3 109 254 2
-1 339 271 7	-1 077 274 7	-0 859 277 0	-0 033 282 3	0 756 278 6	1 018 275 8	1 236 273 5	3 109 264 8
-1 339 262 6	-1 077 265 6	-0 859 267 8	-0 033 273 0	0 756 269 4	1 018 266 6	1 236 264 3	3 109 256 0
-1 339 273 6	-1 077 276 6	-0 859 278 8	-0 033 284 2	0 756 280 4	1 018 277 6	1 236 275 3	3 109 266 7
-1 339 284 6	-1 077 287 6	-0 859 289 9	-0 033 295 3	0 756 291 5	1 018 288 7	1 236 286 3	3 109 277 3
-1 339 275 4	-1 077 278 4	-0 859 280 7	-0 033 286 0	0 756 282 3	1 018 279 5	1 236 277 2	3 109 268 5
-1 339 286 4	-1 077 289 5	-0 859 291 7	-0 033 297 2	0 756 293 4	1 018 290 5	1 236 288 2	3 109 279 2
-1 339 297 4	-1 077 300 5	-0 859 302 8	-0 033 308 4	0 756 304 5	1 018 301 6	1 236 299 2	3 109 289 9
-1 339 289 2	-1 077 292 3	-0 859 294 6	-0 033 300 0	0 756 296 2	1 018 293 4	1 236 291 0	3 109 282 0
-1 339 300 2	-1 077 303 4	-0 859 305 7	-0 033 311 2	0 756 307 4	1 018 304 4	1 236 302 0	3 109 292 7
-1 339 311 2	-1 077 314 4	-0 859 316 7	-0 033 322 3	0 756 318 4	1 018 315 5	1 236 313 0	3 109 303 4

APPENDIX 3

Test Cases

Two test cases are presented and described herein. They were run on a small section of the Brooks Range scene. Measured data from Daedalus exists for this scene. All GENESSIS input parameters were selected to match the conditions present at the time of Daedalus data acquisition in order that the computed results may be compared with the measured data.

A.3.1. Test Case I - Brooks Range (Thermal Band)

A.3.1.1 Atmospheric Module

Display of input file (Fortran Unit 7) for Brooks Range thermal band.

1)	3			16.76			10.4		12.5
2)	1	1	1	1	0	0	0		23.0

Display of atmospheric diagnostic output file (Fortran Unit 6).
 Selected standard atmosphere is represented parametrically for 5 zenith
 angles and 6 altitudes. Air masses are computed using the Chapman function.

RESULTS FOR BACKGROUND ALTITUDE = 0 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0.0	1.0	1.299E-04	8.875E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.551E-05
48.2	1.5	2.433E-05
70.8	3.0	2.117E-05
80.8	6.0	1.615E-05
86.0	12.0	8.773E-06

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0.0
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.091E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48.2	1.5	1.807E-04	8.427E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.434E-05
48.2	1.5	3.324E-05
70.8	3.0	2.027E-05
80.8	6.0	1.550E-05
86.0	12.0	8.440E-06

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48.2
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.455E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70.8	3.0	3.093E-04	7.282E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.122E-05
48.2	1.5	2.031E-05
70.8	3.0	1.780E-05
80.8	6.0	1.368E-05
86.0	12.0	7.501E-06

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70.8
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.592E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80.8	6.0	5.039E-04	5.517E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	1.624E-05
48.2	1.5	1.557E-05
70.8	3.0	1.372E-05
80.8	6.0	1.064E-05
86.0	12.0	5.902E-06

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.355E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86.0	12.0	7.751E-04	2.969E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	8.858E-06
48.2	1.5	8.517E-06
70.8	3.0	7.557E-06
80.8	6.0	5.928E-06
86.0	12.0	3.348E-06

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.455E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	1.034E-04
45	1.368E-04
75	3.175E-04

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.140E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 8.527E-11

RESULTS FOS BACKGROUND ALTITUDE = 1 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0.0	1.0	7.282E-05	9.329E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.792E-05
48.2	1.5	2.718E-05
70.8	3.0	2.511E-05
80.8	6.0	2.156E-05
86.0	12.0	1.541E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0.0
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.573E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48.2	1.5	1.023E-04	9.053E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.719E-05
48.2	1.5	2.648E-05
70.8	3.0	2.450E-05
80.8	6.0	2.107E-05
86.0	12.0	1.509E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48.2
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.091E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70.8	3.0	1.791E-04	8.325E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.517E-05
48.2	1.5	2.454E-05
70.8	3.0	2.278E-05
80.8	6.0	1.968E-05
86.0	12.0	1.416E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70.8
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.110E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80.8	6.0	3.046E-04	7.122E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.167E-05
48.2	1.5	2.117E-05
70.8	3.0	1.974E-05
80.8	6.0	1.715E-05
86.0	12.0	1.244E-05

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 9.095E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86.0	12.0	5.155E-04	5.071E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	1.556E-05
48.2	1.5	1.523E-05
70.8	3.0	1.426E-05
80.8	6.0	1.249E-05
86.0	12.0	9.172E-06

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.573E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	6.050E-05
45	8.039E-05
75	1.922E-04

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.222E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.103E-10

RESULTS FOR BACKGROUND ALTITUDE = 2 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0.0	1.0	3.842E-05	9.618E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.949E-05
48.2	1.5	2.904E-05
70.8	3.0	2.777E-05
80.8	6.0	2.551E-05
86.0	12.0	2.131E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0.0
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.473E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48.2	1.5	5.446E-05	9.456E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.906E-05
48.2	1.5	2.862E-05
70.8	3.0	2.739E-05
80.8	6.0	2.520E-05
86.0	12.0	2.107E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48.2
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.255E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70.8	3.0	9.692E-05	9.020E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.783E-05
48.2	1.5	2.744E-05
70.8	3.0	2.633E-05
80.8	6.0	2.428E-05
86.0	12.0	2.038E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70.8
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.110E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80.8	6.0	1.685E-04	8.278E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.565E-05
48.2	1.5	2.532E-05
70.8	3.0	2.436E-05
80.8	6.0	2.257E-05
86.0	12.0	1.904E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 8.276E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86.0	12.0	3.002E-04	6.904E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	2.151E-05
48.2	1.5	2.126E-05
70.8	3.0	2.053E-05
80.8	6.0	1.912E-05
86.0	12.0	1.627E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.455E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	3.328E-05
45	4.445E-05
75	1.077E-04

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 1.094E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 1.421E-10

RESULTS FOR BACKGROUND ALTITUDE = 4 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0 0	1 0	8 949E-06	9 887E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 097E-05
48 2	1 5	3 080E-05
70 8	3 0	3 032E-05
80 8	6 0	2 945E-05
86 0	12 0	2 777E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0 0
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1 373E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48 2	1 5	1 300E-05	9 835E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 081E-05
48 2	1 5	3 065E-05
70 8	3 0	3 019E-05
80 8	6 0	2 933E-05
86 0	12 0	2 768E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48 2
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1 473E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70 8	3 0	2 429E-05	9 687E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 029E-05
48 2	1 5	3 024E-05
70 8	3 0	2 981E-05
80 8	6 0	2 899E-05
86 0	12 0	2 740E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70 8
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1 455E-10

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 60.8 6.0 4.398E-05 9.426E-01

SOLAR

ZA AM REFLECTED SOLAR
 0.0 1.0 2.961E-05
 48.2 1.5 2.948E-05
 70.8 3.0 2.908E-05
 80.8 6.0 2.833E-05
 86.0 12.0 2.683E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.774E-10

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 86.0 12.0 8.283E-05 8.912E-01

SOLAR

ZA AM REFLECTED SOLAR
 0.0 1.0 2.805E-05
 48.2 1.5 2.794E-05
 70.8 3.0 2.761E-05
 80.8 6.0 2.696E-05
 86.0 12.0 2.563E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.692E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	8.786E-06
45	1.184E-05
75	2.964E-05

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 9.663E-13

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 1.355E-10

RESULTS FOR BACKGROUND ALTITUDE = 7 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0.0	1.0	1.186E-06	9.975E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.147E-05
48.2	1.5	3.141E-05
70.8	3.0	3.125E-05
80.8	6.0	3.093E-05
86.0	12.0	3.032E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0.0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR: 1.810E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48.2	1.5	1.766E-06	9.963E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.143E-05
48.2	1.5	3.138E-05
70.8	3.0	3.121E-05
80.8	6.0	3.089E-05
86.0	12.0	3.029E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48.2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 1.055E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70.8	3.0	3.532E-06	9.926E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.132E-05
48.2	1.5	3.126E-05
70.8	3.0	3.110E-05
80.8	6.0	3.079E-05
86.0	12.0	3.020E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70.8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 9.095E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80.8	6.0	6.888E-06	9.855E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.110E-05
48.2	1.5	3.105E-05
70.8	3.0	3.089E-05
80.8	6.0	3.059E-05
86.0	12.0	3.002E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 6.366E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86.0	12.0	1.389E-05	9.709E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.064E-05
48.2	1.5	3.059E-05
70.8	3.0	3.045E-05
80.8	6.0	3.017E-05
86.0	12.0	2.963E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.473E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	1.714E-06
45	2.337E-06
75	6.122E-06

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 5.258E-13

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR: 1.892E-10

RESULTS FOR BACKGROUND ALTITUDE = 10 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
0 0 1.0 5.221E-07 9.987E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.154E-05
48.2	1.5	3.150E-05
70.8	3.0	3.138E-05
80.8	6.0	3.115E-05
86.0	12.0	3.071E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0.0
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.473E-10

