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PLEXUS (PHILLIPS LABORATORY EXPERT SYSTEM-ASSISTED USER SOFTWARE)

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Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
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11. SUPPLEMENTARY NOTES
This report provides a summary of the PL sponsored project to develop and distribute an expert system assisted software package of PL atmospheric effects models used in the design and development of electro-optical weapons systems and sensors. The PLEXUS software package delivered as part of this project effort has been distributed to over 200 DoD agencies and their contractors

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13. ABSTRACT *(Maximum 200 words)*
This report summarizes the results of the Phillips Lab PLEXUS project to design, build, and distribute a user-friendly, expert system assisted, GUI enhanced software suite of sophisticated atmospheric effects and backgrounds models (FASCODE, MODTRAN, LOWTRAN, SHARC, Celestial Backgrounds Model) developed by PL/GPO to determine the effects of the atmosphere on electro-optic sensor performance. Although a complex task with high technical risk, the project was extremely successful as measured by the fact that PLEXUS has been distributed to over 200 users and has become widely accepted as one of the key E-O engineering support tools within the DoD and NATO. Government Agencies and their contractors may obtain copies of the PLEXUS software by request to Dr. Laila Jeong, PL/GPOC, email: jeong@plh.af.mil.

14. SUBJECT TERMS
Atmospheric E-O Effects Models, Graphical User Interface, GUI, expert system, Hypertext Help, E-O Systems, FASCODE, MODTRAN, LOWTRAN, SHARC, Celestial Backgrounds Model, atmospheric transmission modeling, HITRAN Database, CLIPS expert system

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1. Executive Summary

This report summarizes the results of the Air Force Research Laboratory **PLEXUS** project to design, build, and distribute a user-friendly, expert system assisted, GUI-enhanced software suite of sophisticated models developed by PL/GPO to determine the effects of the atmosphere on electro-optic sensor performance. The project turned out successfully as measured by the fact that **PLEXUS** has been distributed to over 200 users and has become widely accepted as one of the key E-O engineering support tools within the DoD and NATO. As further proof of its scientific utility and graphics display capabilities, **PLEXUS** has been adapted as a teaching tool at the USAF Academy and by the Engineering Physics Department at the Air Force Institute of Technology (AFIT).

By end of contract, the **PLEXUS** software had evolved into several versions to include a state-of-the-art GUI version (**PLEXUS** 2.1a) that will run under WIN3.1, WIN3.11, WIN95, and WIN NT 4.0; a UNIX version without GUI (**PLEXUS** 3.0NI) to support non-interactive simulation efforts under JMASS; and **PLEXUS** 3.0, which is under development to implement a more modular architecture using Microsoft Foundation Classes. Version 3.0 will eventually serve as the single code stream which can be implemented on PC platforms and can be translated to UNIX platforms via the use of translation/porting tools.

PLEXUS was able to achieve its high level of success by being able to deal with the rapid advancements over the past five years in PC technology, operating systems, software development tools, evolving customer support requirements, and improvements in the underlying atmospheric effects models.

1.1 PLEXUS Project Goals

The goals of the **PLEXUS** package are:

- Minimize the code specific expertise required to generate useful output from complex, legacy, FORTRAN based, atmospheric effects codes. In their native form, these codes are very user unfriendly and require a steep learning curve due to their scientific complexity and unstructured, monolithic programming methods which are typical of complex FORTRAN models.
- Provide the user with high quality visualization capabilities using the power of the PC GUI environment for problem definition and data analysis.
- Provide a seamless output between the models when the sensor-target geometry cause the line-of-sight to cross through the regimes best covered by a given model. This feature synergizes the power of the AFRL models into a mega-model capable of simulating the effects of the atmosphere on E-O systems from the boundary layer to outer space.
- Make the AFRL atmospheric effects models simple to apply, reliable, and attractive for use by the widest possible DoD audience. As a result, PLEXUS levers the long term scientific and monetary investment in these codes by upgrading them with an expert

system assisted GUI and adapting them to the power and availability of today's high speed PC platforms.

1.1.1 PROJECT MILESTONES

1.1.1.1 Software Deliverables Produced Under The Project

SOFTWARE	DATE
PLEXUS 1.0	30 Apr 94
PLEXUS 2.0 Beta	30 Sep 94
PLEXUS 3.0 Beta (JMASS)	22 Feb 95
PLEXUS 2.0 Beta D	22 Feb 95
PLEXUS 3.0 (Borland Based)	13 Mar 95
PLEXUS 4.0 (UNIX version for PL)	14 Apr 95
PLEXUS 2.1 (300 copies CDROM)	6 Jun 96
PLEXUS 3.0 NI (UNIX, SUN and SGI)	1 Aug 96
PLEXUS 3.0 alpha 1 (MFC Based)	12 Sep 96
PLEXUS 2.1a (300 copies CDROM)	20 Sep 96
PLEXUS 3.0 alpha 2 (MFC Based)	31 Dec 96
PLEXUS 3.0 NI with UDA (PC Vers)	31 Dec 96

1.1.1.2 Technical Reports Developed Under The Project

TITLE	DATE
Final Report to Smart Weapons Operability Environment on the Addition of the SHARC/SAMM Atmospheric Generator (SAG) to PLEXUS and the CBSD Solar Spectrum, by P. Ip et alia.	25 Jan 94
Design Specifications for Porting PLEXUS from PC Windows to Workstation UNIX Motif, by R. Flanders.	29 April 94
PLEXUS GUI/Screen Functionality Specifications, Final Version, Fall 94, by M. Noah.	Released in sections Sep - Oct 1994.
PLEXUS User's Guide Version 0.98	Summer 1993
PLEXUS User's Guide Version 1.01	Spring 1994
PLEXUS User's Guide Version 2.1	Spring 1996
PLEXUS Project Final Report (draft)	31 Dec 96
PLEXUS Project Final Report (final)	1 Mar 97

1.2 THE PLEXUS SCIENTIFIC AND MONETARY RETURN ON INVESTMENT

PLEXUS has been distributed in various versions as a commercial grade software package to over 200 users, which attests to its user-friendliness and its utility. It has become one of the key E-O system design tools within the DoD and has become the primary vehicle by which the Phillips Laboratory suite of atmospheric effects tools are distributed to the DoD E-O community.

1.2.1 DoD PROJECTS SUPPORTED BY PLEXUS

The following is a partial list of DoD projects that have used or are presently using **PLEXUS** in the design and analysis of various Electro-Optical Systems. This list was derived from various letters of request for the **PLEXUS** package on file with PL/GPOB. As can be seen from the list, **PLEXUS** has been a key tool in the development and analysis of high priority strategic and tactical E-O weapon systems throughout the DoD.

Table 1. Partial List of Programs/Projects Supported by PLEXUS

PROGRAMS / PROJECT
Advanced Electro-Optics System Program (AEOS)
Advanced Sensor Technology Program
AEM*AT
AFIT IR Sensor Design Class
AGM-130/GBU-15 Data Link
Airborne Laser Program
Aircraft Signature Analysis
Argonne Lab JMASS Support
AWACS Theater Missile Defense Sensor Program
BE Simulations at NTF
BLIRB Model Initialization
BLUE OCTOBER Support
BMDO Combined Optical Measurements Team
Brilliant Eyes Program Support
CBN Effects Modeling Support
CIRRIS-1A Modeling Support
Common Missile Warning System T&E Support
DARPA Dynamic Virtual Worlds
DNA TMD Performance Simulations
DNA UFS(Underground Facilities Signatures)

Table 1. Partial List of Programs/Projects Supported by PLEXUS
PROGRAMS / PROJECT
DSP Analysis
ENDOSIM
EOS MODIS Land Temp Measurements Analysis
ESC/XRP MASC (Mod & Sim Spt Center)
EXCEDE III Program
F-22 Signature Analysis
IBSS, CIRRIS-1A Analysis
Integrated Data Analysis Project
IR Camera Performance Analysis
JCS/J-8 Support
JMASS Analysis
JSTARS Flare Analysis
Brooks AFB Laser/Opthamolgy Analysis
Mission Simulation Support
MSTI Earth Backgrounds Experiment
MSTI3 Support
MSX Earth-Limb Experiment Support
MSX Experiment Planning
SAF Space Systems
SBIRS and SMTS
SBIRS Support
SSMIS Support
Standard Plume Flow and Std IR Model Verification
SWOE Support
Texas Instruments EAGLE Team
THAAD Support
US Atomic Energy Detection System (AFTAC)
USAEDC Support
USAF Academy Science Department
USAF High Altitude Balloon Experiment (HABE)
USASSDC FASTPROP Simulation Support
USASSDC HEDI Support
USN TOPSCENE FLIR Sensor Analysis

1.2.2 The Value of PLEXUS

PLEXUS has had significant scientific, technical, and monetary payoffs as shown below.

AFRL has gained the following payoff on its investment in **PLEXUS**:

- **PLEXUS** synergizes Air Force Research Laboratory (AFRL) models into a more powerful tool than the AFRL models provide in their stand-alone, native state.
- It provides easy, reliable application of the AFRL atmospheric effects codes, which levers the long term investment and research that has gone into these models over several decades.
- The commercial grade GUI-wrap architecture ensures continued use of the AFRL Models and expands their audience by making these available to run on PC platforms.
- **PLEXUS** has saved at least 1 month level of effort that would be required to learn the application of just one of the AFRL atmospheric effects codes. At a cost of $12k per month LOE, this results in a salary payoff of $2.4M.
- **PLEXUS** has also resulted in a huge technical payoff which cannot be estimated by assisting users in correctly computing the effects of the atmosphere on E-O weapon systems early on in the design phase.
- **PLEXUS** is currently the only "shrink wrapped", COTS grade design tool that is being distributed by AFRL. It is not only an example of the Lab's technical prowess as a center of excellence in atmospheric effects modeling, it also is a trend setter for other AFRL programs to follow if AFRL is to survive in today's competitive laboratory environment.
- **PLEXUS** is on the leading edge of support to JMASS distributed system simulation support by turning AFRL E-O effects models into intelligent objects that can be applied to JMASS problems.
- **PLEXUS** has been adapted as a teaching tool by the AF Academy and AFIT, thus making the AFRL models the standard by which future E-O Design tools will be judged by fast track Air Force Engineering Students who will become the SPO directors and Lab Commanders of the 21st Century Air Force.

2. PLEXUS Model Platforms, Architectures, and Components

This section discusses the structure and components of **PLEXUS**. For additional details about a particular AFRL model or component such as CLIPS, the reader should refer to technical reports that are available on those particular modules.

2.1 Recommended Platform Hardware and Operating System Requirements:

2.1.1 PLEXUS 2.1A

For **PLEXUS** 2.1a, the following configuration is recommended to efficiently run the software:

- Pentium Processor
- 16 MB RAM
- 150 MB free disk space for complete **PLEXUS** installation (excluding the HITRAN database, which requires an additional 70 MB). An additional 10 MB of disk space is required to store most code outputs. For large spectral ranges, up to 60MB of free disk space may be needed.
- VGA monitor with video card (Windows accelerator recommended)
- Two button mouse
- CD ROM Drive
- Windows 3.1/3.11 with a swap space of >15 MB (permanent is highly recommended). This is set in Windows 3.1 under Control Panel/386 Enhanced Mode/Virtual memory. If DOS 6.0 Double Space is being used, the swap file must be set up on the non-compressed host drive.

2.1.2 PLEXUS 3.0NI

For **PLEXUS** 3.0NI[1] (the UNIX based, non-interactive version), the following configuration[2] is recommended to efficiently run the software:

2.1.2.1 PLEXUS for SOLARIS:

- SOLARIS 2.x (**PLEXUS** 3.0NIhas been tested on SOLARIS 2.3 but it should run on any SOLARIS)
- 250 Mbytes of disk space

2.1.2.2 PLEXUS on SGI:

- IRIX 5.3
- 250 Mbytes of disk space

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[1] *PLEXUS 3.0NI must be installed in a directory that has a short path name because of static allocation of the path string in FORTRAN.*

[2] *PLEXUS 3.0NI is designed as a single user system, which uses temporary files in the bin directory and requires that the user must have write access to the bin directory and the output directories.*

2.2 ARCHITECTURES

The original **PLEXUS** architecture is shown in Figure 1. This architecture provided the foundation for GUI wrapping the AFRL atmospheric codes with an embedded expert system to guide the user through application of the AFRL models. This architecture was used in versions up through 2.1a and was improved over the life of the project to meet the ever-increasing capabilities and power of PCs as these machines evolved from the 286 to the Pentium.

Although the original structure is fairly complex, it was developed with sufficient object oriented programming techniques to allow inclusion of additional legacy atmospheric codes and it has been shown that the **PLEXUS** architecture can be readily adapted to other applications without having to make major modifications to the structure. Major components of the architecture, e.g., the input GUI, the analysis GUI, and the expert system can thus be readily applied to GUI wrapping other legacy FORTRAN based models. Thus, the investment in the **PLEXUS** architecture has had multiple payoffs:

- It has protected the AFRL investment in their atmospheric effects models by upgrading the models to run on PC platforms and making them relatively easy to use;
- The investment in the architecture has the added payoff of being readily adaptable at low cost and low technical risk to other legacy FORTRAN codes.

