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User's Guide for the Thermal Analyst's Help Desk Expert System

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User's Guide for the Thermal Analyst's Help Desk Expert System

Rachel A. Ormsby

January 26, 1994

The following is a user's guide for the expert system software, Thermal Analyst's Help Desk. Thermal Analyst's Help Desk was created to assist the thermal engineer in obtaining a first approximation for the thermal capacity of a spacecraft. Analyses can be performed on a single flat plate or a rectangular box enclosure. The enclosure analysis can be performed at a single orbit point or at a user-defined number of orbit points. The orbit itself may be any elliptical conic section around any planet.

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1 INTRODUCTION

1.1 PURPOSE

This document is designed to give the user a "hands-on" guide for running the Thermal Analyst's Help Desk, version 1.0 (also referred to in this document as Help Desk). The document gives an overview of using the expert system shell EXSYS®, installing Help Desk and a description of each analysis performed by Help Desk. The analysis for each option is explained showing all screens and describing each input.

1.2 SAMPLE APPLICATIONS FOR HELP DESK

1.2.1 Surface

Some of the surface analysis options are:

- calculate the surface area of a radiator (Figure 1) given the total heat load to dissipate and the temperature of the surface
- calculate the surface area of a radiator for a spacecraft bus subjected to environmental radiation, given the internal heat load to dissipate.
- calculate the surface temperature of a radiator for a spacecraft bus subjected to environmental radiation, given the internal heat load to dissipate.
- calculate the environmental equilibrium temperature of a surface

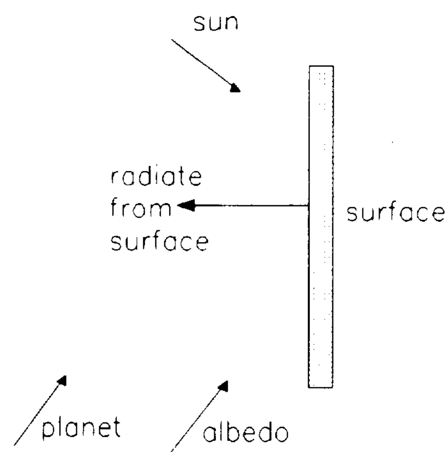

Figure 1 Surface Analysis Geometry

- calculate the surface area of a radiator to keep an enclosure at a given temperature (Figure 2)

1.2.2 Enclosure

Some of the analyses the enclosure analyses options are (Figure 3):

- calculate the "best" and "worst" case positions in the orbit. "Best" and "worst" being the most isothermal and the most nonisothermal positions, respectively.
- given the "worst case" position in the orbit, determine the temperature variations across the enclosure with a planet shield on the radiator.
- calculate the steady state temperature of the enclosure to determine the necessity for thermal coolers or heaters.