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
48.2 1.5 7.821E-07 9.980E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.152E-05
48.2	1.5	3.148E-05
70.8	3.0	3.136E-05
80.8	6.0	3.113E-05
86.0	12.0	3.069E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48.2
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.573E-10

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
70.8 3.0 1.574E-06 9.960E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.146E-05
48.2	1.5	3.142E-05
70.8	3.0	3.130E-05
80.8	6.0	3.107E-05
86.0	12.0	3.063E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70.8
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.091E-10

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80.8	6.0	3.180E-06	9.919E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.133E-05
48.2	1.5	3.129E-05
70.8	3.0	3.118E-05
80.8	6.0	3.093E-05
86.0	12.0	3.052E-05

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 9.913E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86.0	12.0	6.612E-06	9.832E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0.0	1.0	3.106E-05
48.2	1.5	3.102E-05
70.8	3.0	3.091E-05
80.8	6.0	3.069E-05
86.0	12.0	3.027E-05

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 1.573E-10

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	1.049E-06
45	1.430E-06
75	3.752E-06

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 9.948E-13

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL: 4
 SUM SQUARE ERROR: 2.010E-10
 FIT OF SKYSHINE TO ALTITUDE
 DEGREE OF BEST FIT POLYNOMIAL: 5
 SUM SQUARE ERROR: 6.323E-10

Display of atmospheric module output database (Fortran Unit 5). Header (Line 1) contains parameters used to generate the database. Lines 2-44 contain the coefficients of the polynomial curve fits to the computed atmospheric values.