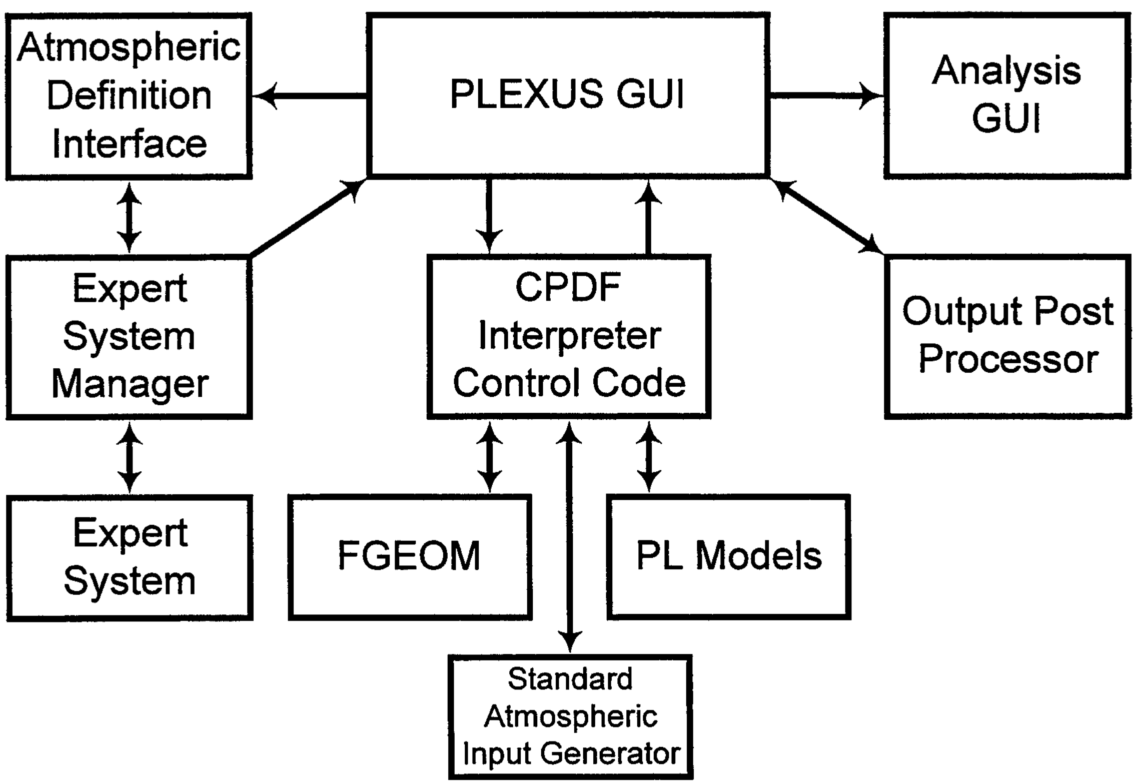

Figure 1. The Initial PLEXUS Architecture For PC Platforms

2.3 PLEXUS COMPONENTS

The functionality of the major modules shown in the **PLEXUS** architecture in Figure 1 is discussed in the sections that follow. A brief walk through of an actual **PLEXUS** run is then provided to give the reader an understanding of how the software leads the user through an application of the AFRL atmospheric effects models. To the extent possible, these are illustrated by displays of screen captures from **PLEXUS** 2.1a that was running in another window during the development of this report. This also illustrates the power of **PLEXUS** running under Windows®95 when developing test results: *the user can capture the results directly from **PLEXUS** and insert them into a word processor report format or briefing package.*

2.3.1 COMPONENTS OF THE PLEXUS ARCHITECTURE

2.3.1.1 The PLEXUS GUI

As shown in the diagram, the **PLEXUS** GUI interacts directly with the following components:

- the Atmospheric Definition Interface (ADI);
- the Hypertext Help;
- the Expert System;
- the CPDF Interpreter;
- the Output **Post-Processor**;
- the Standard Atmosphere Generator (SAG);
- and the Analysis GUI.

One of the initial screens encountered is used to set the level of expertise of the User which then determines the amount of expert system interaction and amount of input choices that will be allowed to be provided to the user.

2.3.2 ATMOSPHERIC DEFINITION INTERFACE

The Atmospheric Definition Interface walks the user through several screens to set up the target/sensor/background geometry, location of the target scenario, time of day, season, solar-geophysical environmental parameters, and atmospheric boundary layer and aerosol inputs required to run the required E-O effects model(s).

2.3.3 THE PLEXUS EXPERT SYSTEM

The **PLEXUS** Expert System is based on the NASA C Language Integrated Production System (CLIPS). To deliver source code, the **PLEXUS** team purchased CLIPS from COSMIC. This allows **PLEXUS** to be distributed without license and at no cost. As implemented in **PLEXUS**, the expert system provides the following assistance as a function of the skill selected by the user:

- Range checking
- Units conversion
- Suggests reasonable default values for input
- Provides consistency checking of inputs
- Aids the user in selecting the best model for the input scenario
- Checks target/sensor alignment geometry
- Issues warnings and allows the user to proceed if ignored (allows for parametric studies that may require inputs which are out the norm.)

2.4 User Experience Level As An Input To The Expert System

PLEXUS successfully implemented the NASA CLIPS expert system with the objective of assisting all levels of users in modeling atmospheric effects on Electro-Optics. The users may be novices, narrow-topic experts, intermediate, or experts in the field of electro-optics and atmospheric effects on E-O systems. The **PLEXUS** knowledge base is built on first principles, encompassing fundamental and advanced knowledge in the essential domains. The expert system is coupled to the problem definition interface to serve the role of an advisor making suggestions, reporting inconsistencies, deriving model input parameters, and offering the best solution for the user's problem. The user, who has the option of accepting or rejecting the expert system's advice, decides the final input.

2.4.1 Description Of The Expert System Implementation

The following functions were designed into the application of the **PLEXUS** expert system:

2.4.1.1 Focus On User's Problem

Coupling the CLIPS expert system to the problem definition interface provides an environment whereby the user can concentrate on the problem and its solution rather than having to figure out which AFRL E-O effects model is appropriate for the scenario and going through manuals to determine the input parameters and how to run a particular AFRL model.

2.4.1.2 Minimize Queries

Based on user's initial inputs, the CLIPS expert system can be used to determine the additional input parameters to be queried. The expert system provides an efficient mechanism to eliminate questions of an inconsequential nature. For example, if the user's problem is for a nighttime case, then CLIPS does not ask any question related to the Sun. For novices, CLIPS will provide default values for model input parameters unfamiliar to them.

2.4.1.3 Perform Range And Consistency Checks

CLIPS can dynamically check whether the user input values lie within the proper ranges of the code and whether the parameters are consistent with one another.

2.4.1.4 Offer Instant Solution

CLIPS can determine from the user inputs whether the problem matches a case in the library of pre-calculated results. The user can instantly view an approximate answer. After viewing the pre-calculated results, the user can still choose to continue running the phenomenology models. This feature is a real time-saver since some model calculations are extremely time-consuming.

2.4.1.5 Choose Best Model

An important function of the expert system is to determine the best code(s) to solve the atmospheric effects problem. For all users, this is performed transparently and a list of possible codes and commentary information are provided.

A diagram that depicts the interaction of the expert system with the **PLEXUS** user as a function of the user skill level is shown in Figure 2.

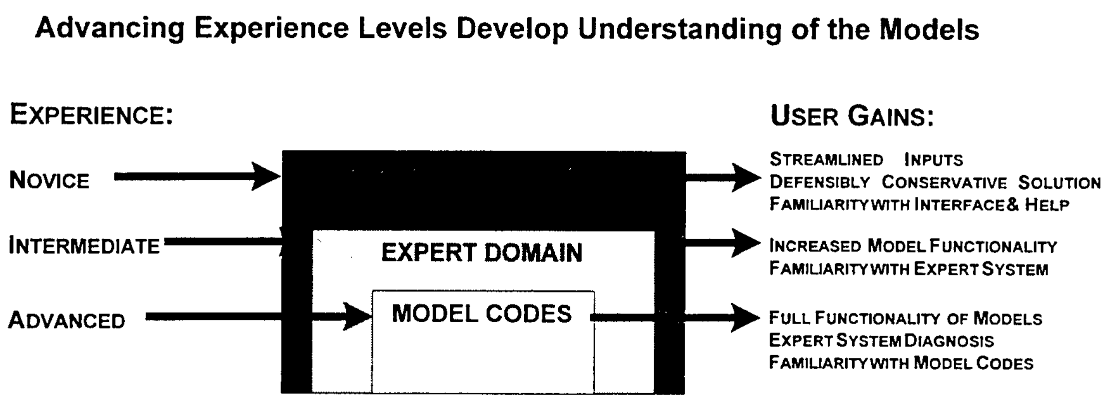

Figure 2. User Access to E-O Model Features as Monitored by the Expert System

2.5 THE C LANGUAGE INTEGRATED PRODUCTION SYSTEM (CLIPS)

The next section provides some additional insight on the CLIPS expert system. Since the use of an expert system makes **PLEXUS** unique from other efforts to GUI wrap legacy FORTRAN codes, it is important that some of the details of this implementation be documented in this report.

2.5.1 BACKGROUND

CLIPS was developed at NASA/Johnson Space Center to provide a low-cost and portable alternative to Lisp based shells. The shell itself is written in ANSI C to facilitate portability and efficiency. The CLIPS language is Lisp-like but is written in a more declarative style than the recursive list processing method characteristic of Lisp.

The system has been installed on a variety of computer hardware ranging from x86s to Cray supercomputers and various researchers are working on parallel versions of CLIPS. Because it is a NASA funded effort, it is free to NASA and Air Force organizations and their contractors. For a nominal fee, others may purchase CLIPS from COSMIC, University of Georgia, Athens, GA.

CLIPS is currently distributed for DOS, Windows, Macintosh, and X/UNIX platforms. Because the source code is distributed, one may examine the actual algorithms in detail, quickly add patches, and when needed, put low-level hooks into the shell.

2.5.2 Methods of Usage

CLIPS can be constructed into a self-standing executable without difficulty since that is the default usage. A major strength of CLIPS is that rule/knowledge base libraries can either be constructed that have the domain specific rules actually embedded into the library or they can have a library that can read the rule and fact bases "on the fly." **PLEXUS** has made the CLIPS library into a DLL (dynamic link library) on the Windows system and has distributed the libraries to end users with great success.

The **PLEXUS** approach is to have the expert system libraries read the compiled knowledge bases. In that manner, through the expert system itself, **PLEXUS** can control the actual knowledge bases that are used. This also provides the capability for the end users to load a knowledge base of their choice without having to download separate dynamic libraries.

2.5.3 Extensibility to Conventional Software

PLEXUS has added C++ wrapper classes to the CLIPS library so the application programmer using the system does not have to deal directly with the expert system shell. All bookkeeping operations such as resetting the agenda and controlling the loading of auxiliary libraries are handled through the use of CLIPSMgr objects.

A walk-through example will illustrate this point. For example, when a programmer in one part of the project may find the knowledge base useful either at the GUI or underlying code sections, they can instantiate a CLIPSMgr object. This library can be told to explicitly use or disregard specific portions of the entire knowledge base. Data is entered into the object and then retrieved. The applications programmer need not worry about what rule phase to invoke or how or when to retrieve facts. This approach has many benefits.

- The applications programmer does not have to concern themself with the underlying details of the CLIPS interface. If changes are needed, they are made in specific code modules so changes are isolated to new code written and do not directly involve modifying the expert shell source.
- Another advantage is if unforeseen capabilities are needed from the knowledge base that conventional code might offer a better alternative than the expert shell. Then these code libraries could be further integrated into the CLIPS Manager object without the applications programmer being concerned about what is actually occurring. For

example, a simple relational database add-on might do frame-like searching more quickly and efficiently than the expert system shell.

2.6 PLEXUS Knowledge Base Development

2.6.1 Overall Approach

PLEXUS has developed a knowledge base of facts and rules pertaining to the Phillips Laboratory atmospheric and celestial phenomenology codes. The **PLEXUS** expert system functionality includes diagnosis of user input, advice to non-experts for model selection and set-up, and assistance in establishing parameter values. The **PLEXUS** requirements are that the system transparently provide over-the-shoulder diagnosis of input parameters and model selections and that the user may always overwrite a recommended value and be allowed to proceed even against the warnings of the expert system.

PLEXUS has rule packets for:

- parameter checking (range and inter-consistency),
- checking scenario consistency with nature,
- selecting match to database of pre-calculated results, and
- selecting the appropriate model or set of models for a user-defined scenario.

2.6.2 Input parameter Range Checking

It should also be noted that along with the checks provided by the expert system, some range checking is done in the code modules behind the Visual Basic screens that make up the GUI.

2.6.3 Sample of PLEXUS Parameter Consistency Diagnostics by the Expert System

Table 2. Examples of PLEXUS 2.1a rules for diagnostic warnings for inconsistencies with nature and inconsistencies of input values within a code.

Condition	Warning
Auroral Region bottom altitude is >= top altitude	"Auroral bottom altitude is greater than or equal to top altitude. Please reset one of the altitudes."
if (TanAlt < 0.0) then the Earth is intersected	"The Earth is intersected by the unrefracted LOS. Will cause run-time error in MODTRAN."
if (MinAlt > 300.0 km) then LOS doesn't intersect the atmosphere	"The line-of-sight does not intersect the Earth's atmosphere."

Table 2. Examples of PLEXUS 2.1a rules for diagnostic warnings for inconsistencies with nature and inconsistencies of input values within a code.

Condition	Warning
if (H1/H2Alt > 300.0 km) then explain partitioning of LOS above 302 km -- use 302 instead of 300 to cross threshold	"The line-of-sight extends beyond the atmosphere. Help file explains how the AIM preprocessor partitions the line-of-sight."
if (Obs-Tgt-LOS and Obs-Sun-LOS are within 2 degrees of each other) then line-of-sight is directed toward the Sun (ouch close your eyes!)	"The Sun is within 2 degrees of the line-of-sight. Help file explains that direct solar light is not included."
Solar scattering included in a Night Case	"For the specified time, the Sun is not visible from the observer, yet Solar Scattering is included. This results in a longer execution time. Reset time or location."
Solar scattering not included in a Day Case	"For the specified time, the Sun is visible from the observer, yet Solar Scattering is excluded. Recommend the inclusion of Solar scattering."
Aurora should be included since high SunSpot number (Get SunSpot Number Observation Date stored in text file)	"The recorded Sunspot number for this observation date is greater than 100. Consider including aurora."
if LOS terminates on Earth surface then warn about TBOUND/SALB	"The line-of-sight terminates on the Earth surface. Help file explains how the surface albedo and temperature affect the results."
Observer Altitude is below Ground Altitude.	"The observer altitude is below the ground altitude. Help file explains how observer altitude is reset to ground altitude."
Target Altitude is below Ground Altitude.	"The target altitude is below the ground altitude. Help file explains how target altitude is reset to ground altitude."
Tangent Altitude is below Ground Altitude	"The tangent altitude is below the ground altitude. Help file explains how the program may crash."
if (TanAlt < GndAlt+2.0) then the Earth may be intersected by the refracted MODTRAN LOS.	"The tangent altitude may be refracted below the ground altitude. Help file explains how the program may crash."

Table 2. Examples of PLEXUS 2.1a rules for diagnostic warnings for inconsistencies with nature and inconsistencies of input values within a code.

Condition	Warning
if $\nu_1 \geq \nu_2$ or $\nu_1 > \nu_2$	"Lower frequency is greater than or equal to upper frequency. Please reset either frequency."
Auroral Region bottom altitude is $\geq$ top altitude	"Auroral bottom altitude is greater than or equal to top altitude. Please reset one of the altitudes."

2.6.4 Code Selection

As part of the model selection process, the rule-returned messages acknowledge areas where the models are weak or don't fully address the application.

2.6.4.1 Run-Time Diagnostic Predictions

While the expert system does "watch" over the development of a particular test scenario, it does not predict run time and memory requirements. These checks are left up to the user and the operating system.

2.6.4.2 CPD Interpreter Control Code

As the user interacts with the **PLEXUS** system, a control/input file is being built which will drive the application. This file is known as the Common Parameter Definition (CPD) File and is stored under a unique file name for each separate **PLEXUS** run. The CPD file also maintains a cross-reference to the output files generated during the run. This storage and linkage of the inputs and outputs ensures that users are able to closely track inputs and output files and do not have to do a lot of file management to regenerate a set of results, nor do they have to start completely from scratch, should they choose to see the effects of modifying a single parameter or subset of input parameters. The CPD Control Code is the module that provides this capability to the user.