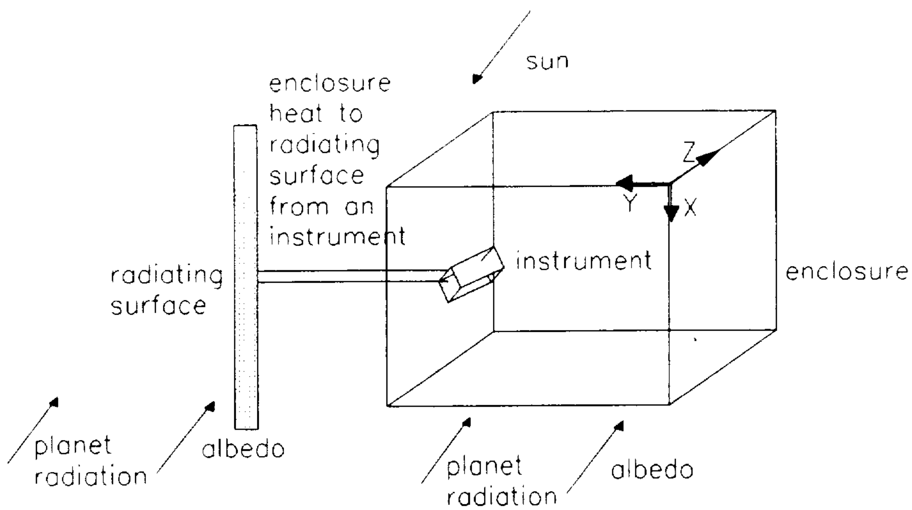

Figure 2 Enclosure Geometry with Radiating Surface

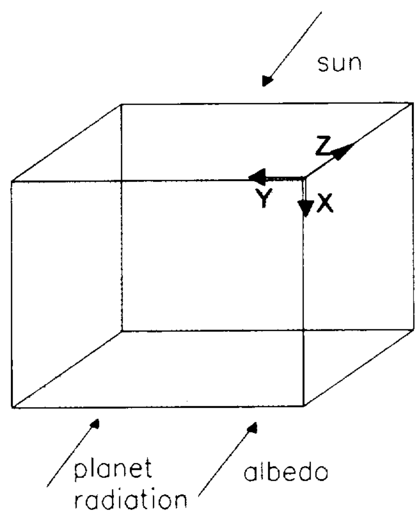

Figure 3 Enclosure Analysis Geometry

1.3 DOCUMENT ORGANIZATION

This guide is organized in two sections.

The first section is a description of EXSYS®. It contains a brief explanation of each of the four software packages available within EXSYS® and some notes on executing Help Desk.

The second section is a description of the Thermal Analyst's Help Desk. The user can choose an analysis and follow this guide as it is performed. The guide contains each of the screens encountered and explanations of the inputs. There is some repetition of inputs, because certain screens are used in more than one analysis. The figure containing the screen appears once at the first encounter of the screen. However, the description of the user inputs are included at each occurrence of the screen. In each case the figure containing the screen is referenced by figure and page number.

2 EXSYS®

EXSYS® is an expert system shell that has recently been modified for MICROSOFT® WINDOWS$_{TM}$. The current version of EXSYS®, version 4.0, requires MICROSOFT® WINDOWS$_{TM}$ version 3.1 operating in the 386 enhanced mode.

2.1 EXSYS® PACKAGES

EXSYS® has four software packages to aid in the development and maintenance of an expert system:

1) EDITXSP$_{TM}$ is a knowledge and rule base editor for the development and maintenance of the rules and the knowledge base. It includes debugging capabilities for checking the logic flow.
2) EXSYSP$_{TM}$ is a run time code that allows the execution of an expert system.
3) EXSYSRC$_{TM}$ is a rule compiler that enables the designer to compile an expert system written in the correct ASCII format. It offers the designer the use of a word processor to modify the knowledge and rule bases.
4) EXDESIGN$_{TM}$ is a screen editor which allows the designer to create interactive user screens.

2.2 EXSYS® MENUS

When executing Help Desk in EXSYSP$_{TM}$, the main menu provides several options:

File allows only file opening and closing.

Edit options are inactive during the execution of EXSYSP$_{TM}$, in the current version of EXSYS®.

Options has a notebook feature allowing the user to take or read notes while running the expert system. Options also has a help key, used in the same manner as other WINDOWS$_{TM}$ help keys.

Question is for input data retrieval and for asking questions of the expert system while it is running. It assists the user in interpreting the actions of the expert system. The user can ask the expert system questions and determine the current direction of logic.

- Known Data displays all of the currently known information.
- Why? is the expert system asking for a certain input?
- Display Rule display the current rule in the rule base and its status.
- Display Choices display the system choices and their status.
- Explain Question allows the user to ask EXSYS® about the logic flow
- Undo Prev. Answer undoes the most recent answer given by the user.
- Save Input saves all the current expert system information to an external file for recovery during a later analysis run.
- Recover Input recovers the information stored in an external file from a previous run. This option is a toggle switch. It should be selected before running the expert system. The data can only be recovered at the beginning of a run.

2.3 RUNNING DOS CODES FROM EXSYS®

The Help Desk may execute many DOS routines during an analysis. The user will be able to observe the execution, because the screen blanks out when Help Desk runs a DOS routine from the WINDOWS$_{TM}$ environment.