PRSCRA>DRAPER>AMK. ATMSPH. CUT1

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1) 10.40 12.50 2 2 1 1 1 1 3 3 3 23.00
2) 6 4 0 -4 59326E 00 -7 89541E-02 -2 61340E-01 3 14837E-01 -3 46999E-01
3) 6 4 0 -4 61362E 00 -7 62383E-02 -2 60405E-01 3 14517E-01 -3 47019E-01
4) 6 4 0 -4 67320E 00 -7 18782E-02 -2 52246E-01 3 04209E-01 -3 41877E-01
5) 6 4 0 -4 78952E 00 -6 62978E-02 -2 53493E-01 3 15605E-01 -3 46782E-01
6) 6 4 0 -5 05269E 00 -6 03881E-02 -2 52162E-01 3 25010E-01 -3 48786E-01
7) 6 4 0 8 87542E-01 -2 15883E-01 -2 02091E-01 -9 32986E-02 -4 26052E-03
8) 6 4 0 -3 88650E 00 8 24803E-01 -4 18577E-02 -7 62313E-02 2 26438E-02
9) 6 4 0 -4 55402E 00 -4 57499E-02 -1 43330E-01 1 63474E-01 -1 82708E-01
10) 6 4 0 -4 56554E 00 -4 46328E-02 -1 41305E-01 1 62373E-01 -1 82544E-01
11) 6 4 0 -4 59918E 00 -4 08432E-02 -1 43886E-01 1 71667E-01 -1 87517E-01
12) 6 4 0 -4 66406E 00 -3 79587E-02 -1 33861E-01 1 59578E-01 -1 80915E-01
13) 6 4 0 -4 80799E 00 -3 36733E-02 -1 34668E-01 1 70270E-01 -1 84895E-01
14) 6 4 0 9 32920E-01 -1 26791E-01 -1 76578E-01 5 78591E-02 -1 15521E-01
15) 6 4 0 -4 13776E 00 8 43565E-01 -1 43116E-02 -1 11035E-01 7 10694E-02
16) 6 4 0 -4 53032E 00 -2 66672E-02 -7 54294E-02 7 74168E-02 -9 00134E-02
17) 6 4 0 -4 53676E 00 -2 67539E-02 -7 15051E-02 7 46079E-02 -8 95482E-02
18) 6 4 0 -4 55553E 00 -2 33272E-02 -7 36055E-02 7 80394E-02 -9 05309E-02
19) 6 4 0 -4 59094E 00 -2 17035E-02 -6 90229E-02 7 72063E-02 -9 06321E-02
20) 6 4 0 -4 66727E 00 -1 96165E-02 -6 31279E-02 7 21464E-02 -8 67119E-02
21) 6 4 0 9 61813E-01 -7 16439E-02 -1 29004E-01 8 99944E-02 -1 16057E-01
22) 6 4 0 -4 41546E 00 8 64030E-01 5 07067E-03 -1 61819E-01 1 16908E-01
23) 6 4 0 -4 50912E 00 -1 05611E-02 -1 83363E-02 1 12846E-02 -2 11925E-02
24) 6 4 0 -4 51124E 00 -9 79073E-03 -2 00226E-02 1 38421E-02 -2 22447E-02
25) 6 4 0 -4 51722E 00 -8 93966E-03 -1 97966E-02 1 36947E-02 -2 18937E-02
26) 6 4 0 -4 52856E 00 -8 10631E-03 -2 02461E-02 1 72982E-02 -2 37717E-02
27) 6 4 0 -4 55204E 00 -7 07087E-03 -1 82874E-02 1 60502E-02 -2 25099E-02
28) 6 4 0 9 88674E-01 -2 13511E-02 -5 38013E-02 4 84879E-02 -5 37432E-02
29) 6 4 0 -5 04821E 00 9 10515E-01 1 14639E-01 -3 51154E-01 2 15552E-01
30) 6 4 0 -4 50207E 00 -3 43650E-03 -6 56931E-03 3 07842E-03 -6 44504E-03
31) 6 4 0 -4 50260E 00 -3 49846E-03 -6 39680E-03 2 97737E-03 -6 42083E-03
32) 6 4 0 -4 50421E 00 -3 38141E-03 -5 53514E-03 1 37477E-03 -5 49528E-03
33) 6 4 0 -4 50724E 00 -3 39597E-03 -4 37231E-03 -5 87997E-04 -4 38643E-03
34) 6 4 0 -4 51366E 00 -2 92654E-03 -6 54856E-03 3 80021E-03 -6 41356E-03
35) 6 4 0 9 97527E-01 -4 79561E-03 -1 34789E-02 1 10582E-02 -1 45328E-02
36) 6 4 0 -5 92579E 00 9 46583E-01 2 80240E-01 -5 10162E-01 2 67284E-01
37) 6 4 0 -4 50110E 00 -2 32612E-03 -5 17328E-03 2 93591E-03 -5 05607E-03
38) 6 4 0 -4 50139E 00 -2 36292E-03 -4 92426E-03 2 69867E-03 -5 00112E-03
39) 6 4 0 -4 50226E 00 -2 44486E-03 -4 27801E-03 1 76970E-03 -4 56799E-03
40) 6 4 0 -4 50402E 00 -2 20475E-03 -4 94241E-03 2 55295E-03 -4 78402E-03
41) 6 4 0 -4 50785E 00 -2 21831E-03 -4 48939E-03 1 91881E-03 -4 38155E-03
42) 6 4 0 9 98677E-01 -2 66467E-03 -6 77741E-03 5 47854E-03 -8 54138E-03
43) 6 4 0 -6 28225E 00 9 85047E-01 8 81497E-02 -1 39739E-01 8 35264E-02
44) 7 5 0 -3 26326E 00 1 36249E-01 -6 08680E 00 1 58157E 01 -2 47246E 01 1 19027E 01

```

A.3.1.2 Geometric Module

Display of input file (Fortran Unit 13).

1)	F			
2)	1.100			
3)		0.E0	-149.5E0	67.78E0
4)	1	9 1982	2210.00	
5)		16.76E0	-149.5E0	67.78E0
6)	100 100			
7)		.0025E0	.0025E0	

Hex display of the binary shadow map (Fortran Unit 11).

[illegible]

3-17

3-18

ASCII display of a portion of the binary pseudo radiance map (Fortran Unit 6). One third of the scene (leftmost portion) is shown. Columns 1-10 are uniformly zero (the field of view extends beyond the edge of the scene) and are not included.

3-19

	11	12	13	14	15	16	17	18	19	20																				
51	0	0000E	00	0	6499E	00	0	6580E	00	0	6624E	00	0	6628E	00	0	6592E	00	0	6590E	00	0	6594E	00	0	6596E	00	0	6453E	00
52	0	0000E	00	0	6553E	00	0	6475E	00	0	6594E	00	0	6619E	00	0	6510E	00	0	6457E	00	0	6456E	00	0	6444E	00	0	6452E	00
53	0	0000E	00	0	6648E	00	0	6607E	00	0	6437E	00	0	6412E	00	0	6574E	00	0	6679E	00	0	6623E	00	0	6448E	00	0	6449E	00
54	0	0000E	00	0	6628E	00	0	6623E	00	0	6610E	00	0	6611E	00	0	6508E	00	0	6457E	00	0	6446E	00	0	6441E	00	0	6443E	00
55	0	0000E	00	0	6626E	00	0	6626E	00	0	6627E	00	0	6628E	00	0	6598E	00	0	6581E	00	0	6583E	00	0	6583E	00	0	6582E	00
56	0	0000E	00	0	6632E	00	0	6626E	00	0	6626E	00	0	6626E	00	0	6626E	00	0	6633E	00	0	6636E	00	0	6637E	00	0	6644E	00
57	0	0000E	00	0	6601E	00	0	6618E	00	0	6627E	00	0	6626E	00	0	6626E	00	0	6629E	00	0	6619E	00	0	6590E	00	0	6620E	00
58	0	0000E	00	0	6510E	00	0	6611E	00	0	6643E	00	0	6641E	00	0	6641E	00	0	6652E	00	0	6606E	00	0	6460E	00	0	6610E	00
59	0	0000E	00	0	6544E	00	0	6457E	00	0	6442E	00	0	6463E	00	0	6443E	00	0	6460E	00	0	6499E	00	0	6593E	00	0	6489E	00
60	0	0000E	00	0	6609E	00	0	6582E	00	0	6563E	00	0	6583E	00	0	6589E	00	0	6510E	00	0	6441E	00	0	6474E	00	0	6451E	00
61	0	0000E	00	0	6620E	00	0	6628E	00	0	6635E	00	0	6636E	00	0	6640E	00	0	6587E	00	0	6528E	00	0	6511E	00	0	6429E	00
62	0	0000E	00	0	6672E	00	0	6662E	00	0	6629E	00	0	6629E	00	0	6624E	00	0	6658E	00	0	6688E	00	0	6677E	00	0	6595E	00
63	0	0000E	00	0	6797E	00	0	6768E	00	0	6657E	00	0	6642E	00	0	6639E	00	0	6727E	00	0	6809E	00	0	6825E	00	0	7003E	00
64	0	0000E	00	0	6581E	00	0	6631E	00	0	6796E	00	0	6814E	00	0	6811E	00	0	6810E	00	0	6811E	00	0	6814E	00	0	6828E	00
65	0	0000E	00	0	6765E	00	0	6774E	00	0	6807E	00	0	6811E	00	0	6814E	00	0	6734E	00	0	6649E	00	0	6634E	00	0	6637E	00
66	0	0000E	00	0	6722E	00	0	6718E	00	0	6703E	00	0	6703E	00	0	6703E	00	0	6703E	00	0	6699E	00	0	6699E	00	0	6686E	00
67	0	0000E	00	0	6609E	00	0	6618E	00	0	6632E	00	0	6635E	00	0	6649E	00	0	6734E	00	0	6816E	00	0	6813E	00	0	6836E	00
68	0	0000E	00	0	6635E	00	0	6663E	00	0	6774E	00	0	6789E	00	0	6800E	00	0	6802E	00	0	6793E	00	0	6809E	00	0	6934E	00
69	0	0000E	00	0	6833E	00	0	6777E	00	0	6610E	00	0	6586E	00	0	6728E	00	0	6808E	00	0	6795E	00	0	6781E	00	0	6774E	00
70	0	0000E	00	0	6705E	00	0	6808E	00	0	6782E	00	0	6777E	00	0	6777E	00	0	6791E	00	0	6820E	00	0	6911E	00	0	6797E	00
71	0	0000E	00	0	6698E	00	0	6671E	00	0	6784E	00	0	6786E	00	0	6792E	00	0	6787E	00	0	6798E	00	0	6880E	00	0	6889E	00
72	0	0000E	00	0	6736E	00	0	6665E	00	0	6786E	00	0	6836E	00	0	6806E	00	0	6819E	00	0	6825E	00	0	6796E	00	0	6914E	00
73	0	0000E	00	0	6791E	00	0	6799E	00	0	6803E	00	0	6918E	00	0	6841E	00	0	6874E	00	0	6936E	00	0	6806E	00	0	6780E	00
74	0	0000E	00	0	6691E	00	0	6818E	00	0	6790E	00	0	6607E	00	0	6725E	00	0	6810E	00	0	6795E	00	0	6799E	00	0	6790E	00
75	0	0000E	00	0	6629E	00	0	6638E	00	0	6653E	00	0	6770E	00	0	6694E	00	0	6623E	00	0	6667E	00	0	6793E	00	0	6810E	00
76	0	0000E	00	0	6621E	00	0	6620E	00	0	6629E	00	0	6661E	00	0	6632E	00	0	6608E	00	0	6661E	00	0	6661E	00	0	6668E	00
77	0	0000E	00	0	6615E	00	0	6622E	00	0	6620E	00	0	6608E	00	0	6631E	00	0	6646E	00	0	6617E	00	0	6607E	00	0	6607E	00
78	0	0000E	00	0	6646E	00	0	6620E	00	0	6618E	00	0	6616E	00	0	6723E	00	0	6704E	00	0	6617E	00	0	6617E	00	0	6605E	00
79	0	0000E	00	0	6736E	00	0	6602E	00	0	6620E	00	0	6631E	00	0	6642E	00	0	6496E	00	0	6634E	00	0	6608E	00	0	6445E	00
80	0	0000E	00	0	6714E	00	0	6765E	00	0	6626E	00	0	6612E	00	0	6725E	00	0	6702E	00	0	6616E	00	0	6621E	00	0	6608E	00
81	0	0000E	00	0	6615E	00	0	6675E	00	0	6744E	00	0	6630E	00	0	6641E	00	0	6644E	00	0	6608E	00	0	6621E	00	0	6613E	00
82	0	0000E	00	0	6711E	00	0	6708E	00	0	6719E	00	0	6724E	00	0	6643E	00	0	6649E	00	0	6705E	00	0	6641E	00	0	6716E	00
83	0	0000E	00	0	6774E	00	0	6741E	00	0	6639E	00	0	6744E	00	0	6673E	00	0	6693E	00	0	6749E	00	0	6645E	00	0	6708E	00
84	0	0000E	00	0	6621E	00	0	6614E	00	0	6621E	00	0	6609E	00	0	6621E	00	0	6620E	00	0	6629E	00	0	6607E	00	0	6431E	00
85	0	0000E	00	0	6741E	00	0	6619E	00	0	6622E	00	0	6622E	00	0	6632E	00	0	6532E	00	0	6481E	00	0	6621E	00	0	6627E	00
86	0	0000E	00	0	6652E	00	0	6625E	00	0	6624E	00	0	6634E	00	0	6643E	00	0	6625E	00	0	6577E	00	0	6502E	00	0	6497E	00
87	0	0000E	00	0	6615E	00	0	6629E	00	0	6617E	00	0	6541E	00	0	6524E	00	0	6546E	00	0	6534E	00	0	6492E	00	0	6442E	00
88	0	0000E	00	0	6651E	00	0	6627E	00	0	6615E	00	0	6503E	00	0	6479E	00	0	6460E	00	0	6440E	00	0	6433E	00	0	6436E	00
89	0	0000E	00	0	6750E	00	0	6619E	00	0	6626E	00	0	6651E	00	0	6663E	00	0	6597E	00	0	6447E	00	0	6434E	00	0	6462E	00
90	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
91	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
92	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
93	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
94	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
95	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
96	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
97	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
98	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
99	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00
100	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00	0	0000E	00

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	21	22	23	24	25	26	27	28	29	30
51	0 6535E 00	0 6599E 00	0 6603E 00	0 6634E 00	0 6565E 00	0 5966E 00	0 5955E 00	0 6224E 00	0 6255E 00	0 6412E 00
52	0 6442E 00	0 6430E 00	0 6483E 00	0 6592E 00	0 6579E 00	0 6632E 00	0 6390E 00	0 6152E 00	0 6300E 00	0 6408E 00
53	0 6449E 00	0 6443E 00	0 6410E 00	0 6403E 00	0 6376E 00	0 6557E 00	0 6623E 00	0 6556E 00	0 6400E 00	0 6423E 00
54	0 6432E 00	0 6518E 00	0 6599E 00	0 6593E 00	0 6564E 00	0 6591E 00	0 6569E 00	0 6629E 00	0 6698E 00	0 6570E 00
55	0 6575E 00	0 6599E 00	0 6558E 00	0 6483E 00	0 6568E 00	0 6591E 00	0 6642E 00	0 6735E 00	0 6766E 00	0 6831E 00
56	0 6636E 00	0 6626E 00	0 6584E 00	0 6534E 00	0 6569E 00	0 6572E 00	0 6670E 00	0 6765E 00	0 6787E 00	0 6938E 00
57	0 6591E 00	0 6591E 00	0 6606E 00	0 6591E 00	0 6625E 00	0 6671E 00	0 6752E 00	0 6792E 00	0 6827E 00	0 6938E 00