2.6.4.3 Standard Atmospheric Input Generator

The SHARC/SAMM Atmosphere Generator (SAG) is a Phillips Laboratory code that calculates atmospheric profiles based on user input for geophysical and geographical information. To address the strategic requirements for modeling infrared (IR) background radiation in the upper atmosphere, SAG has been designed to incorporate the major known systematic variabilities in the atmosphere, including terminator and other diurnal effects.

SAG draws primarily on two existing empirical atmospheric models: MSISE-90 (Mass Spectrometer Incoherent Scatter Extension) [A.E. Hedin, JGR 96(A2), 1159-1172 (1991)] and the NRL (Naval Research Laboratory) climatology database. The MSISE-90 model revises the MSIS-86 model in the lower thermosphere and extends the MSIS-86 model into the mesosphere and lower atmosphere to provide a single analytic model for temperature and density profiles of major species (N_2, O_2, O, and H). The NRL database provides profiles for CH_4, CO, N_2O, NO_2, HNO_3 up to an altitude of 120 km as well as profiles for O_3 and O at lower altitudes. The NRL database contains mean monthly concentrations at 1 to 5 km increments and 10° latitude increments. SAG interpolates between these values and converts to number densities using the MSISE-90 total densities.

Along with SAG, the user may also select from one of 6 other standard atmospheric models that are available as runtime options within **PLEXUS** to define atmospheric profile inputs required to run the AFRL E-O effects models. These options are listed below:

MODEL Option:	**ATMOSPHERE**
1	Tropical at 15N
2	Midlatitude Summer at 45 N in July
3	Midlatitude Winter at 45 N in January
4	Subarctic Summer at 60 N in July
5	Subarctic Winter at 60 N in January
6	1976 U.S. Standard
9	User-Defined Atmosphere Profile (Prototype only and not distributed as of 31 Dec 96)

2.6.4.4 AFRL Models

PLEXUS 2.1a has the following AFRL Atmospheric Effects models integrated into the architecture. For additional technical information on these models and databases, the reader should consult technical reports from the model or database developer.

- MODTRAN 3 Version 1.5, dated April 96
- SHARC3 dated December 93 with auroral patch received from SSI in March 96
- FASCODE3P dated December 94 with the HITRAN96 database
- SAG1 dated December 93
- CBSD (Version 3.0 installed in **PLEXUS** 3.0)

The Celestial Background Scene Descriptor (CBSD) is a collection of Phillips Laboratory codes that calculate positions and fluxes of astronomical objects. This includes models for point sources, diffuse objects, and solar system objects. CBSD, under **PLEXUS**, runs with a 1 μm bandwidth, user-specified initial and final wavelengths from 2 to 30 μm, and a user-specified stare point. Under **PLEXUS**, all output images are assumed to be 256 x 256 pixels with the field-of-view given by the instantaneous field-of-view of each pixel. A sample output screen from CBSD is shown in Figure 2.

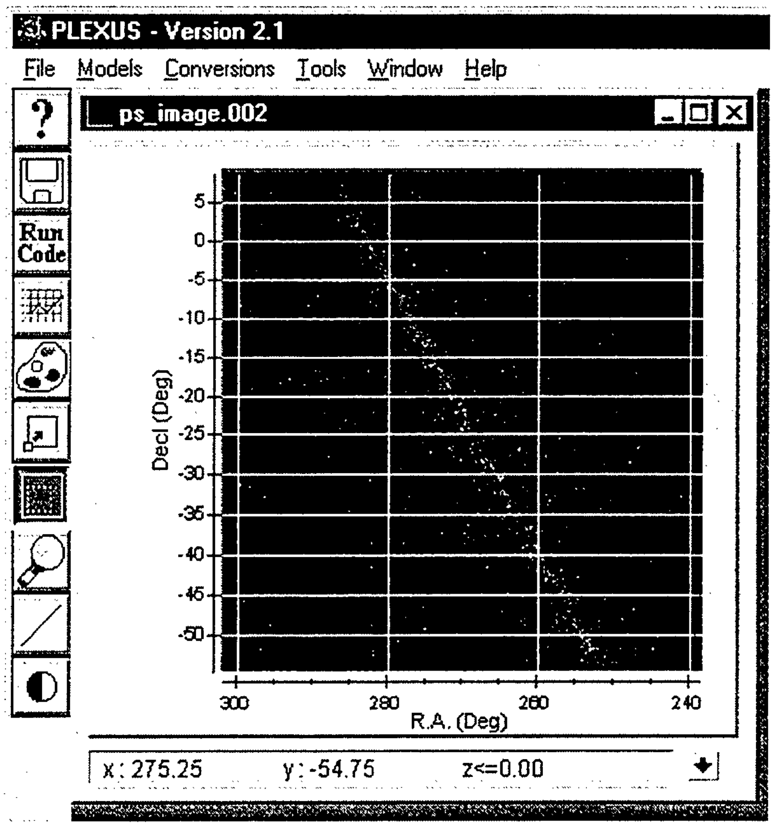

Figure 3. CBSD Sample Output

The CBSD software suite is currently composed of the following models:

Model Name	**Description**
CBZODY	Zodiacal light from broadly dispersed dust and the dust bands.
CBAMP	Flux and position of Sun, Moon, Planets, and asteroids.
CBPSC	Infrared Astronomical Satellite (IRAS) stellar point source catalog.
CBSKY	Stellar point source model based on the PL/NASA/Ames SKY model.

2.6.4.5 Output Post-Processor

The different AFRL codes generate different outputs. Listed below is the output generated by **PLEXUS** for each code. The ### denotes an incrementing number starting a 001. If 001 already exists, 002 will be used. **PLEXUS** will always start with 001 and increment until a unique name is created. The Output post-processor operates on the native model output data/formats and converts the data sets into formats that can be ingested and displayed by the display tools in the **PLEXUS** Analysis/Display GUI.

PLEXUS

FILENAME	CONTENT
AIM###.FIT	Spectral Radiance and Transmittance file in cm-1 space in FITS format
AIM###.SPC	Spectral Radiance file in cm-1 space written in ASCII format
AIM###.TRN	Spectral Transmittance file in cm-1 space written in ASCII format
AIM###.CPD	Common Parameter Definition File

MODTRAN/LOWTRAN

FILENAME	CONTENT
MOD###.FIT	MODTRAN3 Spectral Radiance and Transmittance file in cm-1 space written in FITS format
MOD###.TP6	MODTRAN3 Tape 6 saved only when an error is detected
MOD###.TP7	MODTRAN3 Tape 7 in its original format
MOD###.CPD	MODTRAN3 Common Parameter Definition File

CBSD

FILENAME	CONTENT
CBAMP###.FIT	CBAMP FITS Output
CBZDY###.FIT	CBZODY FITS Output
CBPSC###.FIT	Point Source Catalog FITS Output
CBPTS###.FIT	Point Source Model FITS Output

2.7 MULTI-PLATFORM PLEXUS ARCHITECTURE

In late 1995, AFRL defined the requirement to develop a version of **PLEXUS** to operate on UNIX platforms. The intent in this effort was to provide an expert system monitored structure for the AFRL codes that allowed their use in JMASS simulations support in a distributed computing environment. To meet this need, it was directed by PL/GPOB to develop a new **PLEXUS** architecture that could thus be multi-platform and be run with or without the GUI.

The major differences between the new architecture and the initial architecture are:

- The new architecture allows for use or non-use of the GUI. The GUI thus becomes a separate, optional module which can be used or not used as in the case of a UNIX based batch application.

- This new architecture allows for a single code stream by developing with Microsoft™ Foundation Classes (MFC) and thus is easily converted to UNIX using COTS porting tools. This gives both PC and UNIX users the ability to use the AFRL models interactively on the platform of choice.
- The newer architecture is modular and allows for faster integration of new or additional models into the **PLEXUS** framework.

2.8 Databases Included In PLEXUS

Along with the Standard Atmosphere databases, **PLEXUS** 2.1a also uses the HITRAN96 database as input to FASCODE3P. This database may be loaded into the **PLEXUS** directory, or it may be accessed directly from the **PLEXUS** 2.1a distribution CDROM. The reader should refer to the latest technical papers and reference materials on the contents of the HITRAN96 Database.

2.8.1 Analysis GUI

Once the user has set up a problem and the calculation is completed, the results are stored in output files that follow the Flexible Image Transport System (FITS) format -- the standard format used for transferring data in the astronomical community. Examples of the display capabilities of the analysis portion of the GUI are provided in Section 3 of this report which gives a walk through of an actual **PLEXUS** application.

3. A Sample PLEXUS Application

This section provides a tour through an actual application of **PLEXUS** in order to show the ease of use and the power of the **PLEXUS** software in applying the AFRL atmospheric effects models.

3.1 Initial PLEXUS Screen

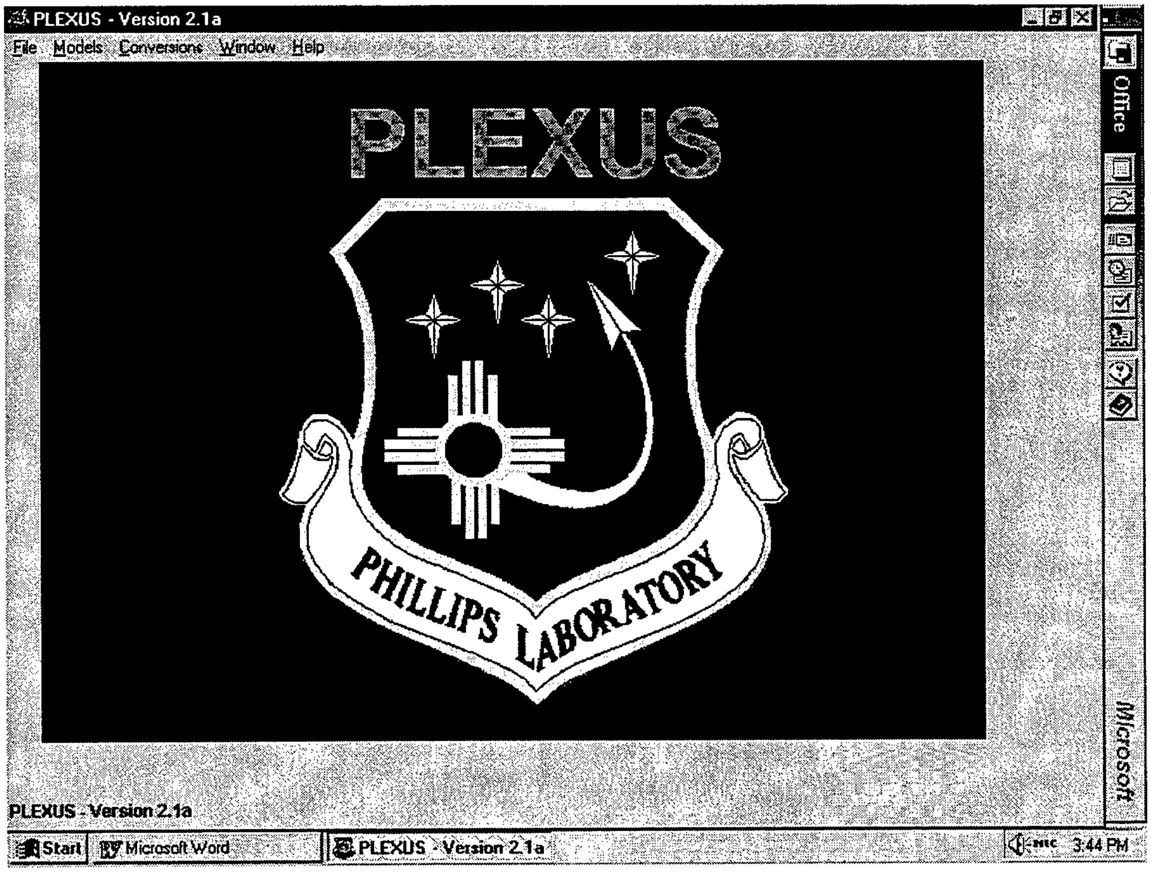

Figure 4. Initial PLEXUS Screen

After starting **PLEXUS**, the user will see the opening screen shown in Figure 4. This screen not only serves to show the user that the program has initiated, but also advertises that **PLEXUS** is clearly a product of the Phillips Laboratory.

Since **PLEXUS** encompasses both data visualization and code execution capabilities, the installation verification consists of two parts: data display and run codes. To make the verification after installation, six test cases with input and output data files have been provided in the **PLEXUS** installation from the CDROM. These files are located in the **\PLEXUS**\AIM\TEST\ directory. It should be noted that the version number of **PLEXUS** shows at the top of this initial window and can also be accessed by checking the Help|About feature of the software which also provides a point of contact for technical support on **PLEXUS**.

3.2 User Name and Experience Levels

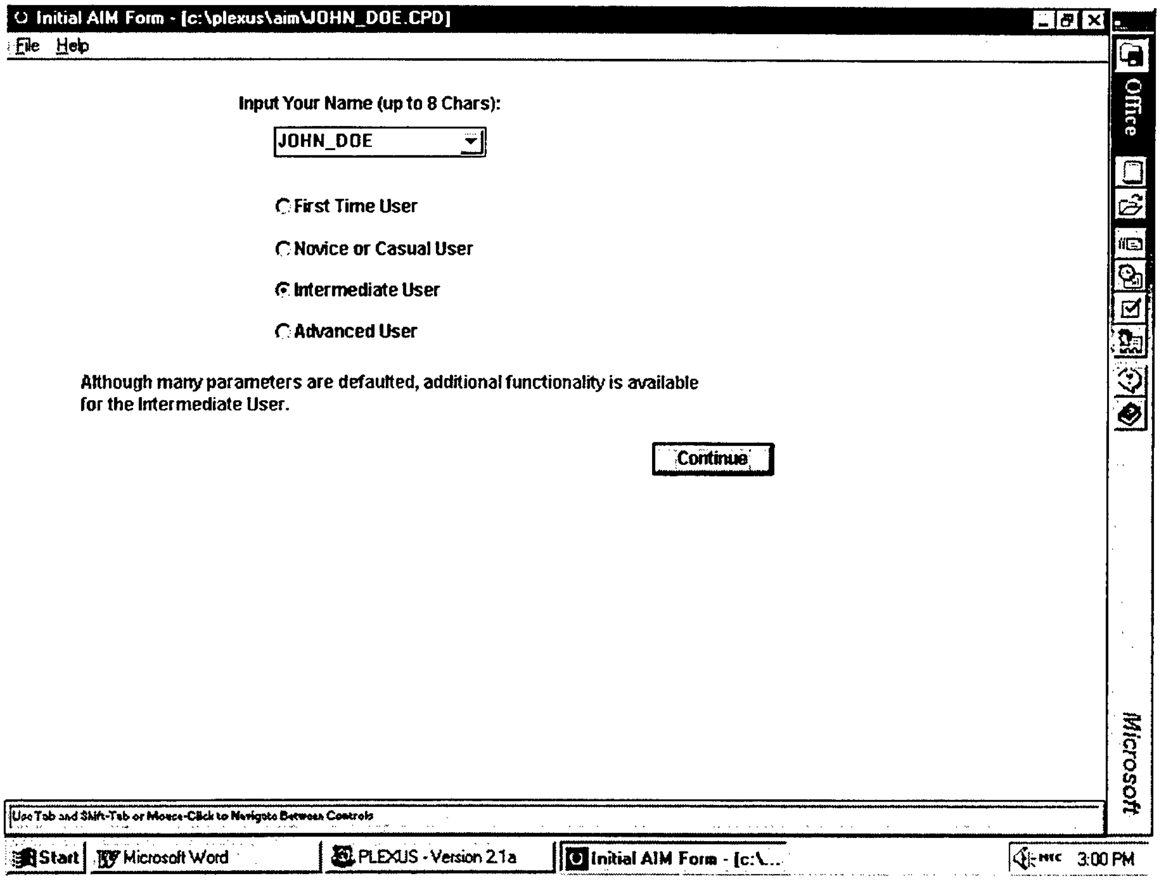

Figure 5. Screen Requesting User Name and Experience Level

The User Name entered in this window shown in Figure 5 becomes the filename for a **PLEXUS** "*.cpd" file which stores the parameter values and settings of the present run. These values become the defaults whenever that user name is entered.