2.4 EDITING EXSYS® NUMBER BOXES

Custom screens are used to get information from the user as conveniently as possible. To change numbers on the screen:

1) Place the cursor in the exit box
2) delete the number using the delete or backspace key, or double-click on the number box, highlighting the whole number
3) type a new value

After entering a value **Do Not Hit The Return Key.** EXSYS® allows multiple lines of input, regardless of the size of the edit box. If the return key is pressed, the screen will appear to go blank, even though the number that was input is still there, but not visible. Therefore, if the return key is pressed after entering a number the first value entered will be used. EXSYS® will only process the number of data lines that the knowledge engineer assigned to the variable, which is defined in the knowledge base.

2.5 EXSYS® SCREENS

At the end of each analysis run, EXSYS® displays two helpful screens.

2.5.1 Results

The first screen (Figure 4), states that the analysis has been completed and whether a value has been found or not found. The buttons on the bottom are to assist the user in working with the finished analysis.

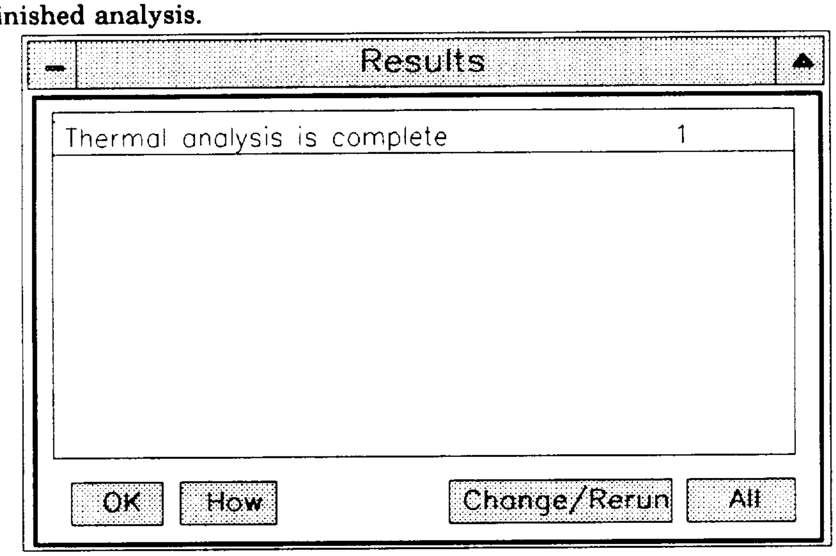

Figure 4 EXSYS® Results Screen

OK continue to the second screen, "Run Again?"

Change/ Rerun Allows the user to change any of the input variable and immediately rerun the analysis. When using this feature with Help Desk the final report screen is not redisplayed on the rerun analysis. Each report screen is attached to a variable, which initially has a null value. when the user presses the "continue" button on the report screen a value is assigned to the report screen variable. Once the variable is defined, it cannot be nulled. But, the expert system only displays the report screen when the variable has a nul value. However, the information is written to a report file. When selecting the report file options on the report results the user has three options:

1) write a new file	the information will be written over the file every time the user changes a value and reruns, unless the user also changes the file options using the Change/rerun button.
2) append to file	Help Desk will continue to append the information as long as the user continues the Change/rerun option.
3) no file output	no file output is generated

All Displays all of Help Desk Choices and their current values.

How Enables the user to determine the method used to deduce the result. To use this feature, highlight, from the list in Figure 4, the analysis to be checked. (In this example there is only one item on the list, "Thermal analysis is complete".) Press the How button. EXSYS® displays the value (in this case 1) and displays the rule that completed the analysis (Figure 5).