58	0 6494E 00	0 6505E 00	0 6545E 00	0 6469E 00	0 6769E 00	0 6952E 00	0 6979E 00	0 7022E 00	0 7160E 00	0 7133E 00
59	0 6553E 00	0 6596E 00	0 6625E 00	0 6563E 00	0 6478E 00	0 6575E 00	0 6734E 00	0 6810E 00	0 6802E 00	0 6821E 00
60	0 6560E 00	0 6617E 00	0 6577E 00	0 6496E 00	0 6560E 00	0 6588E 00	0 6609E 00	0 6664E 00	0 6784E 00	0 6901E 00
61	0 6541E 00	0 6622E 00	0 6599E 00	0 6592E 00	0 6578E 00	0 6675E 00	0 6740E 00	0 6812E 00	0 6890E 00	0 6950E 00
62	0 6585E 00	0 6612E 00	0 6563E 00	0 6476E 00	0 6621E 00	0 6759E 00	0 6881E 00	0 6934E 00	0 6924E 00	0 6944E 00
63	0 6731E 00	0 6586E 00	0 6595E 00	0 6503E 00	0 6753E 00	0 6798E 00	0 6769E 00	0 6742E 00	0 6774E 00	0 6935E 00
64	0 6688E 00	0 6597E 00	0 6543E 00	0 6463E 00	0 6717E 00	0 6883E 00	0 6924E 00	0 6981E 00	0 7066E 00	0 6954E 00
65	0 6604E 00	0 6544E 00	0 6723E 00	0 6965E 00	0 6975E 00	0 7117E 00	0 7119E 00	0 7068E 00	0 7096E 00	0 7060E 00
66	0 6634E 00	0 6754E 00	0 6874E 00	0 7350E 00	0 7577E 00	0 7517E 00	0 7349E 00	0 7250E 00	0 7183E 00	0 7189E 00
67	0 7010E 00	0 6960E 00	0 6928E 00	0 7248E 00	0 7591E 00	0 7702E 00	0 7570E 00	0 7404E 00	0 7321E 00	0 7324E 00
68	0 6828E 00	0 6856E 00	0 6899E 00	0 6692E 00	0 6533E 00	0 7382E 00	0 7602E 00	0 7439E 00	0 7472E 00	0 7459E 00
69	0 6777E 00	0 6767E 00	0 6781E 00	0 6796E 00	0 6805E 00	0 6547E 00	0 7034E 00	0 7734E 00	0 7743E 00	0 7594E 00
70	0 6878E 00	0 6864E 00	0 6786E 00	0 6792E 00	0 6804E 00	0 6652E 00	0 6799E 00	0 7327E 00	0 7723E 00	0 7565E 00
71	0 6883E 00	0 6836E 00	0 6792E 00	0 6772E 00	0 6705E 00	0 6688E 00	0 6933E 00	0 7478E 00	0 7899E 00	0 7711E 00
72	0 6833E 00	0 6776E 00	0 6797E 00	0 6748E 00	0 6664E 00	0 6694E 00	0 7019E 00	0 7355E 00	0 7459E 00	0 7343E 00
73	0 6788E 00	0 6792E 00	0 6791E 00	0 6797E 00	0 6806E 00	0 6686E 00	0 6619E 00	0 6421E 00	0 6101E 00	0 6133E 00
74	0 6801E 00	0 6807E 00	0 6806E 00	0 6805E 00	0 6805E 00	0 6813E 00	0 6788E 00	0 6994E 00	0 7083E 00	0 6288E 00
75	0 6696E 00	0 6631E 00	0 6640E 00	0 6640E 00	0 6640E 00	0 6639E 00	0 6631E 00	0 6676E 00	0 5796E 00	0 6349E 00
76	0 6640E 00	0 6618E 00	0 6621E 00	0 6621E 00	0 6621E 00	0 6636E 00	0 6606E 00	0 4704E 00	0 1500E 00	0 6107E 00
77	0 6621E 00	0 6621E 00	0 6621E 00	0 6622E 00	0 6623E 00	0 6596E 00	0 6580E 00	0 5470E 00	0 3684E 00	0 5962E 00
78	0 6619E 00	0 6625E 00	0 6615E 00	0 6604E 00	0 6608E 00	0 6503E 00	0 6532E 00	0 6611E 00	0 6420E 00	0 6089E 00
79	0 6549E 00	0 6643E 00	0 6557E 00	0 6408E 00	0 6408E 00	0 6576E 00	0 6642E 00	0 6569E 00	0 6378E 00	0 6208E 00
80	0 6614E 00	0 6625E 00	0 6620E 00	0 6605E 00	0 6607E 00	0 6494E 00	0 6525E 00	0 6498E 00	0 6236E 00	0 6340E 00
81	0 6615E 00	0 6621E 00	0 6626E 00	0 6620E 00	0 6618E 00	0 6494E 00	0 6660E 00	0 6504E 00	0 6355E 00	0 6507E 00
82	0 6660E 00	0 6620E 00	0 6633E 00	0 6620E 00	0 6617E 00	0 6694E 00	0 6664E 00	0 6546E 00	0 6468E 00	0 6580E 00
83	0 6664E 00	0 6590E 00	0 6596E 00	0 6624E 00	0 6622E 00	0 6610E 00	0 6593E 00	0 6574E 00	0 6576E 00	0 6602E 00
84	0 6632E 00	0 6532E 00	0 6487E 00	0 6644E 00	0 6640E 00	0 6626E 00	0 6603E 00	0 6565E 00	0 6592E 00	0 6723E 00
85	0 6311E 00	0 6545E 00	0 6578E 00	0 6606E 00	0 6458E 00	0 6574E 00	0 6610E 00	0 6628E 00	0 6733E 00	0 6741E 00
86	0 6471E 00	0 6598E 00	0 6593E 00	0 6451E 00	0 6434E 00	0 6449E 00	0 6524E 00	0 6646E 00	0 6767E 00	0 6876E 00
87	0 6463E 00	0 6535E 00	0 6309E 00	0 6471E 00	0 6533E 00	0 6523E 00	0 6536E 00	0 6648E 00	0 6801E 00	0 7006E 00
88	0 6430E 00	0 6537E 00	0 6318E 00	0 6470E 00	0 6567E 00	0 6619E 00	0 6594E 00	0 6648E 00	0 6830E 00	0 7120E 00
89	0 6320E 00	0 6263E 00	0 6323E 00	0 6443E 00	0 6437E 00	0 6553E 00	0 6595E 00	0 6654E 00	0 6833E 00	0 7153E 00
90	0 0000E 00	0 6216E 00	0 6325E 00	0 6429E 00	0 6359E 00	0 6513E 00	0 6601E 00	0 6657E 00	0 6835E 00	0 7153E 00
91	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
92	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
93	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
94	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
95	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
96	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
97	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
98	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
99	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
100	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00

A.3.1.3. Radiance Module

Display of user specified input file (Fortran Unit 5).

1)	3	9	1 1981 2210.			
2)		10.4	12.5	16.76	-149.5	67.70
3)		0.	-149.5	67.78		
4)	100	100				
5)		286.	280.			
6)		0025	0025			

Display of run time diagnostics and statistics output file (Fortran Unit 6).

ZENITH ANGLE OF SUN (DEGS): 59.4
ZENITH ANGLE OF OBSERVER (DEGS): 0.0

IN-BAND DIFFUSE REFLECTANCES
BAND (MICRONS): 10.4
TO 12.5

MATERIAL	REFLECTANCE
----------	-------------

1	0.01
2	0.08
3	0.03
4	0.03
5	0.09
6	0.03
7	0.03
8	0.05
9	0.03
10	0.14
12	0.10
13	0.07
14	0.02

RESULTS OF CURVE FITS TO
ATMOSPHERIC VALUES VS' ALTITUDE
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 0.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.592E-10
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 1.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.010E-10
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 2.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.692E-10
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 4.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.573E-10
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 7.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.091E-10
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 10.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 1.010E-10

REFLECTED SOLAR
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 2.592E-10

PATH TRANSMISSION
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 3.112E-12

PATH RADIANCE
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 1.032E-09

APPARENT REFLECTED SOLAR (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	2 266E-07	1 921E-07	0 000E-01	4 107E-07

APPARENT REFLECTED SKYSHINE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	1 659E-05	2 183E-06	1 163E-05	1 960E-05

APPARENT THERMAL RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	1 320E-03	6 264E-05	1 234E-03	1 490E-03

APPARENT PATH RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	8 063E-05	1 255E-05	5 364E-05	9 375E-05

SURFACE TEMPERATURE (K)

MATERIAL	MEAN	SDEV	MIN	MAX
8	2 823E 02	3 006E 00	2 779E 02	2 900E 02

APPARENT SCENE RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	1 236E-03	2 130E-04	2 839E-04	1 464E-03

DIFFUSE OR BI-DIRECTIONAL REFLECTANCE

MATERIAL	MEAN	SDEV	MIN	MAX
8	4 707E-02	0 000E-01	4 707E-02	4 707E 02

[illegible]

	11	12	13	14	15	16	17	18	19	20	
51	0	0000E	00	0	1430E-02	0	1431E-02	0	1432E-02	0	1433E-02
52	0	0000E	00	0	1434E-02	0	1435E-02	0	1436E-02	0	1437E-02
53	0	0000E	00	0	1438E-02	0	1439E-02	0	1440E-02	0	1441E-02
54	0	0000E	00	0	1442E-02	0	1443E-02	0	1444E-02	0	1445E-02
55	0	0000E	00	0	1446E-02	0	1447E-02	0	1448E-02	0	1449E-02
56	0	0000E	00	0	1450E-02	0	1451E-02	0	1452E-02	0	1453E-02
57	0	0000E	00	0	1454E-02	0	1455E-02	0	1456E-02	0	1457E-02
58	0	0000E	00	0	1458E-02	0	1459E-02	0	1460E-02	0	1461E-02
59	0	0000E	00	0	1462E-02	0	1463E-02	0	1464E-02	0	1465E-02
60	0	0000E	00	0	1466E-02	0	1467E-02	0	1468E-02	0	1469E-02
61	0	0000E	00	0	1470E-02	0	1471E-02	0	1472E-02	0	1473E-02
62	0	0000E	00	0	1474E-02	0	1475E-02	0	1476E-02	0	1477E-02
63	0	0000E	00	0	1478E-02	0	1479E-02	0	1480E-02	0	1481E-02
64	0	0000E	00	0	1482E-02	0	1483E-02	0	1484E-02	0	1485E-02
65	0	0000E	00	0	1486E-02	0	1487E-02	0	1488E-02	0	1489E-02
66	0	0000E	00	0	1490E-02	0	1491E-02	0	1492E-02	0	1493E-02
67	0	0000E	00	0	1494E-02	0	1495E-02	0	1496E-02	0	1497E-02
68	0	0000E	00	0	1498E-02	0	1499E-02	0	1500E-02	0	1501E-02
69	0	0000E	00	0	1502E-02	0	1503E-02	0	1504E-02	0	1505E-02
70	0	0000E	00	0	1506E-02	0	1507E-02	0	1508E-02	0	1509E-02
71	0	0000E	00	0	1510E-02	0	1511E-02	0	1512E-02	0	1513E-02
72	0	0000E	00	0	1514E-02	0	1515E-02	0	1516E-02	0	1517E-02
73	0	0000E	00	0	1518E-02	0	1519E-02	0	1520E-02	0	1521E-02
74	0	0000E	00	0	1522E-02	0	1523E-02	0	1524E-02	0	1525E-02
75	0	0000E	00	0	1526E-02	0	1527E-02	0	1528E-02	0	1529E-02
76	0	0000E	00	0	1530E-02	0	1531E-02	0	1532E-02	0	1533E-02
77	0	0000E	00	0	1534E-02	0	1535E-02	0	1536E-02	0	1537E-02
78	0	0000E	00	0	1538E-02	0	1539E-02	0	1540E-02	0	1541E-02
79	0	0000E	00	0	1542E-02	0	1543E-02	0	1544E-02	0	1545E-02
80	0	0000E	00	0	1546E-02	0	1547E-02	0	1548E-02	0	1549E-02
81	0	0000E	00	0	1550E-02	0	1551E-02	0	1552E-02	0	1553E-02
82	0	0000E	00	0	1554E-02	0	1555E-02	0	1556E-02	0	1557E-02
83	0	0000E	00	0	1558E-02	0	1559E-02	0	1560E-02	0	1561E-02
84	0	0000E	00	0	1562E-02	0	1563E-02	0	1564E-02	0	1565E-02
85	0	0000E	00	0	1566E-02	0	1567E-02	0	1568E-02	0	1569E-02
86	0	0000E	00	0	1570E-02	0	1571E-02	0	1572E-02	0	1573E-02
87	0	0000E	00	0	1574E-02	0	1575E-02	0	1576E-02	0	1577E-02
88	0	0000E	00	0	1578E-02	0	1579E-02	0	1580E-02	0	1581E-02
89	0	0000E	00	0	1582E-02	0	1583E-02	0	1584E-02	0	1585E-02
90	0	0000E	00	0	1586E-02	0	1587E-02	0	1588E-02	0	1589E-02
91	0	0000E	00	0	1590E-02	0	1591E-02	0	1592E-02	0	1593E-02
92	0	0000E	00	0	1594E-02	0	1595E-02	0	1596E-02	0	1597E-02
93	0	0000E	00	0	1598E-02	0	1599E-02	0	1600E-02	0	1601E-02
94	0	0000E	00	0	1602E-02	0	1603E-02	0	1604E-02	0	1605E-02
95	0	0000E	00	0	1606E-02	0	1607E-02	0	1608E-02	0	1609E-02
96	0	0000E	00	0	1610E-02	0	1611E-02	0	1612E-02	0	1613E-02
97	0	0000E	00	0	1614E-02	0	1615E-02	0	1616E-02	0	1617E-02
98	0	0000E	00	0	1618E-02	0	1619E-02	0	1620E-02	0	1621E-02
99	0	0000E	00	0	1622E-02	0	1623E-02	0	1624E-02	0	1625E-02
100	0	0000E	00	0	1626E-02	0	1627E-02	0	1628E-02	0	1629E-02

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A.3.2 Test Case II - Brooks Range (Solar Band)

A.3.2.1 Atmospheric Module

Display of input file (Fortran Unit 7) for Brooks Range solar reflective band.