3.2.1 User Experience Levels

The User Experience level entered invokes the system response applicable to the user's needs. The Interface supports a broad range of users by providing a different response based on the selected experience level. There are four broad categories of users: First Time User, Novice, Intermediate, and Advanced. The differences in these categories are described in Figure 5 and below:

3.2.1.1 First Time User

The First Time User will follow a brief on-line tutorial designed for familiarization with the graphical interface controls. All other defaults are the same as for the Novice User.

3.2.1.2 The Novice User

The Novice User is assumed to be familiar with the graphical interface, but unfamiliar with the AFRL codes. The Preprocessor provides the Novice User with streamlined inputs to reach a defensibly conservative solution to atmospheric modeling. The user will gain familiarity with the graphical interface and with the context sensitive on-line help.

3.2.1.3 Intermediate User

The Intermediate User is assumed to have knowledge of the graphical interface and a limited knowledge of the AFRL codes. The Preprocessor provides the Intermediate User with increased model functionality to reach a solution that is more specific to a particular scenario. At this stage, the user will gain familiarity with the expert system.

3.2.1.4 Advanced User

The Advanced User is assumed to have knowledge of the graphical interface, and experience with the AFRL codes. The Preprocessor provides the Advanced User with full model functionality to reach a solution that is highly specific to his scenario. At this stage, the user will gain familiarity with the model codes and may override values set by the expert system.

3.3 SPECTRAL DATA INPUT SCREEN

PLEXUS next displays a screen requesting spectral data.

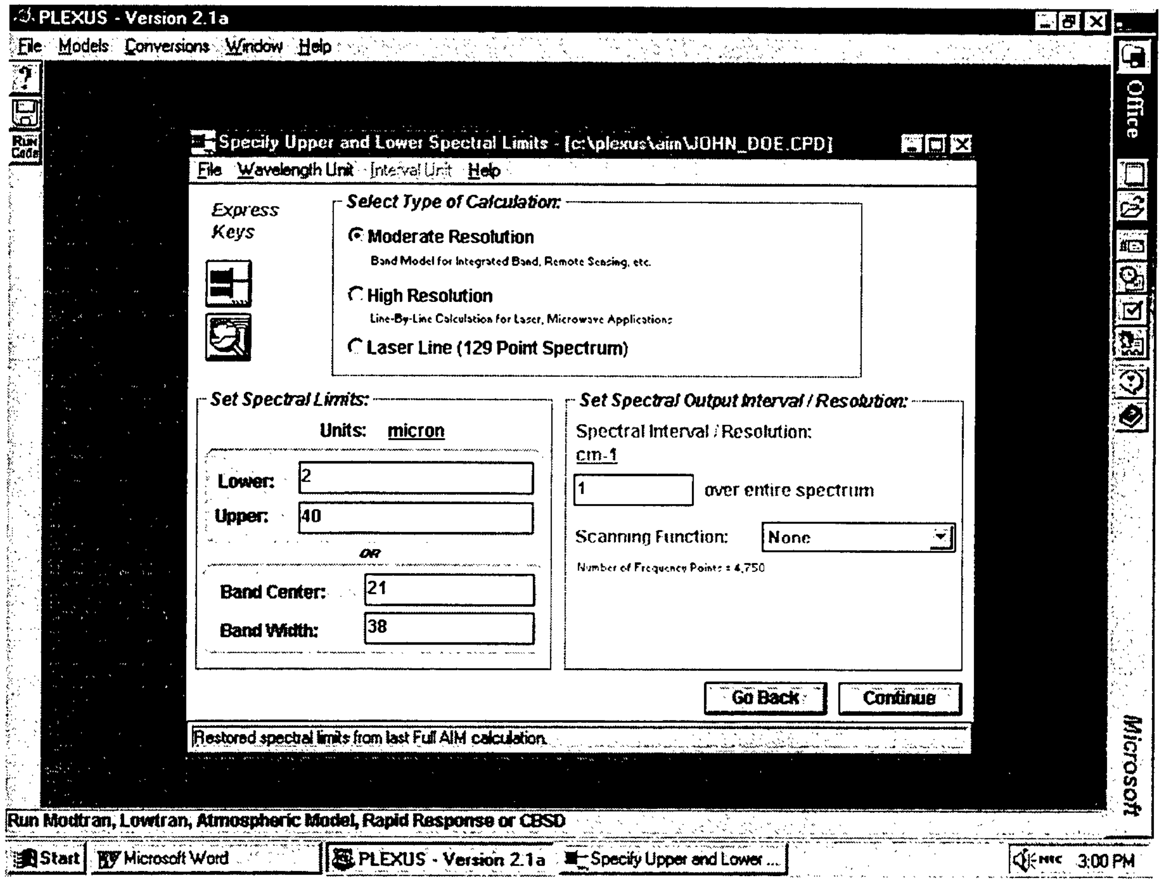

Figure 6. Spectral Data Input Screen

3.3.1 INPUT CATEGORIES

The three categories of inputs on the screen shown in Figure 6 are:

3.3.1.1 Type Of Calculation

For most applications, the user should select the Moderate Resolution option for band model calculations. The options for High Resolution or Laser Line should be reserved for problems which require extremely well-resolved spectra. These two options will use the FASCODE line-by-line model, which requires long runtimes from one to several hours, based on the input scenario and the speed of the processing platform.

3.3.1.2 Spectral Limits For Defining The Output Spectrum

The user can input either the lower and upper breakpoints OR the band center and full width. If the user has selected the High Resolution option, the spectral range is limited by FASCODE to 520 cm-1. To input the spectral limits in a different unit, the user can click on the blue text adjacent to the label 'Units:' or pull down the Wavelength unit menu to choose the desired unit. The available units are: centimeter, millimeter, micron, nanometer, Angstrom, picometer, KHz, GHz, and cm-1. The spectral limits are converted to cm-1 for use in MODTRAN, SHARC, and FASCODE.

3.3.1.3 Spectral Interval and Scanning Function

For moderate resolution calculations, the spectral interval is defaulted to 1 cm-1 and no scanning is applied. For high resolution calculations, the user can input a spectral resolution and the type of scanning function by selecting the option labeled 'User-defined'. The scanning is performed by FASCODE in wavenumber space. If the user inputs a spectral interval in a Wavelength unit, this number is converted to cm-1 at the reference wavelength. For laser line calculations, the spectral interval is calculated by FASCODE and no scanning is applied.

3.4 LINE-OF-SIGHT SPECIFICATION

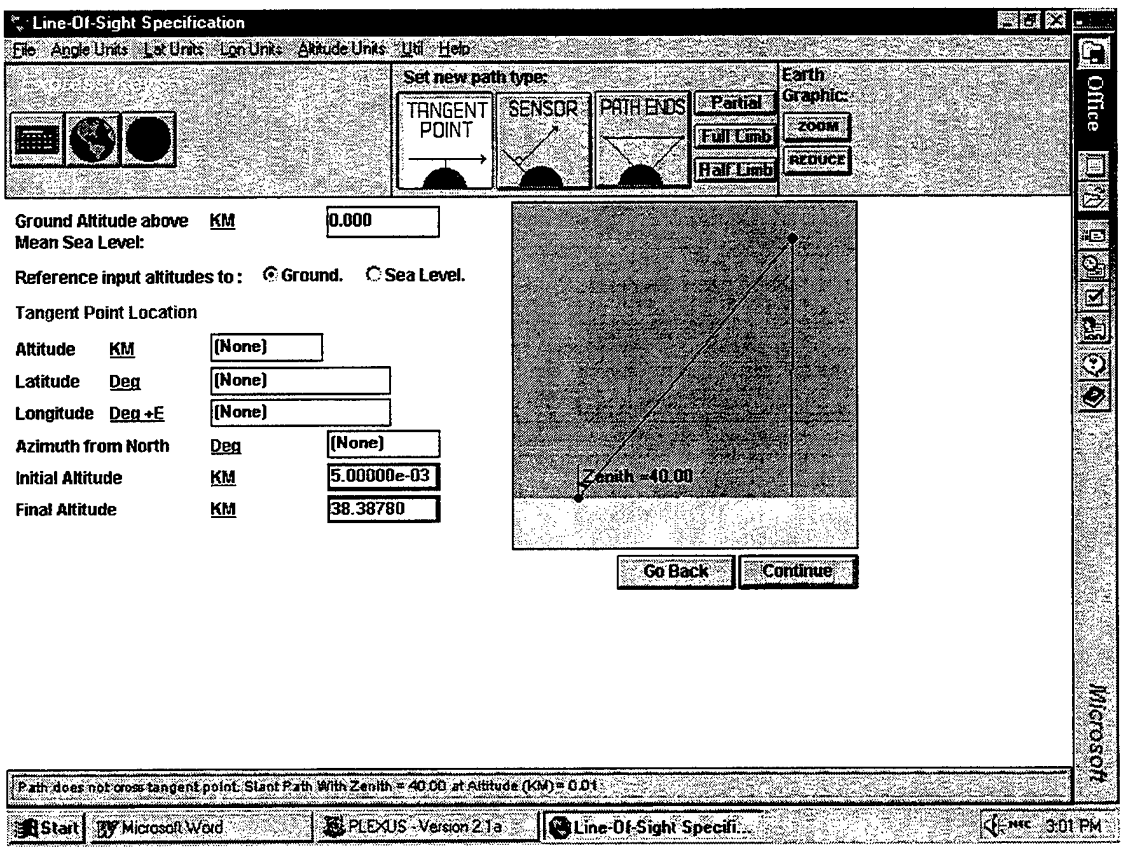

Figure 7. Line-of-sight Specification Screen

3.4.1 GEOMETRIC SPECIFICATIONS

The user can specify the line-of-sight inputs in one of the following geometric specifications:

3.4.1.1 Tangent Point Line-of-Sight

Tangent Point Altitude, Latitude, and Longitude; Azimuth angle at the tangent point; Observer and Target Altitude.

3.4.1.2 Sensor Parameters

- Observer Altitude, Latitude, and Longitude
- Sensor Zenith and Azimuth angles
- Path distance.

3.4.1.3 Observer and Target Positions

- Observer Altitude, Latitude, and Longitude
- Target Altitude, Latitude, and Longitude

The user is asked to enter values into edit boxes. Associated unit conversions can be accessed by clicking on the blue labels or via the pull down menus described in Section 3.4.2. Additionally, Express Keys provide an alternate way to enter data into the edit boxes.

3.4.2 PULL DOWN MENUS

Pull down menus are displayed with the following choices:

3.4.2.1 Altitudes

Altitudes may be specified in meters, kilometers, feet, miles, nautical miles, inches, astronomical units, or light years. The altitudes may be referenced to Ground or to Mean Sea Level. The range is limited to positive values. The accuracy is limited to several decimal places.

3.4.2.2 Latitudes

Latitudes may be specified in decimal degrees or degrees-minutes-seconds. The range is from -90 (South Pole) to +90 degrees (North Pole).

3.4.2.3 Longitudes

Longitudes may be specified in decimal degrees or degrees-minutes-seconds either positive East of Greenwich (SHARC convention) or positive West of Greenwich (MODTRAN convention). The range for longitude is from 0 to 360 degrees or from -180 to +180 degrees.

3.4.2.4 Angles

Angles (such as zenith angles and azimuth angles) may be entered in either degrees or radians. The range for zenith angle is 0 (Zenith) to 180 (Nadir) degrees. The range for azimuth angles is from 0 (North) to 360 (North) degrees and is referenced to be positive East of Due North.