2.5.1.1 HOW?

The screen shows the rule number, the rule name and its status, TRUE or FALSE. It also shows the entire IF-THEN rule. There are three options at the bottom of the How screen (Figure 5):

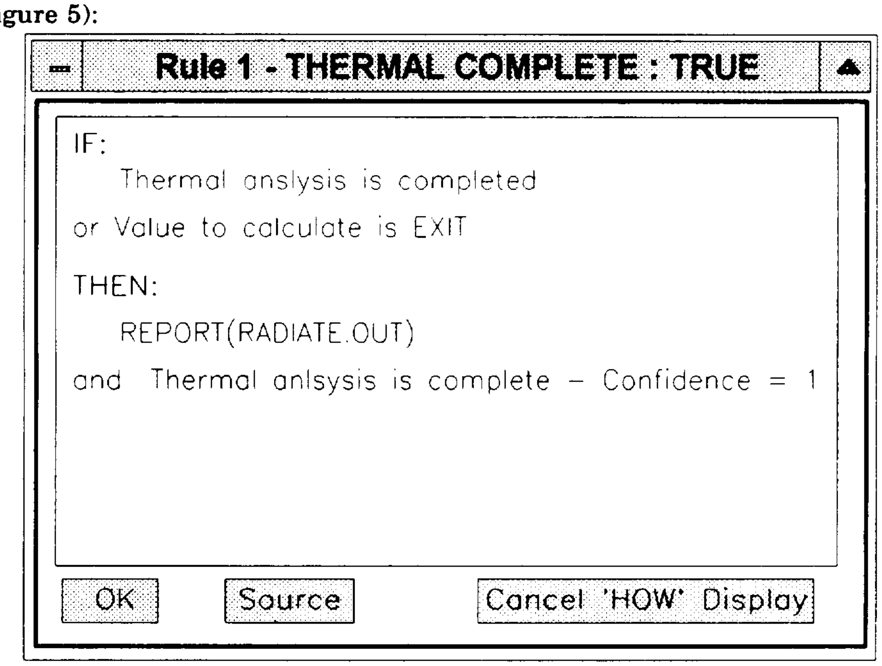

Figure 5 HOW Option, Rule 1

OK continues the analysis

Cancel 'HOW' goes back one screen in the rule stack.

Display

Source enables the user to trace the clauses in an IF-THEN rule. It works in a similar way as the How button. To use this feature, select the clause of interest from the IF-THEN rule and press Source. EXSYS® displays the next screen in the rule chain, which looks similar to Figure 5, but with the next rule and it's values. This procedure can be followed all the way to the end of the rule chain.

2.5.2 Run Again?

The second screen asks the user to "Run Again?", with Yes and No buttons. "Yes" returns the user to the main menu of Help Desk. "No" takes the user completely out of EXSYS®.

2.6 EXSYS® NOTES

EXSYS® does not accept scientific notation. All input variables must be entered as floating point numbers. If an external program returns a value in scientific notation, it is read into the expert system in floating point notation. Therefore, if any extremely large number is returned when expecting a small number, the user should refer to the knowledge engineer to check the format of the externally supplied values.

3 THERMAL ANALYSTS'S HELP DESK

The following is a description of the Expert System Thermal Analyst's Help Desk. It covers installing and running the different options in Help Desk. It includes information for each of the screens and variables.

3.1 SYSTEM REQUIREMENTS

Help Desk requires a DOS based computer that has a 386 processing chip or better (or equivalent) and operates in conjunction with the expert system shell EXSYS® version 4.0.

This document covers the Thermal Analyst's Help Desk, version 1.0.

3.2 INSTALLING HELP DESK

Follow the EXSYS® manual to install the EXSYS® software onto the computer.

1) create a subdirectory called "THERMAL" to the EXSYS® main directory.

   - activate the MICROSOFT® WINDOWS$_{TM}$ file manager
   - highlight the EXSYS® main directory
   - select the File Manager File menu
   - select the Create Directory option
   - type "THERMAL"
   - press the OK button
   - verify the directory was created
   - exit File Manager

2) copy the files from Help Desk disk to the THERMAL subdirectory

3) change the WINDOWS$_{TM}$ EXSYS® RUNTIME icon properties to have a working directory path to the THERMAL subdirectory

   - highlight the EXSYS® RUNTIME icon
   - select the File menu
   - select the Properties option
   - change the working directory path to include the THERMAL subdirectory
   - press the OK button

4) edit the RADIATE.CFG file. This is Help Desk configuration file. It can be accessed by any ASCII Editor, such as MICROSOFT® WINDOWS$_{TM}$ Notepad.