```
1) 3      16.76      3.6      4.0
2) 1 1 1 1 0 0 0      23.0
```

Display of the atmospheric diagnostic output file (Fortran Unit 6). Selected standard atmosphere is represented parametrically for 5 zenith angles and 6 altitudes. Air masses computed using the Chapman function.

RESULTS FOR BACKGROUND ALTITUDE = 0 KM

APPARENT REFLECTED SOLAR

OBSERVER

```
ZA  AM  PATH RADIANCE  PATH TRANSMISSION
0 0  1 0 4 370E-07 8 695E-01
```

SOLAR

```
ZA  AM  REFLECTED SOLAR
0 0  1 0 3 445E-04
48 2  1 5 3 239E-04
70 8  3 0 2 718E-04
80 8  6 0 1 969E-04
86 0 12 0 1 026E-04
```

REFLECTED SOLAR

```
OBSERVER ZENITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 3 138E-11
```

OBSERVER

```
ZA  AM  PATH RADIANCE  PATH TRANSMISSION
48 2  1 5 6 145E-07 8 150E-01
```

SOLAR

```
ZA  AM  REFLECTED SOLAR
0 0  1 0 3 245E-04
48 2  1 5 3 059E-04
70 8  3 0 2 579E-04
80 8  6 0 1 877E-04
86 0 12 0 9 850E-05
```

REFLECTED SOLAR

```
OBSERVER ZENITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5 070E-11
```

OBSERVER

```
ZA  AM  PATH RADIANCE  PATH TRANSMISSION
70 8  3 0 1 040E-06 6 783E-01
```

SOLAR

```
ZA  AM  REFLECTED SOLAR
0 0  1 0 2 733E-04
48 2  1 5 2 590E-04
70 8  3 0 2 206E-04
80 8  6 0 1 630E-04
86 0 12 0 8 711E-05
```

REFLECTED SOLAR