3.5 TIME OF OBSERVATION

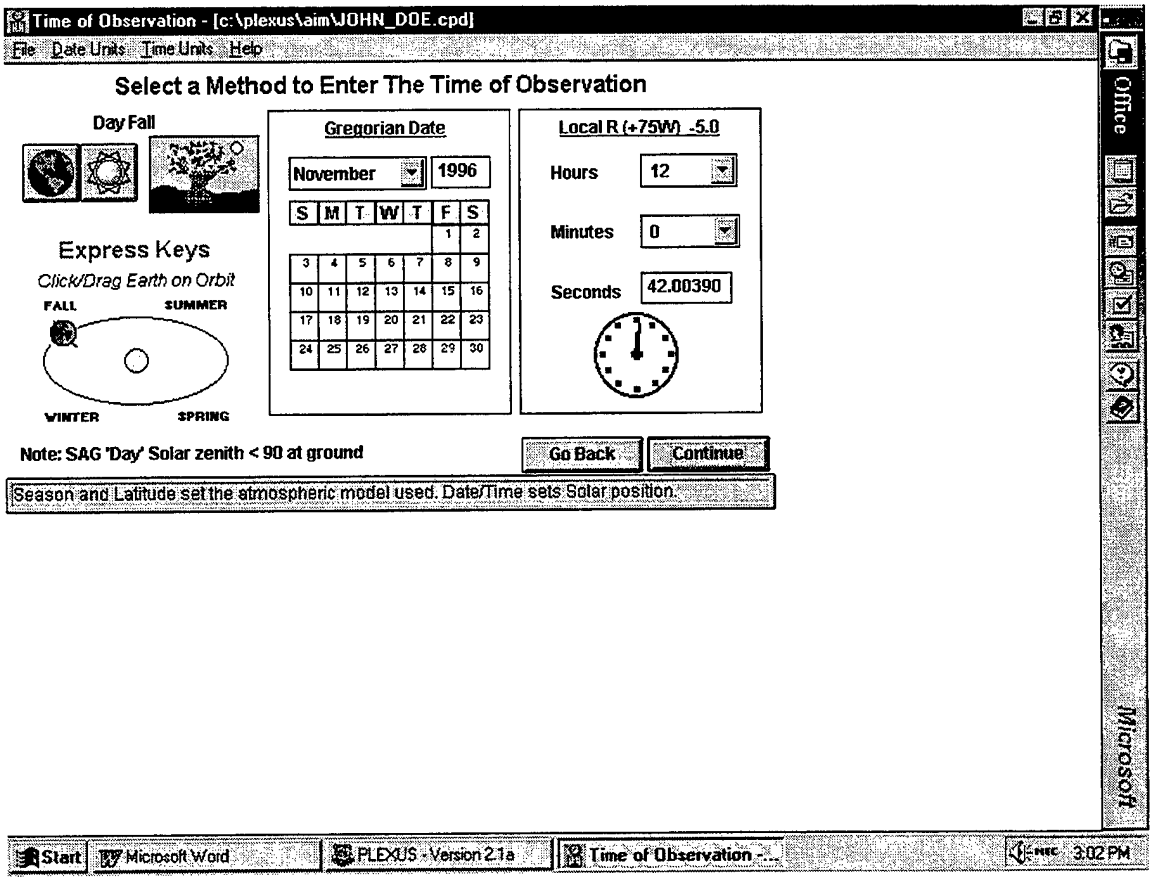

Figure 8. Time of Observation Screen

PLEXUS displays a default Observation Time input based on the system clock. This screen allows the user to enter the following related variables: Date of Observation, Season, and/or Time.

3.5.1 EXPRESS KEYS

3.5.1.1 Earth Orbit around Sun

The "Earth Orbit around Sun" graphic shown in Figure 8 is an Express Key to quickly input a date for a particular season. Click any point on the orbit to reposition the Earth icon and update the season and date; or click and drag the Earth icon along the orbit.

3.5.1.2 Clock

The clock icon shown in Figure 8 provides the analog rendering of the input time. Users may also click on the dial to set the hour and minute hands.

3.5.2 Defaults

If the user wishes to change the defaults, he may pull down the menus to access the following:

- Date Units: Gregorian, Julian, Day-of-Year
- Time Units: Local, Greenwich, USA, South America, Africa, World Time Zones

3.5.3 Gregorian

When the Gregorian unit is selected, the user is presented with a calendar as shown in Figure 8. The month is selected by choosing a value in the drop down list box. This will automatically update the calendar layout. By clicking the day box, the selected day is highlighted in red text. The integer year is entered in an edit box in which a negative number indicates year B.C. Changing the date automatically updates the Season graphic and the Earth Orbit graphic. The time is specified by selecting the hours and minutes from the drop down list boxes and by entering the decimal seconds in the seconds edit box. Any time zone can be selected by clicking the underlined blue field or by selecting TIME UNITS from the menu bar. The number of hours difference with respect to Greenwich is provided at the right hand side of the text field.

3.5.4 Julian

When Julian date units are selected, the user is presented with an edit box in which to enter the decimal Julian date.

3.5.5 Day-of-the-Year

When Day of the Year and Year units are selected, the user is presented with two edit boxes in which to enter the integer day of the year (1 to 365 or 366 for leap year) and the integer year. Negative years indicate years B.C. The time is specified by scrolling through the hours and minutes list boxes and entering the decimal seconds in the seconds edit box.

The default is a case with date and time of the computer system. Here, the computer clock time is assumed to be at the selected time zone. The day of the year is computed from the date and used to determine the season (northern hemisphere bias: day of the year between 81 and 172 is set to spring, 173 to 264 is summer, 265 to 355 is fall, ≥ 356 or ≤ 80 is winter). The date/time and observer location are used as inputs to the SAG model atmosphere code.

The day and time inputs are used by **PLEXUS** to determine the positions of the Sun and Moon. The solar position information is annotated on the Geometry View tool picture of the world map. **PLEXUS** also computes the solar zenith angle for use in SHARC. Before the Environmental Parameter screens appear, the user can choose to enter new values for the subsolar latitude and longitude.

3.5.6 Special Tools

The **PLEXUS** Time of Observation input screen features three additional tools:

1. The calculation and reporting of the Sun's location,

2. A graphical view of the line-of-sight, and

3. The calculation and reporting of the (northern hemisphere) season and day/night status.

3.5.6.1 The Solar Information Button

The Solar Information Button reports the subsolar locations and the solar zenith and azimuth angle with respect to the observer. The system determines whether or not it is a day case or a night case and reports that information here and in the Season Viewer described in Section 3.5.6.3. Additionally, the system determines the day/night case prescribed by SAG. This information is reported here and at the bottom of the Time of Observation screen.

3.5.6.2 The Geometry Viewer

The Geometry Viewer allows the user to visualize the line-of-sight and the subsolar and sublunar locations. The world continent and island boundaries are depicted with the observer, path end, and tangent point geographic regions annotated. The maps may be in one of four projections: Greenwich Rectangular, Longitude 180 Rectangular, North Pole Circular, and South Pole Circular.

3.5.6.3 The Season Viewer

The Season Viewer allows the user to visualize the season and whether the case is a day or night scenario. This tool is always displayed on the screen and its 5 possible states are winter day, spring day, summer day, fall day, or night as shown in Figure 8. The seasonal states displayed are relative to the Northern Hemisphere.

3.6 Selecting the Type of Output

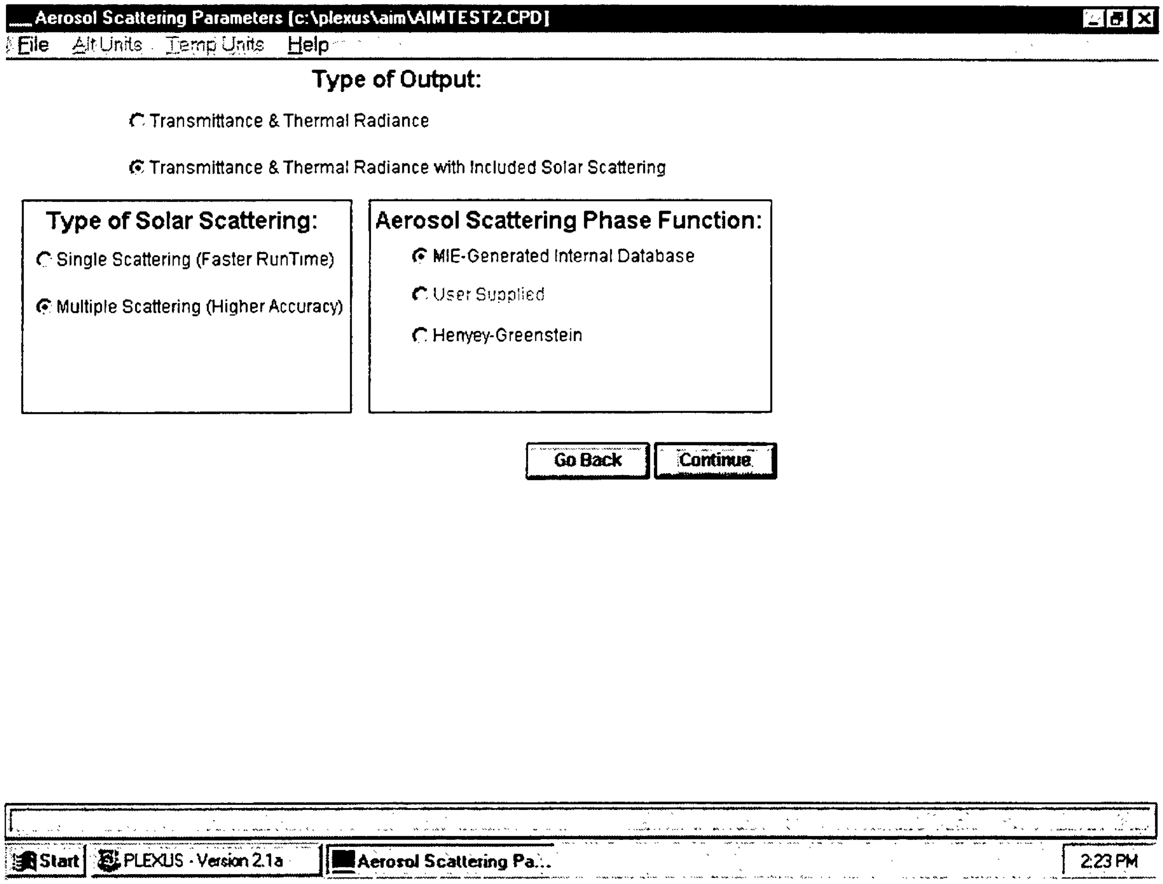

Figure 9. Type of Output Screen

While PLEXUS (exclusive of CBSD) always calculates transmittance, the user may control the calculation of radiance and the quantity of information reported in the output. These inputs are derived from the choices selected by the user on the above screen.

MODTRAN3 calculates both the transmittance and the emitted atmospheric radiance of the path. The MODTRAN3 output includes the total transmittance, total radiance, and the component radiances for each molecular band, continuums, aerosols, etc. Only the total transmittance (i.e., the product of each of the transmission components) is reported in the outputs. To analyze the component radiances and transmittances, the model must be executed both with IEMSCT=0 and with IEMSCT=1.

3.6.1 Radiance with Scattering (IEMSCT=2):

MODTRAN3 calculates the path transmittance and the path-emitted radiance, with the inclusion of solar and lunar radiance single scattered into the path by the atmosphere. Multiple scattering is controlled by a separate variable, IMULT, which is only available when IEMSCT is 1 or 2.

3.6.2 TRANSMITTED SOLAR IRRADIANCE (IEMSCT=3):

MODTRAN3 computes the solar emitted irradiance that passes through the atmospheric path from the Sun to the observer.

3.7 EARTH SURFACE PARAMETERS

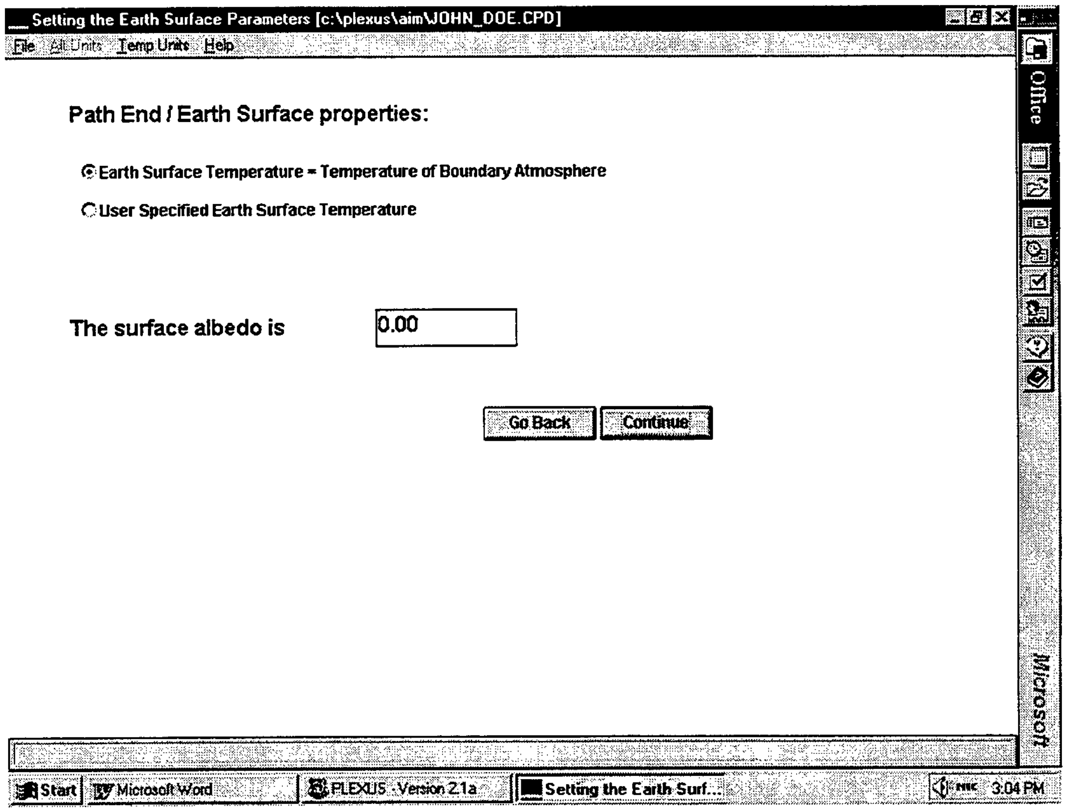

Figure 10. Earth Surface Parameters Screen

The screen shown in Figure 10 allows definition of the Earth Surface Albedo at the Path Origin and has values that range from 0.0 (blackbody) to 1.0 (perfect reflector) with the default being set at 0.0. The temperature of this radiating surface is set by the boundary temperature (TBOUND) on this screen. The reflectivity and temperature of the surface are used to calculate the greybody source spectrum from the origin of the path.