   The current file is displayed below.

   ```
   NODELETE
   PASS=c:\WINEXSYS\THERMAl\RADIATE.DAT
   RETURN=c:\WINEXSYS\THERMAL\RETURN.DAT
   TRACE=RADIATE.TRC
   ```

Modify the file to have the correct path on the PASS and RETURN commands, to the THERMAL subdirectory.

NODELETE
PASS=c:***EXSYS MAIN DIRECTORY***\THERMAl\RADIATE.DAT
RETURN=c:***EXSYS MAIN DIRECTORY***\THERMAL\RETURN.DAT
TRACE=RADIATE.TRC

5) save the file and exit the ASCII editor

3.3 RUNNING EXSYS®
To start EXSYS® double-click on the EXSYSP$_{TM}$ RUNTIME icon from the WINDOWS$_{TM}$ environment.

To open Help Desk expert system, select the File menu and then select Open... A list of available expert systems is displayed. Select the Thermal Analyst's Help Desk "RADIATE.RUL". The following screen specifies the name of the expert system, the author and a "RUN EXPERT SYSTEM" button. To start the system, press the RUN EXPERT SYSTEM button.

3.4 HELP DESK
The expert system displays a screen describing the purpose of the Thermal Analyst's Help Desk (Figure 6). Press the "Continue" button.

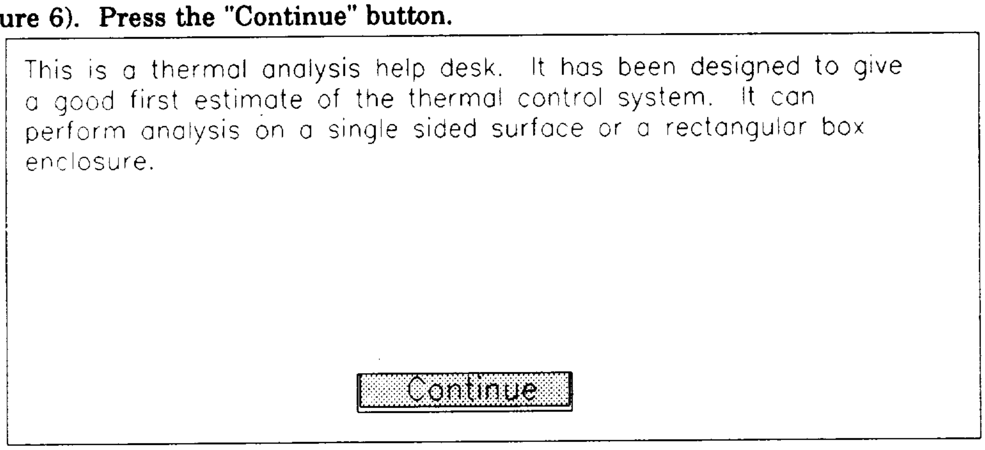

Figure 6 Description Screen

3.4.1 Default Data Files
Help Desk presents the user with many screens containing boxes to enter information. All the screens have default values displayed. These values are located in the default data files. All values chosen are explained in the description of the user inputs throughout this guide. The files are intended to make user input less tedious. Each file may be edited using an ASCII editor. Therefore, a user can change the default values for a specific configuration and have minimum modifications during an analysis run.

The default data is contained in two file locations. The first, "filename.DAT" is used during an analysis run, it contains the data used by the expert system. The second, "filename.DT!" contains all of the original default values. Once the series of runs is complete the user can reset the original numbers by copying the *.DT! files to the *.DAT files.

The format for the input data files is one variable per line. Each line corresponds to a variable defined in the screen file, in order of appearance. When the expert system executes a screen, it places the information from the data file into the available input boxes. The variables are placed one per line in sequence of the appearance in the screen file. Applicable default data files are defined with each screen description (e.g. The default data file for this screen is "ALPSCR.DAT"). See the EXSYS® manual and Help Desk technical guide for more information.

3.4.2 Main Menu

The main menu screen of Help Desk (Figure 7) shows the available analysis options for the user.