```
OBSERVER ZENITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 6 298E-11
```

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 80 8 5 0 1 110E-08 9 475E-01

SOLAR

ZA AM REFLECTED SOLAR
 0 0 1 0 4 236E-04
 48 2 1 5 4 214E-04
 70 8 3 0 4 153E-04
 80 8 6 0 4 042E-04
 86 0 12 0 3 842E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 80 8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 7 071E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 86 0 12 0 2 058E-08 9 019E-01

SOLAR

ZA AM REFLECTED SOLAR
 0 0 1 0 4 042E-04
 48 2 1 5 4 025E-04
 70 8 3 0 3 975E-04
 80 8 6 0 3 882E-04
 86 0 12 0 3 707E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 86 0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 3 683E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15 3 189E-09
 45 4 286E-09
 75 1 005E-08

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 4 832E-13

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 5 684E-10
 FIT OF SKYSHINE TO ALTITUDE
 DEGREE OF BEST FIT POLYNOMIAL 5
 SUM SQUARE ERROR 5 758E-10

OBSERVER
 ZA AM PATH RADIANCE PATH TRANSMISSION 80.8 6.0 1.000E-06 4.867E-01

SOLAR
 ZA AM REFLECTED SOLAR
 0.0 1.0 1.991E-04
 48.2 1.5 1.896E-04
 70.8 3.0 1.640E-04
 80.8 6.0 1.239E-04
 86.0 12.0 6.831E-05

REFLECTED SOLAR
 OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 5.411E-11

OBSERVER
 ZA AM PATH RADIANCE PATH TRANSMISSION
 86.0 12.0 2.137E-06 2.503E-01

SOLAR
 ZA AM REFLECTED SOLAR
 0.0 1.0 1.043E-04
 48.2 1.5 1.000E-04
 70.8 3.0 8.814E-05
 80.8 6.0 6.871E-05
 86.0 12.0 3.980E-05

REFLECTED SOLAR
 OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 8.026E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	3.894E-07
45	5.187E-07
75	1.228E-06

PATH TRANSMISSION
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 7.709E-13

PATH RADIANCE
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2.810E-10

RESULTS FOR BACKGROUND ALTITUDE = 1 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
0 0 1 0 2 427E-07 9 074E-01

SOLAR

ZA AM REFLECTED SOLAR
0 0 1 0 3 738E-04
48 2 1 5 3 579E-04
70 8 3 0 3 166E-04
80 8 6 0 2 534E-04
86 0 12 0 1 639E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5 025E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
48 2 1 5 3 437E-07 8 677E-01

SOLAR

ZA AM REFLECTED SOLAR
0 0 1 0 3 586E-04
48 2 1 5 3 440E-04
70 8 3 0 3 053E-04
80 8 6 0 2 453E-04
86 0 12 0 1 595E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5 957E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
70 8 3 0 5 999E-07 7 635E-01

SOLAR

ZA AM REFLECTED SOLAR
0 0 1 0 3 184E-04
48 2 1 5 3 065E-04
70 8 3 0 2 744E-04
80 8 6 0 2 229E-04
86 0 12 0 1 470E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 4 729E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 80.8 6 0 9 612E-07 6 075E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	2.564E-04
48 2	1 5	2.480E-04
70.8	3 0	2.243E-04
80.8	6 0	1.855E-04
86 0	12 0	1.254E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80.8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 5.957E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 86 0 12 0 1.416E-06 3.891E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	1.665E-04
48 2	1 5	1.619E-04
70 8	3 0	1.488E-04
80.8	6.0	1.262E-04
86 0	12.0	8.868E-05

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86.0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 5.707E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	2.234E-07
45	2.994E-07
75	7.330E-07

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 1.013E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2.146E-10

RESULTS FOR BACKGROUND ALTITUDE = 2 KM
APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0 0	1 0	1 323E-07	9 330E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 943E-04
48 2	1 5	3 819E-04
70 8	3 0	3 493E-04
80 8	6 0	2 976E-04
86 0	12 0	2 189E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 3 638E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48 2	1 5	1 885E-07	9 036E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 827E-04
48 2	1 5	3 712E-04
70 8	3 0	3 403E-04
80 8	6 0	2 908E-04
86 0	12 0	2 147E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 7 026E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70 8	3 0	3 360E-07	8 242E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 514E-04
48 2	1 5	3 418E-04
70 8	3 0	3 155E-04
80 8	6 0	2 718E-04
86 0	12 0	2 029E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5 957E-11

OBSERVER
 ZA AM PATH RADIANCE PATH TRANSMISSION
 80 8 6 0 5 558E-07 6 999E-01

SOLAR
 ZA AM REFLECTED SOLAR
 0 0 1.0 3 011E-04
 48 2 1 5 2 939E-04
 70 8 3 0 2 735E-04
 80 8 6 0 2 387E-04
 86 0 12.0 1 817E-04

REFLECTED SOLAR
 OBSERVER ZENNITH ANGLE = 80 8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 7 026E-11

OBSERVER
 ZA AM PATH RADIANCE PATH TRANSMISSION
 86 0 12.0 6 696E-07 5 118E-01

SOLAR
 ZA AM REFLECTED SOLAR
 0 0 1.0 2 226E-04
 48 2 1 5 2 181E-04
 70 8 3 0 2 055E-04
 80 8 6 0 1 829E-04
 86 0 12 0 1 436E-04

REFLECTED SOLAR
 OBSERVER ZENNITH ANGLE = 86 0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 6 639E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	1 248E-07
45	1 677E-07
75	4 202E-07

PATH TRANSMISSION
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 9 237E-13

PATH RADIANCE
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2 519E-10

RESULTS FOR BACKGROUND ALTITUDE = 4 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
0 0 1 0 3 888E-08 9 616E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4.173E-04
48 2	1 5	4.094E-04
70 8	3 0	3.883E-04
80 8	6 0	3.530E-04
86 0	12 0	2.946E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5.707E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
48 2 1 5 5 649E-08 9 441E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4.102E-04
48 2	1 5	4.028E-04
70 8	3 0	3.825E-04
80 8	6 0	3.483E-04
86 0	12 0	2.914E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5.366E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
70 8 3 0 1 040E-07 8 951E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3.908E-04
48 2	1 5	3.844E-04
70 8	3 0	3.662E-04
80 8	6 0	3.350E-04
86 0	12 0	2.820E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5.670E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
80 8	5 0	1 803E-07	8 145E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 574E-04
48 2	1 5	3 522E-04
70 8	3 0	3 371E-04
80 8	6 0	3 107E-04
86 0	12 0	2 643E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 80 8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 3 388E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
86 0	12 0	3 085E-07	6 788E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 000E-04
48 2	1 5	2 963E-04
70 8	3 0	2 857E-04
80 8	6 0	2 663E-04
86 0	12 0	2 305E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 86 0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 8 527E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SP)

15	3 917E-08
45	5 265E-08
75	1 339E-07

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 1 222E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2 028E-10

RESULTS FOR BACKGROUND ALTITUDE = 7 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0 0	1 0	7 104E-09	9 808E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 335E-04
48 2	1 5	4 291E-04
70 8	3 0	4 171E-04
80 8	6 0	3 966E-04
86 0	12 0	3 617E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 6 639E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48 2	1 5	1 037E-08	9 721E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 299E-04
48 2	1 5	4 257E-04
70 8	3 0	4 140E-04
80 8	6 0	3 941E-04
86 0	12 0	3 599E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 8 481E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70 8	3 0	1 938E-08	9 470E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 199E-04
48 2	1 5	4 160E-04
70 8	3 0	4 054E-04
80 8	6 0	3 868E-04
86 0	12 0	3 543E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 7 799E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 80 8 6 0 3 465E-08 9 037E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 020E-04
48 2	1 5	3 988E-04
70 8	3 0	3 896E-04
80 8	6 0	3 731E-04
86 0	12 0	3 434E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 80 8
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 7 412E-11

OBSERVER

ZA AM PATH RADIANCE PATH TRANSMISSION
 86 0 12 0 6 209E-08 8 266E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	3 692E-04
48 2	1 5	3 667E-04
70 8	3 0	3 595E-04
80 8	6 0	3 464E-04
86 0	12 0	3 216E-04

REFLECTED SOLAR

OBSERVER ZENITH ANGLE = 86 0
 DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2 478E-11

ZENITH ANGLE SKYSHINE (W/CM**2/SR)

15	7 880E-09
45	1 059E-08
75	2 626E-08

PATH TRANSMISSION

DEGREE OF BEST FIT POLYNOMIAL 4 SUM SQUARE ERROR 1 350E-12

PATH RADIANCE

DEGREE OF BEST FIT POLYNOMIAL 4
 SUM SQUARE ERROR 2 674E-10

RESULTS FOR BACKGROUND ALTITUDE = 10 KM

APPARENT REFLECTED SOLAR

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
0 0	1 0 2	162E-09	9 900E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 411E-04
48 2	1 5	4 383E-04
70 8	3 0	4 306E-04
80 8	6 0	4 175E-04
86 0	12 0	3 948E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 0 0
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 6 298E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
48 2	1 5 3	147E-09	9 854E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 392E-04
48 2	1 5	4 364E-04
70 8	3 0	4 290E-04
80 8	6 0	4 161E-04
86 0	12 0	3 937E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 48 2
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 5 025E-11

OBSERVER

ZA	AM	PATH RADIANCE	PATH TRANSMISSION
70 8	3 0 5	995E-09	9 719E-01

SOLAR

ZA	AM	REFLECTED SOLAR
0 0	1 0	4 337E-04
48 2	1 5	4 312E-04
70 8	3 0	4 242E-04
80 8	6 0	4 120E-04
86 0	12 0	3 905E-04

REFLECTED SOLAR

OBSERVER ZENNITH ANGLE = 70 8
DEGREE OF BEST FIT POLYNOMIAL 4
SUM SQUARE ERROR 4 729E-11

Display of the atmospheric module output data base (Fortran Unit 5).
Header (Line 1) contains parameters used to generate the database. Lines
2-44 contain the coefficients of the polynomial curve fits to the computed
atmospheric values.

PRSCRAP:DRAPER:AMK ATMSPH CUT2

MON DEC 20 1967 21 04 48 PAGE 1