3.8 BOUNDARY LAYER AEROSOL PARAMETERS

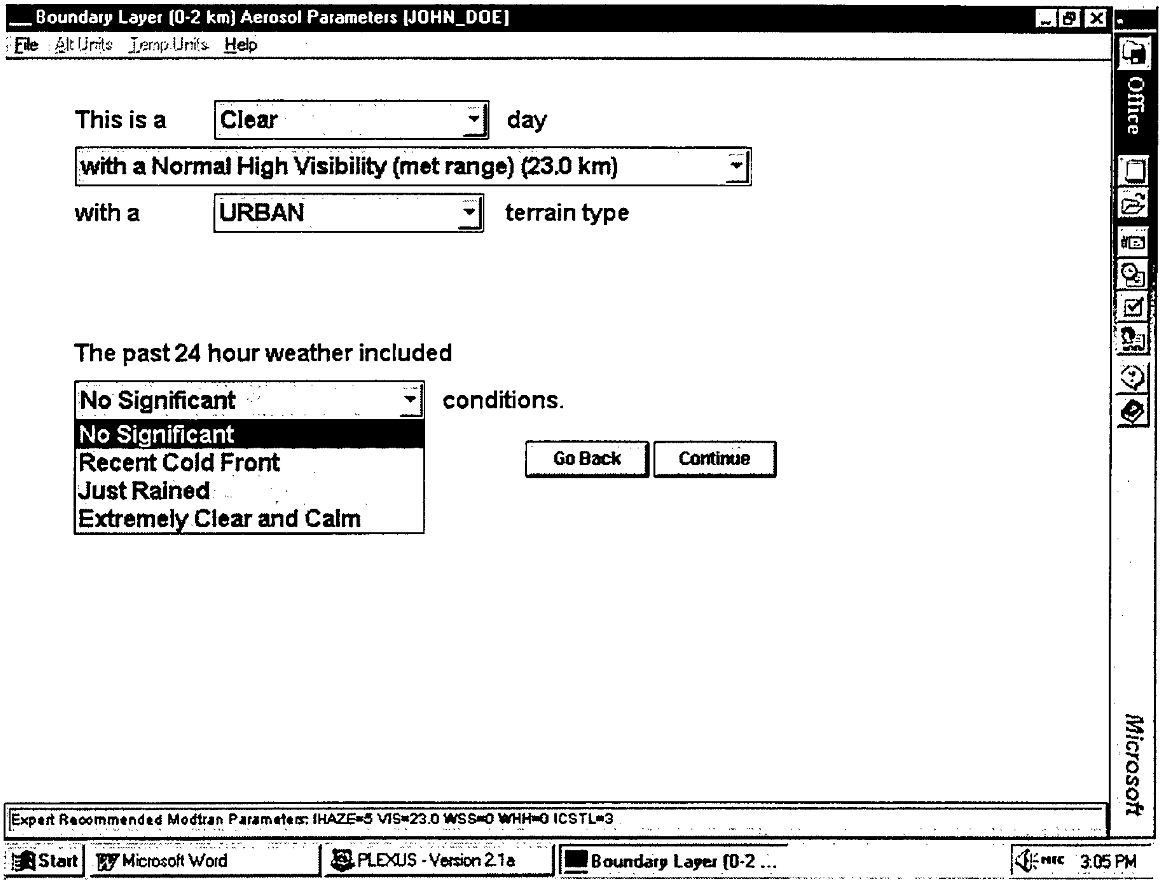

Figure 11. Boundary Layer Aerosol Parameters Screen

The screen in Figure 11 is one of a series used to set the boundary layer conditions that may affect a given **PLEXUS** run. It is through the Boundary Layer Aerosol Parameters Screen that the parameter IHAZE is set to one of the representative aerosols and a default meteorological range is also established. The default meteorological range is overridden if VIS is a non-zero value. A detailed description of how to select the appropriate model is provided in the Section *"How To: Use Representative Aerosol Models For The Boundary Layer"* of the **PLEXUS** on-line hyper-text HELP.

Interpolations of the extinction coefficients based on relative humidity are performed only for the Rural, Maritime, Urban, and Tropospheric coefficients. The relative humidity dependence of the coefficients is based on the water vapor content of the model atmosphere selected by MODEL.

For modeling ocean aerosols, the Navy Maritime model (IHAZE=3) is recommended over the Maritime model (IHAZE=4) since the former model contains an explicit dependence on wind speed. The Navy Maritime model requires the specification of the current wind speed (WSS), the 24-hour average wind speed (WHH), and the weighted inclusion of continental aerosols (ICSTL). The Navy Maritime model cannot be used if the lower bound of the spectral range (IV1) is below 250 cm-1. If IV1 is less than 250 cm-1, the Maritime model (IHAZE=4) should be used instead.

If the desert aerosol model (IHAZE=10) is selected, the current wind speed (WSS) should be set to determine the aerosol concentration.

3.9 STRATOSPHERE AEROSOL PARAMETERS

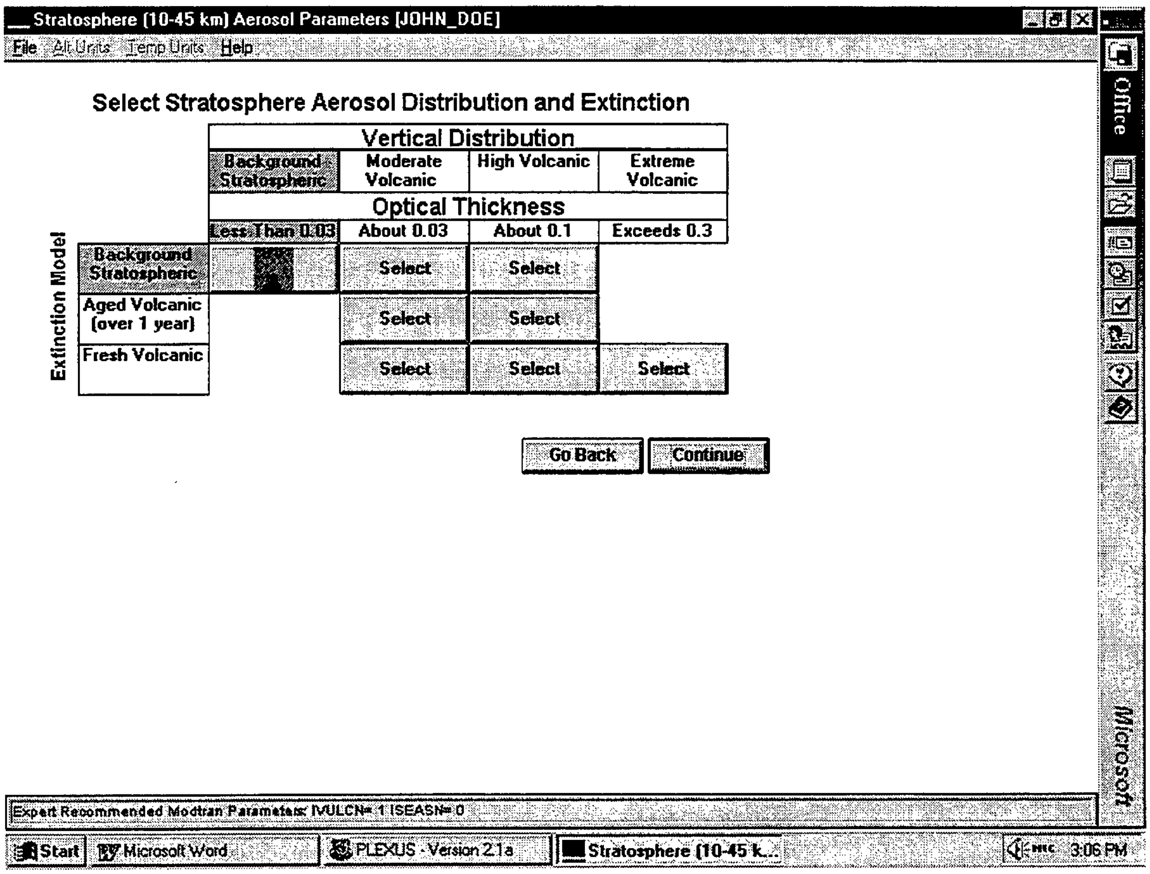

Figure 12. Stratosphere Aerosol Parameters Screen

The Stratosphere Aerosol Parameters Screen is used to set the parameter IVULCN, which selects the extinction model and aerosol profile (vertical distribution) for the stratospheric layer (10 to 30 km) and determines transition profiles from 30 to 100 km. Meteoric dust extinction coefficients are always used for altitudes from 30 to 100 km. Unless there has been recent, severe volcanic activity, which could affect simulations in the upper atmosphere, the user can generally use the **PLEXUS** defaults.

Examples of the range for the parameter IVULCN are as follows:

IVULCN	Extinction Model	Volcanic Profile
0, 1	Background Stratospheric	Background Stratospheric
2	Aged	Moderate
3	Fresh	High
4	Aged	High
5	Fresh	Moderate
6	Background Stratospheric	Moderate
7	Background Stratospheric	High
8	Fresh	Extreme

In the stratospheric region (10-30 km), the background aerosols have a uniform global distribution. The "background" aerosols are composed of sulfate particles formed by photochemical reactions. However, due to sporadic volcanic explosions, volcanic dust in the stratosphere exhibits extreme variations in concentration (vertical profile) and average particulate size (as the particles age), which influences the extinction coefficient. MODTRAN3 offers three wavelength dependent extinction coefficient models:

- Background Stratospheric,
- Aged Volcanic, and
- Fresh Volcanic.

MODTRAN3 offers four vertical distribution profiles:

- Background Stratospheric,
- Moderate Volcanic,
- High Volcanic, and
- Extreme Volcanic.

IVULCN specifies both the size (age) of the particulates and their concentration by providing combinations of these features in a single input.

3.10 OUTPUT TITLE DESIGNATION

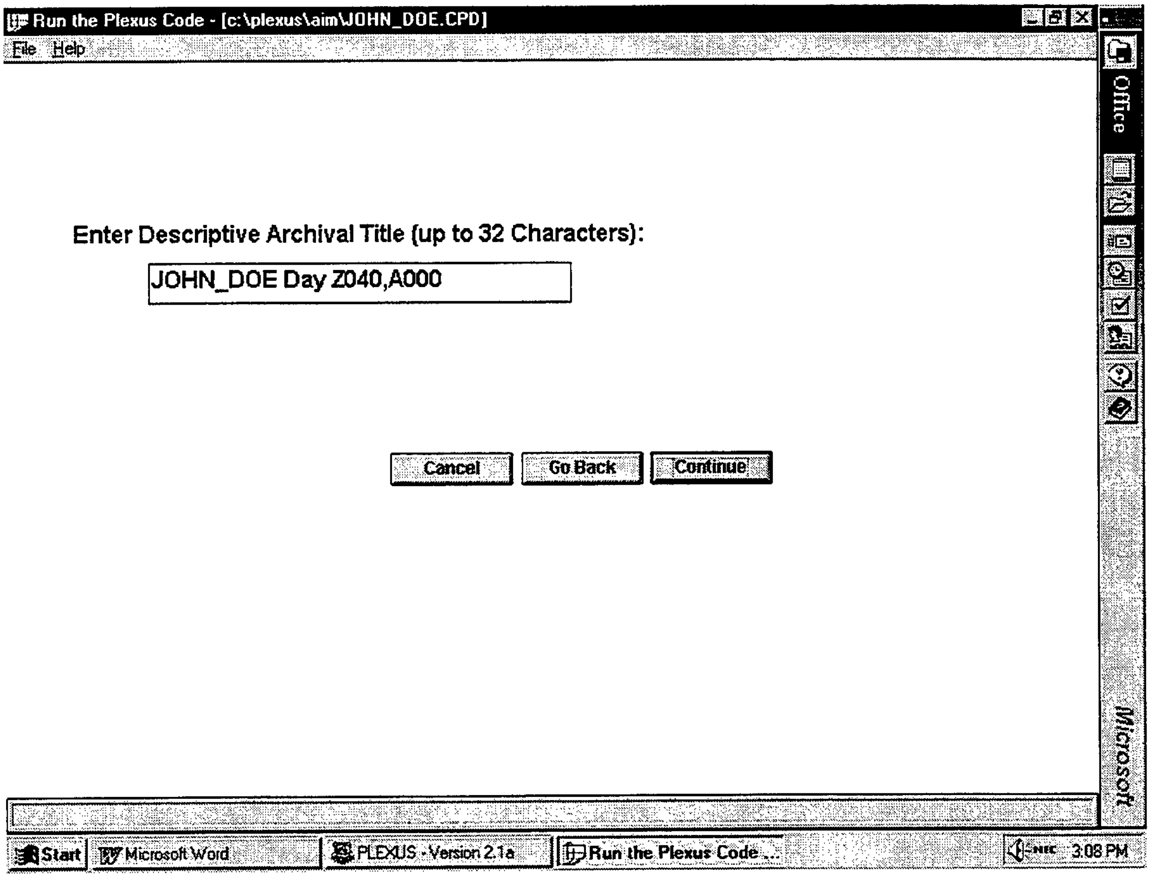

Figure 13. Output Title Designation Input Screen

One of the last inputs before beginning computations is for the user to indicate a description of the file contents. This description will be displayed on the output plots (see Figure 17 and Figure 18). **PLEXUS** allows for the use of up to 32 characters in order to make file naming descriptive and thus easier to track.

3.11 RAPID RESPONSE

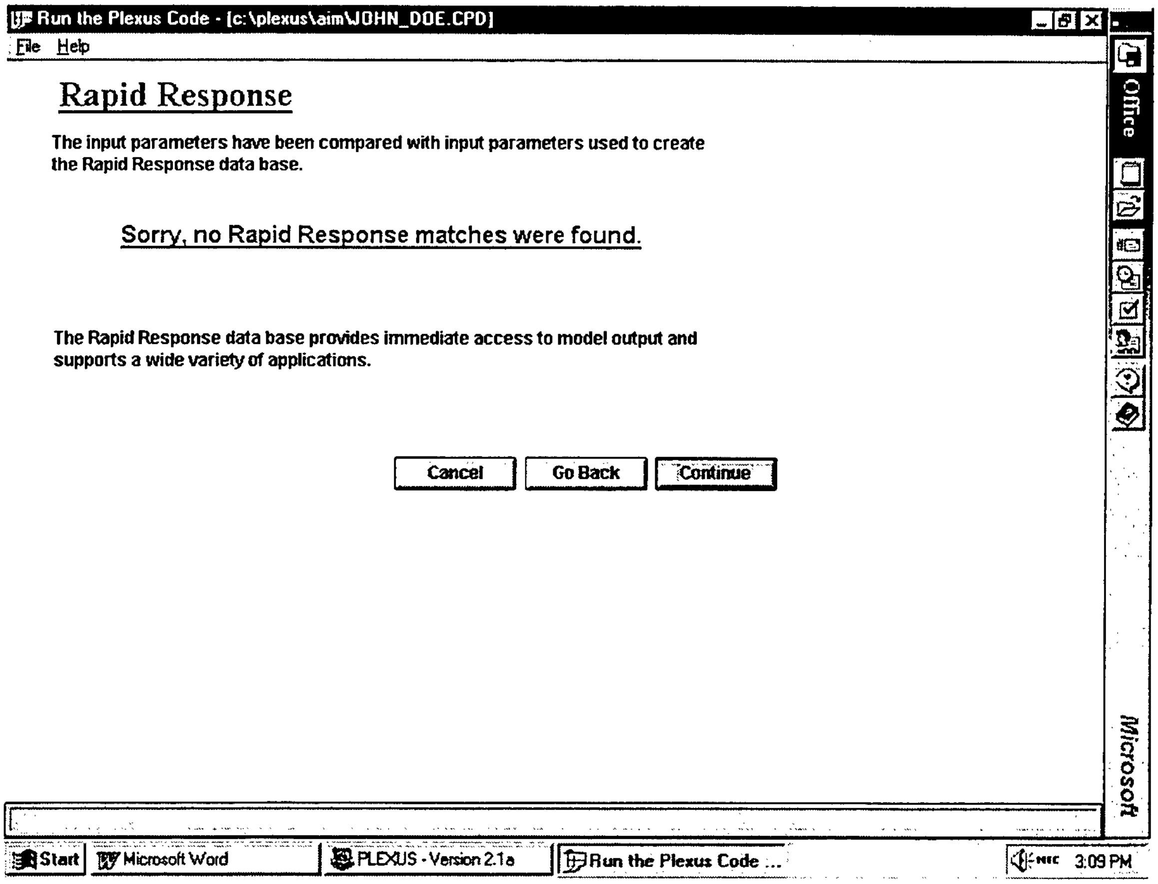

Figure 14. Rapid Response Check Screen

At this point in the **PLEXUS** Run, the expert system goes out and compares the present problem inputs to the inputs of **PLEXUS** runs that may already be on file in the rapid response database. In the case of the example shown in Figure 14, **PLEXUS** has determined that there is no comparable computation already on file. The Rapid Response pre-computed database consists of pre-calculated spectra of radiance and transmittance in the quiescent and auroral atmospheres wherein MODTRAN1 and SHARC2 results are combined.
A representative set of LOS (full limb, half–limb, and zenith) provides quick access results.