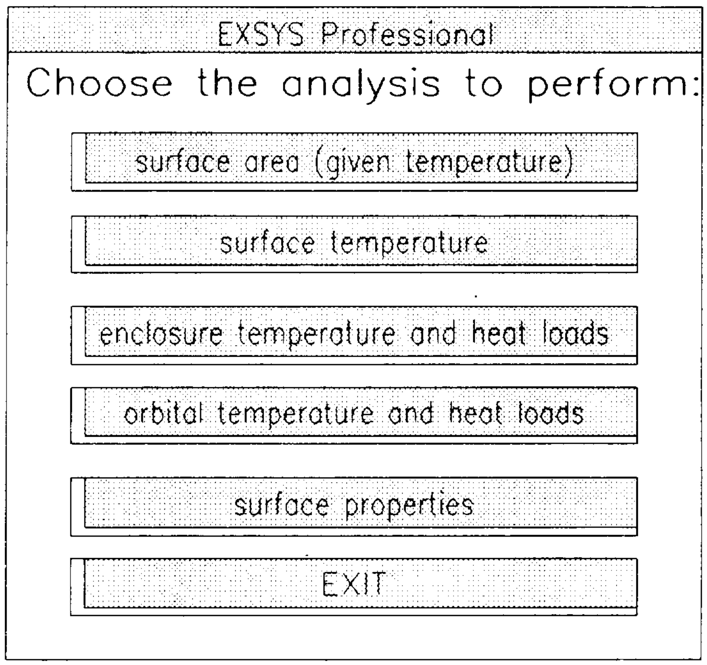

Figure 7 Main Menu

surface area (given temperature) Calculates the effective area of a radiating surface (flat plate). The user supplies information such as temperature, surface and environmental properties.

surface temperature Calculates the effective temperature on a radiating surface (flat plate). There are two sub-options, Surface Temperature (given area) and Environmental Temperature. The user supplies information such as surface and environmental properties and if necessary, surface area.

enclosure temperature and heat loads Calculates the temperatures and heat loads for each side of an enclosure (rectangular box). The user supplies geometric and environmental information. This analysis is performed at a user defined point in an orbit.

orbital temperature and heat loads	Calculates the temperatures and heat loads for each side of an enclosure (rectangular box) over an entire orbit. The user supplies geometric and environmental information. This analysis is performed at any number of points around an orbit as specified by the user.
surface properties	Assists in selecting the emissivity and absorptivity of a surface. The user supplies either the surface material or the surface application, as well as the performance time information (Beginning of Life or End of Life)
EXIT	Exit from the system. The user will still be shown the final EXSYS® screens described in section 2.5

Choose one of the selections by clicking once on the appropriate button.

3.5 SURFACE AREA (GIVEN TEMPERATURE)

This analysis determines the area of a single flat plate surface subjected to environmental and internal heat loads. The user is required to input the temperature of the surface. The position of the surface in an orbit is defined by the user specified solar and planet view factors plus the solar and planetary fluxes. The surface properties are either specified by the user or determined by Help Desk with information from the user about the application or material composition. The environmental radiation effects involved are selected by the user. The user may also specify that an enclosure is attached to the radiating surface.

3.5.1 Radiation Effects

The first Surface Area screen is titled: "Radiation effects to include" (Figure 8) The user specifies the environmental and internal radiation effects to be included in the analysis. The user may choose any or all of the effects listed. These include solar radiation, planet radiation, albedo radiation, enclosure radiation (on an instrument inside an enclosure) and internal power (to dissipate).