```

1) 3 60 4 00 2 2 1 1 1 1 3 3 3 23 00
2) 6 4 0 -3 46284E 00 -1 11549E-01 -2 61007E-01 2 74806E-01 -2 83901E-01
3) 6 4 0 -3 48878E 00 -1 05400E-01 -2 58260E-01 2 19009E-01 -2 79991E-01
4) 6 4 0 -3 56340E 00 -9 03640E-02 -2 71626E-01 2 51000E-01 -2 94428E-01
5) 6 4 0 -3 70089E 00 -8 39613E-02 -2 37777E-01 2 25825E-01 -2 81483E-01
6) 6 4 0 -3 98170E 00 -7 10444E-02 -2 19036E-01 2 10007E-01 -2 77924E-01
7) 6 4 0 8 69542E-01 -2 60930E-01 -2 65659E-01 -8 53581E-02 5 77305E-02
8) 6 4 0 -6 35956E 00 8 61341E-01 -9 08967E-02 -1 43000E-01 3 44700E-02
9) 6 4 0 -3 42735E 00 -8 64749E-02 -1 69492E-01 1 26608E-01 -1 72303E-01
10) 6 4 0 -3 44540E 00 -7 53176E-02 -1 72287E-01 1 30824E-01 -1 73307E-01
11) 6 4 0 -3 49697E 00 -6 85144E-02 -1 60587E-01 1 22007E-01 -1 68979E-01
12) 6 4 0 -3 59112E 00 -5 73153E-02 -1 61956E-01 1 40772E-01 -1 75301E-01
13) 6 4 0 -3 77850E 00 -4 63821E-02 -1 48690E-01 1 47804E-01 -1 74559E-01
14) 6 4 0 9 07389E-01 -1 82809E-01 -2 39290E-01 -8 70806E-03 -2 34240E-02
15) 6 4 0 -6 61501E 00 8 62224E-01 2 60056E-02 -2 76614E-01 1 13052E-01
16) 6 4 0 -3 40422E 00 -5 92082E-02 -1 19595E-01 8 06076E-02 -1 13653E-01
17) 6 4 0 -3 41717E 00 -5 64910E-02 -1 16914E-01 7 71077E-02 -1 11416E-01
18) 6 4 0 -3 45422E 00 -5 03290E-02 -1 10285E-01 7 79641E-02 -1 09028E-01
19) 6 4 0 -3 52126E 00 -4 34176E-02 -1 03583E-01 7 46391E-02 -1 07711E-01
20) 6 4 0 -3 65249E 00 -3 67537E-02 -8 60774E-02 7 05191E-02 -1 02794E-01
21) 6 4 0 9 32966E-01 -1 32491E-01 -1 98621E-01 2 39440E-02 -5 71700E-02
22) 6 4 0 -6 87859E 00 8 68891E-01 8 78490E-02 -3 49367E-01 1 60348E-01
23) 6 4 0 -3 37959E 00 -3 63487E-02 -6 37638E-02 3 43437E-02 -5 98221E-02
24) 6 4 0 -3 38702E 00 -3 39836E-02 -6 58790E-02 3 68729E-02 -6 02250E-02
25) 6 4 0 -3 40807E 00 -3 05594E-02 -6 32523E-02 3 57915E-02 -5 92027E-02
26) 6 4 0 -3 44682E 00 -2 61577E-02 -6 40165E-02 4 53933E-02 -6 30544E-02
27) 6 4 0 -3 52294E 00 -2 15654E-02 -5 45116E-02 4 28898E-02 -6 02340E-02
28) 6 4 0 9 61633E-01 -7 54867E-02 -1 45628E-01 6 43540E-02 -8 33460E-02
29) 6 4 0 -7 41026E 00 9 16719E-01 8 13844E-02 -3 54054E-01 1 92884E-01
30) 6 4 0 -3 36300E 00 -2 01413E-02 -3 14818E-02 1 72578E-02 -2 63735E-02
31) 6 4 0 -3 36662E 00 -1 85577E-02 -3 48747E-02 1 75168E-02 -2 85512E-02
32) 6 4 0 -3 37687E 00 -1 88745E-02 -2 34980E-02 2 51976E-03 -2 16529E-02
33) 6 4 0 -3 39579E 00 -1 46855E-02 -3 12327E-02 1 80983E-02 -2 87780E-02
34) 6 4 0 -3 43279E 00 -1 11985E-02 -3 24670E-02 2 45747E-02 -3 20424E-02
35) 6 4 0 9 80845E-01 -3 73178E-02 -7 66054E-02 3 05650E-02 -5 41863E-02
36) 6 4 0 -8 14853E 00 9 27078E-01 7 88673E-02 -3 07176E-01 1 73919E-01
37) 6 4 0 -3 35543E 00 -1 24087E-02 -2 09358E-02 9 43774E-03 -1 64875E-02
38) 6 4 0 -3 35734E 00 -1 24081E-02 -1 83024E-02 5 68330E-03 -1 47448E-02
39) 6 4 0 -3 36282E 00 -1 03876E-02 -2 29223E-02 1 34728E-02 -1 81711E-02
40) 6 4 0 -3 37303E 00 -1 05441E-02 -1 31133E-02 7 46150E-04 -1 23970E-02
41) 6 4 0 -3 39343E 00 -7 94391E-03 -1 57100E-02 8 10746E-03 -1 54522E-02
42) 6 4 0 9 90024E-01 -1 96063E-02 -4 02397E-02 1 96981E-02 -3 31941E-02
43) 6 4 0 -8 66506E 00 9 04792E-01 1 72356E-01 -3 38503E-01 1 67636E-01
44) 7 5 0 -5 68091E 00 4 54502E-01 -8 34379E 00 2 11032E 01 -2 63076E 01 1 11020E 01

```

A.3.2.2 Geometric Module

Case II is also a nadir view and a new geometric run is not required.

A.3.2.3 Radiance Module

Display of user specified input file (Fortran Unit 5).

1)	3	9	1 1981 2210.			
2)		3.6	4.0	16.76	-149.5	67.78
3)		0.	-149.5	67.78		
4)	100	100				
5)		286.	280.			
6)		.0025	.0025			

Display of run time diagnostics and statistics output file (Fortran Unit 6).

ZENITH ANGLE OF SUN (DEGS): 59.4
ZENITH ANGLE OF OBSERVER (DEGS): 0.0

IN-BAND DIFFUSE REFLECTANCES
BAND (MICRONS): 3.6
TO 4.0

MATERIAL	REFLECTANCE
----------	-------------

1	0.02
2	0.10
3	0.03
4	0.12
5	0.14
6	0.43
7	0.02
8	0.15
9	0.12
10	0.16
12	0.18
13	0.09
14	0.04

RESULTS OF CURVE FITS TO
ATMOSPHERIC VALUES VS' ALTITUDE
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 0.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 7.458E-11
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 1.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 5.707E-11
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 2.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 6.639E-11
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 4.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 4.729E-11
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 7.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 3.683E-11
REFLECTED SOLAR VS OBSERVER POSITION
ALTITUDE = 10.0 KM
DEGREE OF BEST FIT POLYNOMIAL: 4
SUM SQUARE ERROR: 4.729E-11

REFLECTED SOLAR
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 1.050E-10

PATH TRANSMISSION
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 2.544E-12

PATH RADIANCE
DEGREE OF BEST FIT POLYNOMIAL: 5
SUM SQUARE ERROR: 1.074E-09

APPARENT REFLECTED SOLAR (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	9.512E-06	8.062E-06	0.000E-01	1.710E-05

APPARENT REFLECTED SKYSHINE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	2.037E-07	2.911E-08	1.405E-07	2.457E-07

APPARENT THERMAL RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	6.989E-06	1.003E-06	5.628E-06	9.805E-06

APPARENT PATH RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	2.658E-07	3.811E-08	1.812E-07	3.202E-07

SURFACE TEMPERATURE (K)

MATERIAL	MEAN	SDEV	MIN	MAX
8	2.823E 02	3.006E 00	2.779E 02	2.900E 02

APPARENT SCENE RADIANCE (W/CM**2/SR)

MATERIAL	MEAN	SDEV	MIN	MAX
8	1.515E-05	8.637E-06	1.354E-06	2.501E-05

DIFFUSE OR BI-DIRECTIONAL REFLECTANCE

MATERIAL	MEAN	SDEV	MIN	MAX
8	1.520E-01	0.000E-01	1.520E-01	1.520E-01

ASCII display of a portion of the binary radiance map output file (Fortran Unit 17). One third of the scene (leftmost portion) is shown. Columns 1-10 are uniformly zero (the field of view extends beyond the edge of the scene) and are not included.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	C	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
2	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
3	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
6	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
7	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
8	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
9	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
10	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
11	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
12	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
13	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
14	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
15	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
16	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
17	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
18	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
19	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
20	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
21	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
22	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
23	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
24	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
25	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
26	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
27	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
28	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
29	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
30	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
31	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
32	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
33	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
34	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
35	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
36	O	O	O	O																

	11	12	13	14	15	16	17	18	19	20	
51	0	0000E	00	0	2380E-04	0	2383E-04	0	2384E-04	0	2381E-04
52	0	0000E	00	0	2385E-04	0	2379E-04	0	2382E-04	0	2381E-04
53	0	0000E	00	0	2385E-04	0	2383E-04	0	2379E-04	0	2381E-04
54	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
55	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
56	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
57	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
58	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
59	0	0000E	00	0	2381E-04	0	2379E-04	0	2380E-04	0	2381E-04
60	0	0000E	00	0	2381E-04	0	2381E-04	0	2381E-04	0	2381E-04
61	0	0000E	00	0	2384E-04	0	2384E-04	0	2385E-04	0	2381E-04
62	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
63	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
64	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
65	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
66	0	0000E	00	0	2387E-04	0	2387E-04	0	2387E-04	0	2381E-04
67	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
68	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
69	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
70	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
71	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
72	0	0000E	00	0	2387E-04	0	2387E-04	0	2387E-04	0	2381E-04
73	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
74	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
75	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