3.12 Running the PLEXUS Code

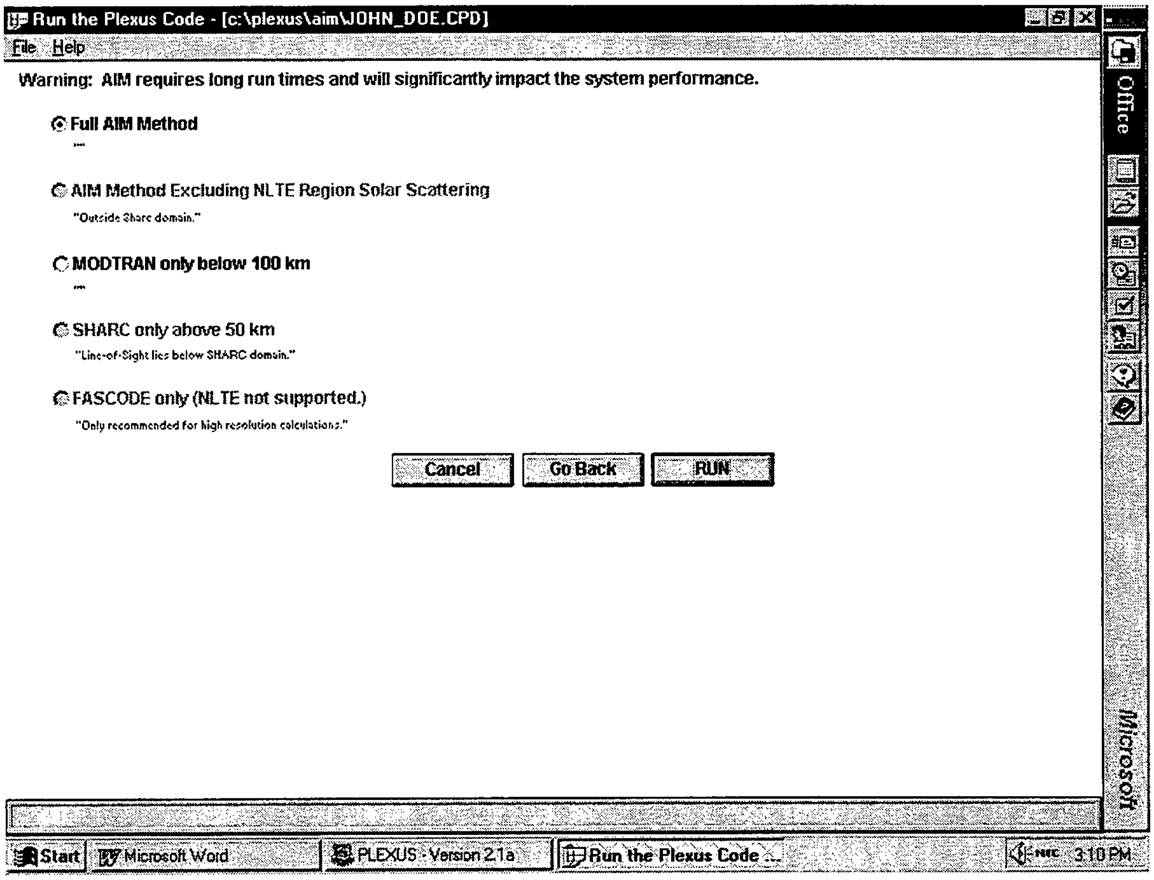

Figure 15. Run the PLEXUS Code Screen

Based on the user's inputs to this point, the expert system has selected the suitable codes that apply to the problem and provides the user with a set of radio buttons to start computations along with providing any warning messages to heed before starting the calculations. For the example shown, the expert system has determined that either the full AIM method or MODTRAN only are appropriate; however, the expert system has also issued a warning to the user in red letters that the full AIM method may require a long run time and could impact system resources, depending on the type of platform.

3.13 Running MODTRAN in a DOS Window

Figure 16. MODTRAN Running in a DOS Window

Once the user launches the **PLEXUS** application, the AFRL codes selected from the choices offered by the expert system begin to execute inside a DOS window. The user is able to watch as the application output and program messages scroll down the screen inside the DOS window. Upon completion of the computations by the legacy FORTRAN module(s), the DOS window closes automatically and the display and analysis functions of the GUI begin processing the output into visual displays shown in the screens that follow.

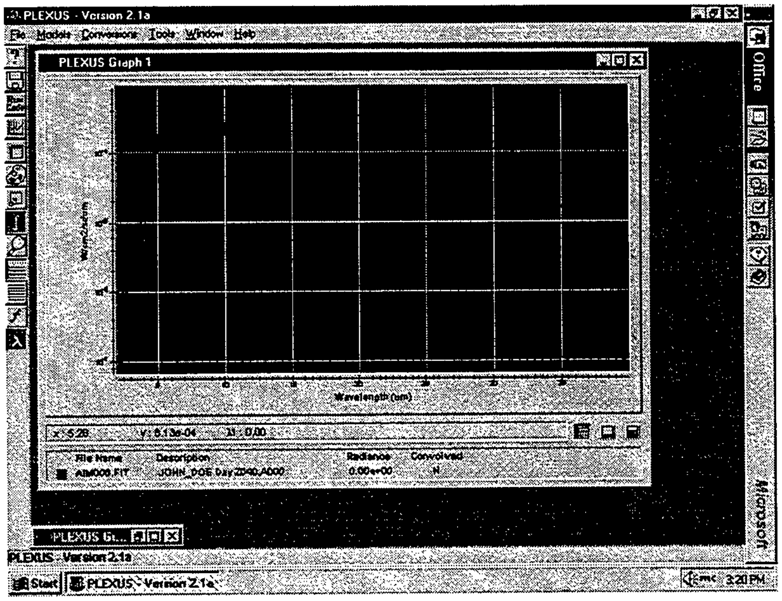

Figure 17. Screen Showing the Results of the Radiance Computations

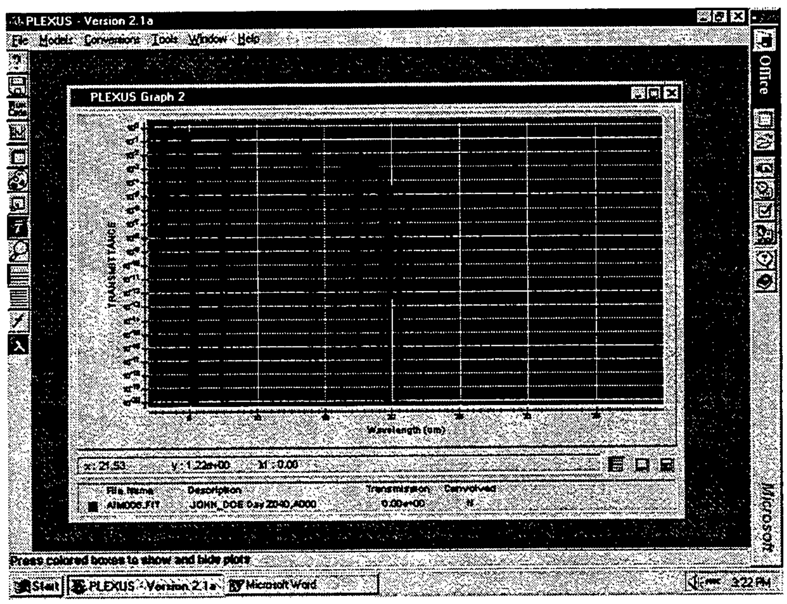

Figure 18. Screen Showing the Results of the Transmittance Computations

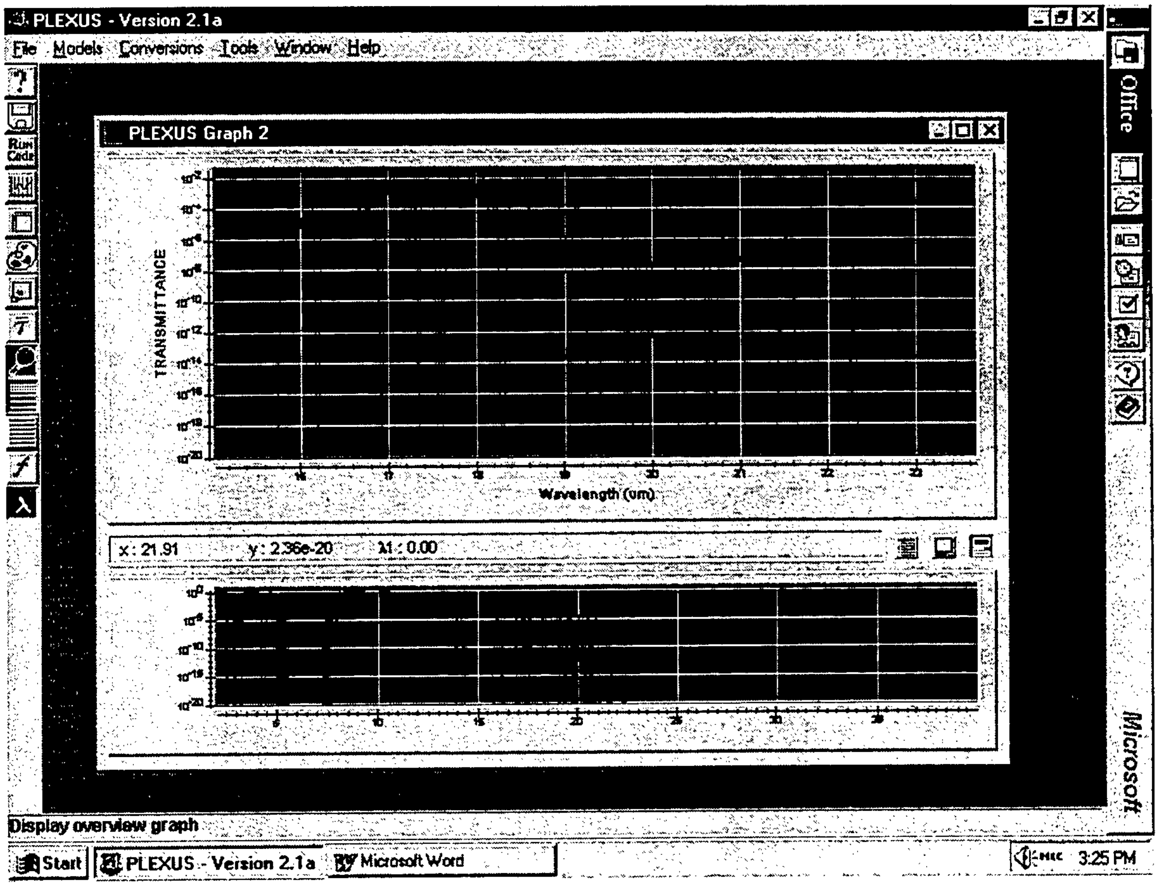

Figure 19. Example of a Spectral Overview Window

Once the user has set up a problem and the calculation is completed, the results are stored in output files that follow the Flexible Image Transport System (FITS) format – the standard format used for transferring data in the astronomical community. The output files generated by the AFRL codes but not saved by **PLEXUS** can be found in the code input directories. The AFRL code output files will be overwritten the next time that code is executed.

3.13.1 VIEWING OUTPUT FILES

The **PLEXUS** output files can be viewed via the menu command File|New|Open or the disk icon on the toolbar. After the command is chosen, a File Open dialog box appears for the user to select the files to be shown. More than one file can be chosen at a time provided they exist in the same subdirectory. The user is provided with a line of descriptive text for a spectral or text file or a postage stamp size view of the image for an image file.

3.13.2 CREATING A NEW WORKING WINDOW

The menu command File|New always creates a new working window while the command File|Open or the icon creates a new window only if no previous window of the same type is present; otherwise, the data is overlaid on top of the pre-existing window.

3.13.3 Spectral Window

Spectral data are displayed in the Spectral Window. Each spectrum is plotted with a unique color, which is duplicated in a small box next to the filename in the File Description Window. By clicking in this small box, the spectrum will become invisible. The File Description Window gives information on the spectra such as filenames, descriptive text, intensities, and in-band values.

3.13.3.1 Dynamic Status Bar

Also present is a Dynamic Status Bar located below the Spectral Window. This status bar displays the position of the cursor in the Spectral Window and the spectral limits of the hairlines used to define a spectral region. **PLEXUS** also provides an Overview Window, which displays spectra for the entire spectral range. When visible, it appears in the same location as the File Description Window.

3.13.3.2 Overview Window

The Spectral Window permits the user to display either the entire data set or a portion of the spectral region while the Overview Window always displays the entire plot. The two windows (Spectral and Overview) are linked so that any action in one graph affects the other graph. The user can quickly change among the three display configurations by selecting one of the three icons adjacent to the Dynamic Status Bar.