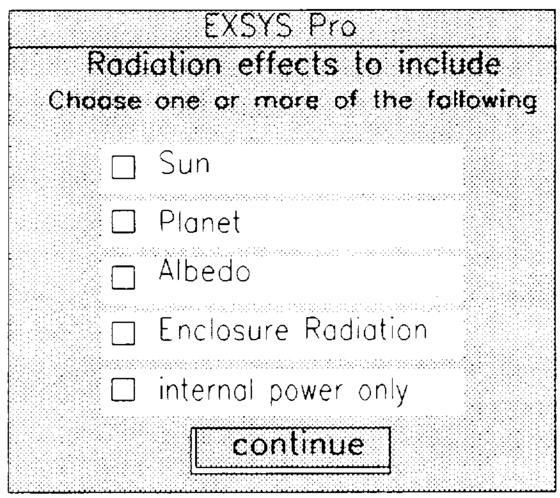

Figure 8 Radiation Effects Screen

To calculate the size of a radiator the system requires an internal heat load to dissipate. The heat load can be some internal power source or from the effects of enclosure radiation on an instrument. Without the internal heat, the area value is irrelevant, as the corresponding surface is in equilibrium (see technical manual for details).

To choose any or all of the environmental effects, highlight the one(s) of interest then select the "CONTINUE" button.

sun radiation emitted by the sun.

planet radiation emitted by the planet.

albedo radiation reflected off the planet's surface due to clouds and the planet's reflectivity

enclosure radiation

Allows the user to specify an enclosure attached to the surface. Help Desk allows the user to input a value for the heat load to dissipate due to the enclosure radiation, or to ask the system to calculate the enclosure radiation effect.

internal power only

Heat from internal sources that is to be radiated from the surface. When calculating area or surface temperature, internal power is always radiated from the surface. This option allows the user to determine the surface area with only the internal power being rejected.

3.5.2 Surface Constants

Figure 9 shows the surface constants screen. These constants determine how the environment effects the surface. They determine the amount of heat absorbed into the surface, the amount of heat radiated from the surface and the effective angle of the surface with respect to the sun and the planet.

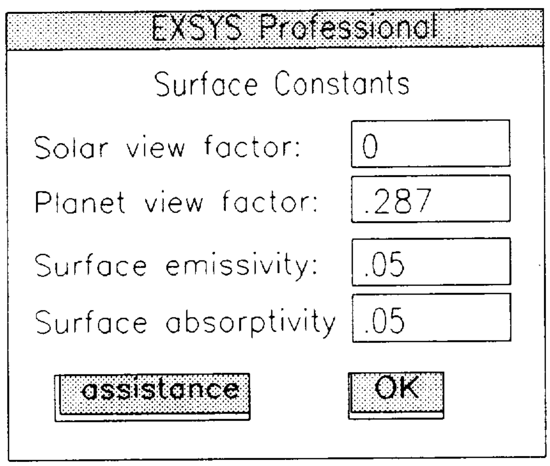

Figure 9 Surface Constants Screen

Solar view factor

The fraction of the total radiation emitted by the sun that is directly incident on the surface. (e.g. 1: fully facing the sun, 0: parallel to the sun's rays, 0: facing away from the sun)

Planet view factor

The fraction of the total thermal radiation emitted by the planet that is directly incident on the surface. (e.g. for Low Earth Orbit: ~.88 for fully facing planet, .287 for perpendicular to the planet's surface, 0 for facing away from the planet)

Surface emissivity

Thermal emissivity of the radiating surface. The default value assumes the use of multilayered insulation (MLI). For assistance in determining emissivity, press the assistance button.

Surface absorptivity

Solar absorptivity of the radiating surface. The default value assumes the use of multilayered insulation (MLI). For assistance in determining absorptivity, press the assistance button.

Enter the appropriate values for the solar and planet view factors. **Remember not to press the return key**. Enter the values and move the cursor to the next field. For the surface emissivity and absorptivity the user has two options. Either enter the known values and press "OK", or ask Help Desk for assistance by pressing the "assistance" button.

The default data file for this screen is "ALPSCR.DAT".

3.5.2.1 Assistance Button

Before using the assistance button make sure view factor values are properly defined because Help Desk does not ask for the values again.

The Assistance button is for assistance in determining the surface emissivity and absorptivity. It allows the user to run the same analysis as the "Surface Properties" option from the main menu. The user is asked for the performance time (Figure 41, Page 48) and the known surface information (Figure 42, Page 48). Help Desk displays a list of valid material or application options from which a selection can be made.