76	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
77	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
78	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
79	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
80	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
81	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
82	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
83	0	0000E	00	0	2387E-04	0	2387E-04	0	2387E-04	0	2381E-04
84	0	0000E	00	0	2381E-04	0	2381E-04	0	2381E-04	0	2381E-04
85	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
86	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
87	0	0000E	00	0	2385E-04	0	2385E-04	0	2385E-04	0	2381E-04
88	0	0000E	00	0	2384E-04	0	2384E-04	0	2384E-04	0	2381E-04
89	0	0000E	00	0	2387E-04	0	2387E-04	0	2387E-04	0	2381E-04
90	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
91	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
92	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
93	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
94	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
95	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
96	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
97	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
98	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
99	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E
100	0	0000E	00	0	0000E	00	0000E	00	0000E	00	0000E

	21	22	23	24	25	26	27	28	29	30
1	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
2	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
3	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
4	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
5	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
6	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
7	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
8	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
9	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
10	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
11	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00	0 0000E 00
12	0 2421E-04	0 2422E-04	0 2401E-04	0 2423E-04	0 2423E-04	0 2424E-04	0 2425E-04	0 2419E-04	0 2424E-04	0 2428E-04
13	0 2424E-04	0 2427E-04	0 2409E-04	0 2429E-04	0 2432E-04	0 2432E-04	0 2433E-04	0 2431E-04	0 2430E-04	0 2427E-04
14	0 2424E-04	0 2428E-04	0 2412E-04	0 2433E-04	0 2435E-04	0 2434E-04	0 2433E-04	0 2431E-04	0 2430E-04	0 2427E-04
15	0 2414E-04	0 2420E-04	0 2401E-04	0 2426E-04	0 2434E-04	0 2433E-04	0 2431E-04	0 2429E-04	0 2429E-04	0 2425E-04
16	0 2394E-04	0 2429E-04	0 2400E-04	0 2406E-04	0 2434E-04	0 2435E-04	0 2434E-04	0 2430E-04	0 2424E-04	0 2223E-04
17	0 2389E-04	0 2399E-04	0 2407E-04	0 2407E-04	0 2433E-04	0 2432E-04	0 2429E-04	0 2427E-04	0 2424E-04	0 2418E-04
18	0 2394E-04	0 2399E-04	0 2401E-04	0 2407E-04	0 2431E-04	0 2432E-04	0 2429E-04	0 2427E-04	0 2424E-04	0 2424E-04
19	0 2392E-04	0 2399E-04	0 2402E-04	0 2409E-04	0 2432E-04	0 2432E-04	0 2429E-04	0 2427E-04	0 2424E-04	0 2424E-04
20	0 2388E-04	0 2393E-04	0 2402E-04	0 2404E-04	0 2432E-04	0 2432E-04	0 2429E-04	0 2427E-04	0 2424E-04	0 2424E-04
21	0 2387E-04	0 2383E-04	0 2393E-04	0 2403E-04	0 2432E-04	0 2432E-04	0 2429E-04	0 2427E-04	0 2424E-04	0 2424E-04
22	0 2386E-04	0 2387E-04	0 2383E-04	0 2389E-04	0 2415E-04	0 2430E-04	0 2427E-04	0 2427E-04	0 2427E-04	0 2425E-04
23	0 2390E-04	0 2390E-04	0 2389E-04	0 2387E-04	0 2408E-04	0 2424E-04	0 2430E-04	0 2430E-04	0 2428E-04	0 2425E-04
24	0 2387E-04	0 2387E-04	0 2389E-04	0 2386E-04	0 2399E-04	0 2422E-04	0 2424E-04	0 2421E-04	0 2415E-04	0 2410E-04
25	0 2384E-04	0 2384E-04	0 2384E-04	0 2384E-04	0 2403E-04	0 2429E-04	0 2425E-04	0 2417E-04	0 2416E-04	0 2414E-04
26	0 2387E-04	0 2389E-04	0 2389E-04	0 2384E-04	0 2397E-04	0 2434E-04	0 2433E-04	0 2422E-04	0 2419E-04	0 2419E-04
27	0 2389E-04	0 2388E-04	0 2384E-04	0 2384E-04	0 2383E-04	0 1958E-04	0 2002E-04	0 2417E-04	0 2410E-04	0 2405E-04
28	0 2384E-04	0 2388E-04	0 2384E-04	0 2384E-04	0 2384E-04	0 1958E-04	0 2002E-04	0 2214E-04	0 2402E-04	0 2204E-04
29	0 2384E-04	0 2385E-04	0 2384E-04	0 2384E-04	0 2403E-04	0 2390E-04	0 1981E-04	0 2194E-04	0 2402E-04	0 2402E-04
30	0 2387E-04	0 2384E-04	0 2389E-04	0 2384E-04	0 2402E-04	0 2418E-04	0 2401E-04	0 2401E-04	0 2401E-04	0 2401E-04
31	0 2385E-04	0 2384E-04	0 2389E-04	0 2384E-04	0 2402E-04	0 2418E-04	0 2401E-04	0 2401E-04	0 2401E-04	0 2401E-04
32	0 2385E-04	0 2384E-04	0 2389E-04	0 2384E-04	0 2402E-04	0 2418E-04	0 2401E-04	0 2401E-04	0 2401E-04	0 2401E-04
33	0 2385E-04	0 2384E-04	0 2389E-04	0 2384E-04	0 2402E-04	0 2418E-04	0 2401E-04	0 2401E-04	0 2401E-04	0 2401E-04
34	0 2385E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
35	0 2385E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
36	0 2385E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
37	0 2385E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
38	0 2387E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
39	0 2387E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
40	0 2387E-04	0 2385E-04	0 2389E-04	0 2385E-04	0 2403E-04	0 2403E-04	0 2421E-04	0 2425E-04	0 2428E-04	0 2433E-04
41	0 2386E-04	0 2386E-04	0 2387E-04	0 2387E-04	0 2400E-04	0 2427E-04	0 2435E-04	0 2434E-04	0 2434E-04	0 2432E-04
42	0 2381E-04	0 2390E-04	0 2389E-04	0 2384E-04	0 2407E-04	0 2421E-04	0 2428E-04	0 2433E-04	0 2433E-04	0 2437E-04
43	0 2389E-04	0 2389E-04	0 2389E-04	0 2389E-04	0 2400E-04	0 2419E-04	0 2418E-04	0 2424E-04	0 2433E-04	0 2434E-04
44	0 2385E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2403E-04	0 2414E-04	0 2414E-04	0 2424E-04	0 2433E-04	0 2434E-04
45	0 2384E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2403E-04	0 2414E-04	0 2414E-04	0 2424E-04	0 2433E-04	0 2434E-04
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47	0 2384E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2403E-04	0 2414E-04	0 2414E-04	0 2424E-04	0 2433E-04	0 2434E-04
48	0 2384E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2403E-04	0 2414E-04	0 2414E-04	0 2424E-04	0 2433E-04	0 2434E-04
49	0 2383E-04	0 2381E-04	0 2382E-04	0 2382E-04	0 2403E-04	0 2414E-04	0 2414E-04	0 2424E-04	0 2433E-04	0 2434E-04
50	0 2383E-04	0 2380E-04	0 2384E-04	0 2404E-04	0 1818E-04	0 1799E-04	0 2107E-04	0 2408E-04	0 2412E-04	0 2416E-04
51	0 2383E-04	0 2385E-04	0 2389E-04	0 2422E-04	0 2421E-04	0 2395E-04	0 2392E-04	0 2406E-04	0 2408E-04	0 2417E-04
52	0 2380E-04	0 2380E-04	0 2381E-04	0 2420E-04	0 2419E-04	0 2423E-04	0 2413E-04	0 2210E-04	0 2411E-04	0 2417E-04
53	0 2381E-04	0 2381E-04	0 2379E-04	0 2411E-04	0 2411E-04	0 2419E-04	0 2424E-04	0 2422E-04	0 2416E-04	0 2418E-04
54	0 2380E-04	0 2385E-04	0 2384E-04	0 2420E-04	0 2420E-04	0 2422E-04	0 2422E-04	0 2425E-04	0 2428E-04	0 2425E-04
55	0 2384E-04	0 2384E-04	0 2382E-04	0 2414E-04	0 2420E-04	0 2422E-04	0 2425E-04	0 2428E-04	0 2430E-04	0 2423E-04
56	0 2386E-04	0 2385E-04	0 2384E-04	0 2415E-04	0 2420E-04	0 2422E-04	0 2424E-04	0 2429E-04	0 2430E-04	0 2423E-04
57	0 2385E-04	0 2385E-04	0 2389E-04	0 2421E-04	0 2421E-04	0 2423E-04	0 2427E-04	0 2429E-04	0 2431E-04	0 2433E-04
58	0 2382E-04	0 2382E-04	0 2384E-04	0 2414E-04	0 2414E-04	0 2431E-04	0 2432E-04	0 2434E-04	0 2439E-04	0 2439E-04
59	0 2384E-04	0 2384E-04	0 2385E-04	0 2420E-04	0 2415E-04	0 2421E-04	0 2427E-04	0 2429E-04	0 2430E-04	0 2432E-04
60	0 2384E-04	0 2384E-04	0 2385E-04	0 2414E-04	0 2419E-04	0 2422E-04	0 2423E-04	0 2426E-04	0 2430E-04	0 2433E-04
61	0 2383E-04	0 2384E-04	0 2382E-04	0 2414E-04	0 2421E-04	0 2425E-04	0 2426E-04	0 2428E-04	0 2431E-04	0 2434E-04
62	0 2384E-04	0 2384E-04	0 2384E-04	0 2415E-04	0 2422E-04	0 2426E-04	0 2430E-04	0 2432E-04	0 2433E-04	0 2434E-04
63	0 2389E-04	0 2385E-04	0 2401E-04	0 2416E-04	0 2426E-04	0 2427E-04	0 2427E-04	0 2428E-04	0 2429E-04	0 2433E-04
64	0 2388E-04	0 2384E-04	0 2405E-04	0 2404E-04	0 2419E-04	0 2429E-04	0 2430E-04	0 2432E-04	0 2435E-04	0 2433E-04
65	0 2386E-04	0 2382E-04	0 2412E-04	0 2414E-04	0 2414E-04	0 2434E-04	0 2435E-04	0 2436E-04	0 2436E-04	0 2436E-04
66	0 2392E-04	0 2389E-04	0 2401E-04	0 2413E-04	0 2429E-04	0 2444E-04	0 2441E-04	0 2438E-04	0 2438E-04	0 2439E-04
67	0 2397E-04	0 2395E-04	0 2395E-04	0 2406E-04	0 2423E-04	0 2430E-04	0 2447E-04	0 2442E-04	0 2441E-04	0 2442E-04
68	0 2391E-04	0 2392E-04	0 2394E-04	0 2387E-04	0 2383E-04	0 2423E-04	0 2432E-04	0 2442E-04	0 2442E-04	0 2443E-04
69	0 2390E-04	0 2389E-04	0 2390E-04	0 2390E-04	0 2390E-04	0 2399E-04	0 2433E-04	0 2430E-04	0 2432E-04	0 2449E-04
70	0 2393E-04	0 2392E-04	0 2392E-04	0 2390E-04	0 2390E-04	0 2390E-04	0 2426E-04	0 2439E-04	0 2432E-04	0 2449E-04
71	0 2392E-04	0 2392E-04	0 2390E-04	0 2389E-04	0 2388E-04	0 2388E-04	0 2419E-04	0 2422E-04	0 2436E-04	0 2454E-04
72	0 2391E-04	0 2390E-04	0 2390E-04	0 2390E-04	0 2387E-04	0 2399E-04	0 2411E-04	0 2444E-04	0 2444E-04	0 2442E-04
73	0 2390E-04	0 2390E-04	0 2390E-04	0 2391E-04	0 2391E-04	0 2387E-04	0 2389E-04	0 2381E-04	0 2104E-04	0 2399E-04
74	0 2390E-04	0 2390E-04	0 2390E-04	0 2391E-04	0 2391E-04	0 2391E-04	0 2390E-04	0 2397E-04	0 2432E-04	0 2113E-04
75	0 2387E-04	0 2385E-04	0 2385E-04	0 2386E-04	0 2386E-04	0 2387E-04	0 2386E-04	0 2388E-04	0 2424E-04	0 2409E-04
76	0 2389E-04	0 2384E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2385E-04	0 2384E-04	0 2384E-04	0	

*MISSION
of
Rome Air Development Center*

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C³I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.