3.14 THE PLEXUS HYPERTEXT HELP UTILITY

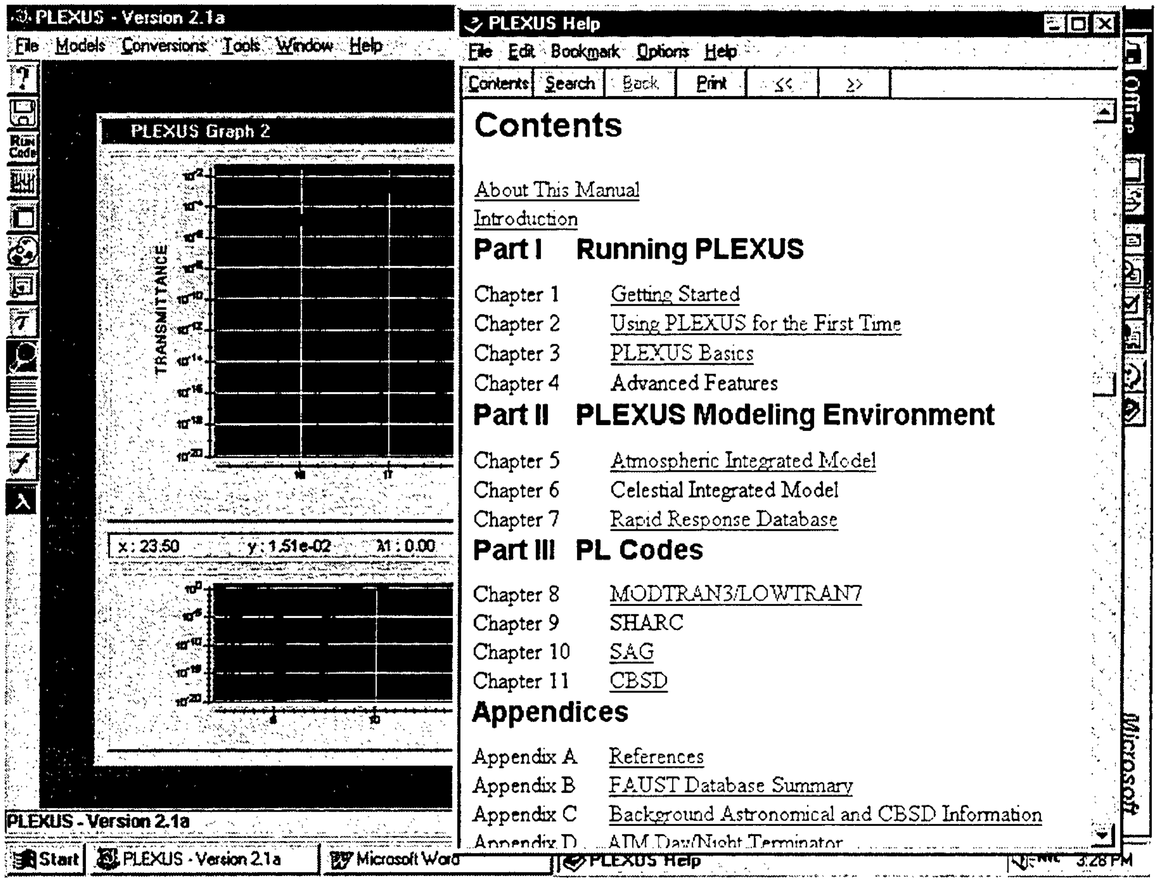

Figure 20. Sample of the PLEXUS HYPERTEXT HELP Utility

PLEXUS has a detailed, commercial grade, HYPERTEXT HELP Utility that can be accessed from any of the GUI screens, or can be run in a separate window by itself. The HYPERTEXT HELP has been designed to be an electronic replica of the User's Guide distributed with the software. The User's Guide is also contained on the CDROM along with a copy of Microsoft WordView™ to allow users to print out desired portions of the guide for internal distribution or instruction on how to use **PLEXUS**. Having the User's Guide available in soft form on the CD also saves distribution costs when multiple copies of the software are shipped to a single organization.

3.15 REFERENCES

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4. The PLEXUS Return on Investment

As noted in the executive summary, **PLEXUS** has been distributed as a commercial grade software package to over 200 users. Since **PLEXUS** is only distributed upon request, this number of users attests to its user-friendliness and to its utility. It has become one of the key E-O system design tools within the DoD and has become the primary vehicle by which the Phillips Laboratory suite of atmospheric effects tools are distributed to the DoD E-O community. As a result, Phillips Laboratory and the Air Force have gained the following payoff on their investment in **PLEXUS**:

4.1 Synergistic Effects On Existing AFRL Models

PLEXUS synergizes Phillips Laboratory Models into a more powerful tool than the models provide in their stand-alone, native state.

PLEXUS offers complete modeling of up-views from local thermodynamic equilibrium (LTE) region to space including the pumping of CO_2 and other species in the non-local thermodynamic equilibrium (NLTE) region. The **PLEXUS** plot in Figure 21 presents the results of just running MODTRAN for an up-viewing observer in green and the AIM Method in red. MODTRAN only underestimates the radiances. SHARC alone can't execute since the observer is below its 50 km lower limit.

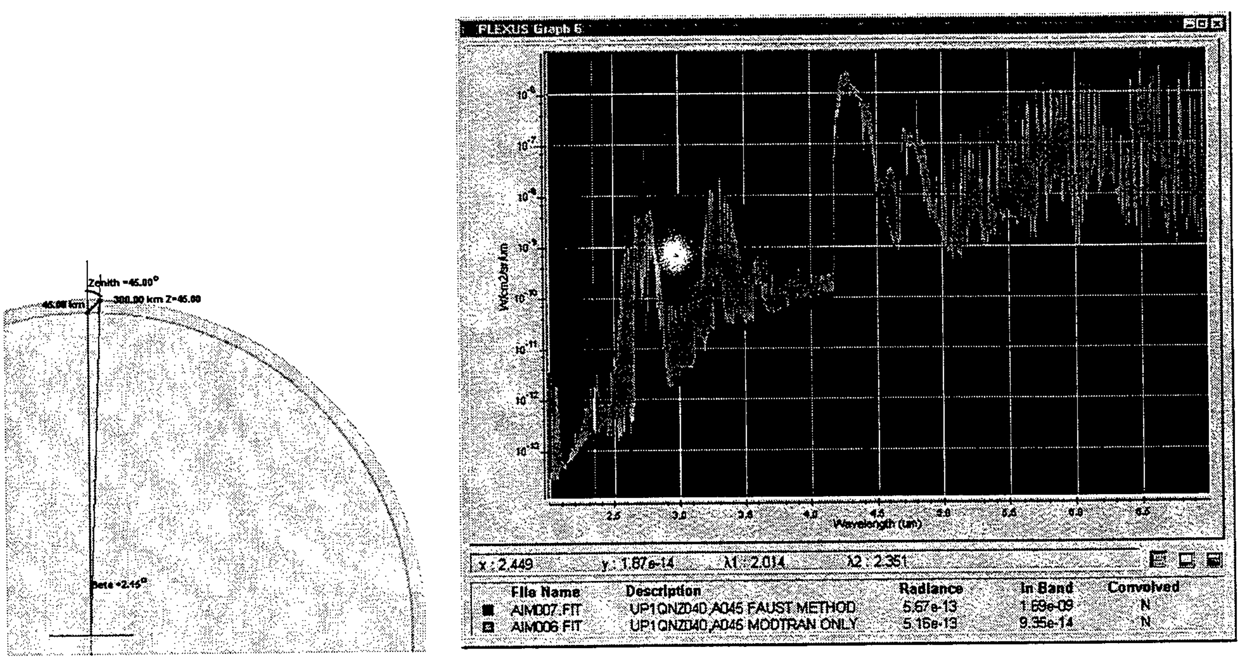

Figure 21. Example PLEXUS Plot

PLEXUS also offers complete modeling of down-views from NLTE region to the Earth surface. The **PLEXUS** plot in Figure 22 presents the results of just running MODTRAN (cyan for day case, green for night case) for a down-viewing observer and the AIM Method results (yellow for day case, red for night case). MODTRAN only underestimates the radiances. SHARC alone can't execute since path end is on the surface of the Earth.

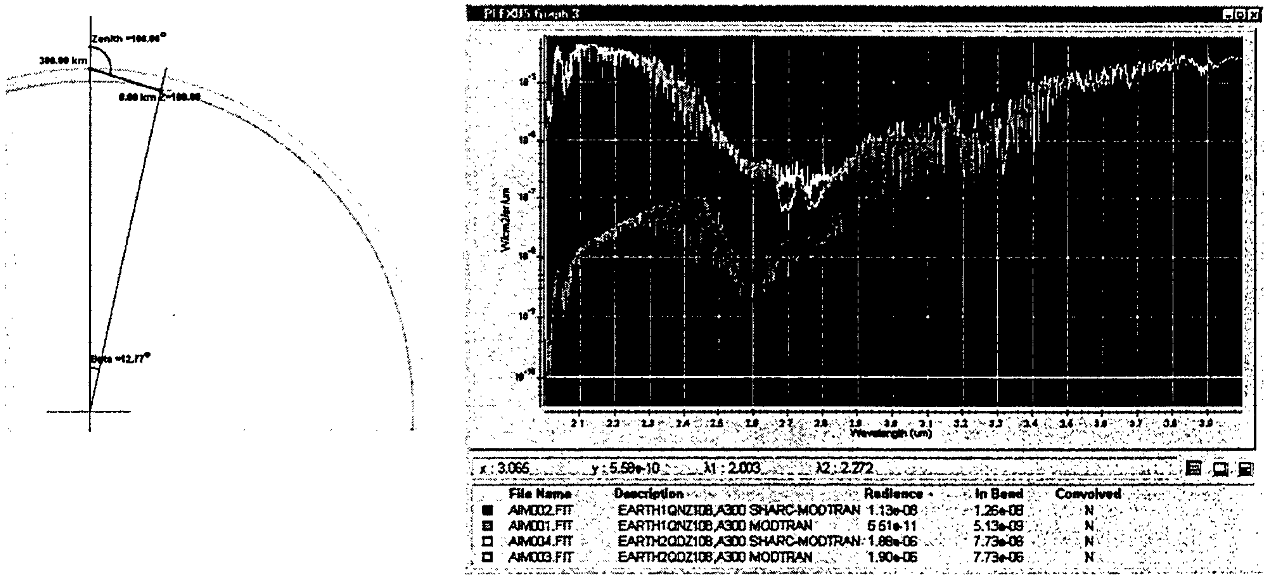

Figure 22. A Sample PLEXUS Plot

The above simulations cannot be easily performed in a seamless fashion in a single run with the AFRL codes in their stand-alone native state. Additionally, the expert system library of shared routines ensures that all code inputs are consistent:

* all use the same solar/lunar position calculation from the CBSD Sunmoon program and have a 2 arc second positional accuracy,
* the default atmosphere is a SAG calculation to ensure continuity even at the 50 km boundary,
* a geometry module allows the user to enter scenario geometries and computes the appropriate inputs for each AFRL code segment,
* a number of range and consistency checks to ensure a physically meaningful, self-consistent set of inputs.

4.2 PLEXUS Payoffs

- It provides easy, reliable application of the AFRL atmospheric effects codes, which levers the long term investment and research that has gone into these models over several decades.
- The commercial GUI-wrap architecture ensures continued use of the AFRL Models and expands their audience by making the models available to run on PC platforms.

- **PLEXUS** has saved, conservatively, at least 1 month level of effort that would be required to learn the application of just one of the AFRL atmospheric effects codes. At a cost of 12k per month LOE, this results in a salary payoff of $2.4M.
- **PLEXUS** has also resulted in a huge technical payoff which cannot be estimated as a result of assisting users in correctly computing the effects of the atmosphere on E-O weapon systems early on in the design phase.
- **PLEXUS** is currently the only "shrink wrapped", COTS-grade design tool that is being distributed by AFRL. Not only is it an example of the Lab's technical prowess as a center of excellence in atmospheric effects modeling, it also is a trend setter for other AFRL programs to follow if AFRL is to survive in today's competitive laboratory industrial funding environment.
- **PLEXUS** is on the leading edge of support to JMASS distributed system simulation support by turning AFRL E-O effects models into intelligent objects that can be applied to JMASS problems.
- **PLEXUS** has been adapted as a teaching tool by AFIT and the USAF Academy, thus making the AFRL models the standard by which future E-O Design tools will be judged by fast track Air Force Engineering Students who will become the SPO directors and Lab Commanders of the 21st Century Air Force.

5. Recommendations

The **PLEXUS** project has successfully met all its objectives, with the end of contract version, **PLEXUS** 2.1a, becoming one of the key E-O engineering design and operational support tools within the DoD. The future direction of the **PLEXUS** program will be based on the identification of evolving customer support needs to refine the present **PLEXUS** package while developing new support tools to meet new requirements of the DoD E-O modeling and simulation community. As a result of recent efforts under the current contract, the **PLEXUS** program is well positioned to meet future challenges in E-O support requirements and is poised to take full advantage of the continued rapid advancements in computer hardware, software development tools, operating systems, and computer network technologies, and advancement of the underlying atmospheric effects models.

5.1 Completion Of Rewrite To MFC

At close of contract, the rewrite of the **PLEXUS** GUI using Microsoft Foundation Class™ based C^{++} **PLEXUS** 3.0 is 90% complete. The intent of rewriting the GUI along with the adaptation of the more modular architecture developed in **PLEXUS** 3.0NI is to upgrade the **PLEXUS** code to ensure its compatibility with future Microsoft operating systems and to prepare the GUI for porting to UNIX. The MFC rewrite thus allows maintenance of a single code stream that is useable on multi-platforms. It also provides the basis to make the entire **PLEXUS** package a 32-bit based software package, vice the current mix of 16 and 32-bit applications. Completion of this task will be key to long term viability of **PLEXUS** in view of the present trend for PCs to move to 32-bit processing.

5.2 Port To UNIX

Although customer requirements for a UNIX based version of **PLEXUS** have been unsteady, the conversion effort to rewrite the GUI in MFC positions **PLEXUS** for porting the GUI to UNIX should it become necessary to meet this need at some future point. The port should be straightforward and can be completed with only a modest effort relative to the amount of code that must converted. One issue that needs additional exploration will be the expense of the conversion software and possible added license requirements that may be needed to distribute the UNIX version of the MFC GUI.

5.3 Initial User Defined Atmosphere Input Capability

A minimal User Defined Atmosphere (UDA) capability was developed using **PLEXUS** 2.1a as a test bed. This UDA prototype was then integrated into **PLEXUS** 3.0NI (PC). Although only an initial start, the UDA has the capability to ingest ASPAM (1 of 3 formats), WSI formatted Rawinsonde data, and AirGPS Sonde formats.

A copy of the 2.1a UDA test bed was also supplied by AFRL to WL for field test and evaluation. ***The initial UDA is a major step forward in PLEXUS capability; however, it is far from complete and this will require significant testing, detailed***

knowledge engineering and integration with the CLIPS expert system. Extensive beta test and verification and additional user feedback on additional features will be needed to make this a fully operational tool within the PLEXUS package.

5.4 Refinement Of PLEXUS 3.0 Non-Interactive Version For Simulation Support

Although operable, **PLEXUS** 3.0NI will require additional work on the expert system interaction and functionality to make this product as reliable as the current PC version, **PLEXUS** 2.1a. This work may or may not be completed in the near future due to the unsteadiness of the requirement and the unstable funding associated with this requirement.

5.5 PLEXUS Web Page and Future Tech Support via the Web

With the widespread use of the INTERNET that has developed during the life of the current contract, AFRL may want to consider developing a **PLEXUS** Web Page to replace the current **PLEXUS** FTP site. This could be used to enhance technical support to current **PLEXUS** Users and could also be used to increase availability of the **PLEXUS** package to the DoD and its subcontractors involved in E-O Research and Development.