3.5.2.2 Modify Assistance Results

Help Desk displays the results of the surface properties analysis (Figure 10). The report contains the surface application, surface material, performance time, emissivity and solar absorptivity. The screen also has two buttons:

1) continue
2) modify

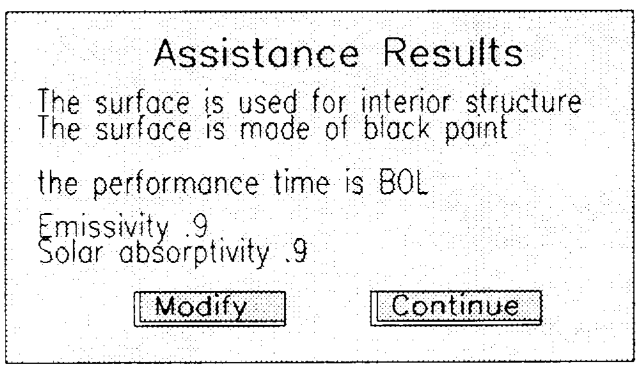

Figure 10 Assistance Results Screen

The "continue" button places the calculated values into the variables for emmissivity and absorptivity and continues with the surface area analysis.

The "modify" button displays another surface properties screen, which shows the current values of the emissivity and absorptivity (Figure 11).

The user may change these values and press the "OK" button when the values are correct. Help Desk uses the modified values for emissivity and absorptivity in the rest of the surface analysis.

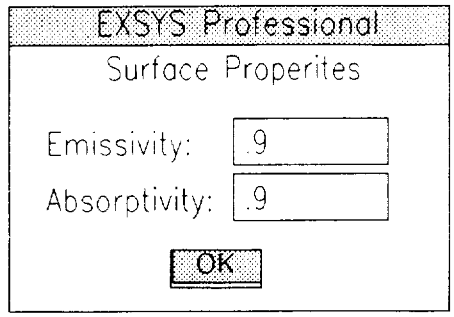

Figure 11 Modify Assistance Analysis Results Screen

3.5.3 Planet Constants screen

Figure 12 shows the planet constants screen. These constants determine the environment effecting the surface. The amount of solar radiation, planet radiation and reflected radiation determines the radiation environment.

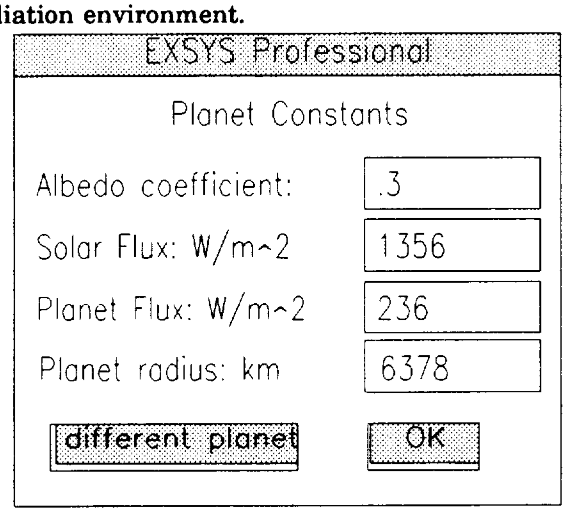

Figure 12 Planet Constants Screen

The user has two options for entering these values.
1) enter the known values and press the "OK" button
2) for a planet other than the Earth, press the "different planet" button.

Albedo coefficient	Percentage of the total solar radiation incident on the planet that is reflected back to space. The default is for Earth ~ 0.3.
Solar Flux	Heat load per unit area on the surface due to the sun's radiation. The default is the yearly average for Earth ~1356 W/m^2.
Planet Flux	Heat load per unit area on the surface due to the planet's thermal radiation. The default is for Earth ~236 W/m^2.
Planet Radius	Radius of the planet under investigation. The default is for Earth ~ 6378 km

The default data file is "ABLSCR.DAT".

3.5.3.1 Different Planet Button

The different planet button allows the user to choose a planet other than Earth for the analysis. Help Desk displays a list of the available planets for analysis (Figure 13). For each planet, the values for Solar flux, Planet flux, Albedo coefficient and Planet radius are shown in Table 1. If the values desired are different from those shown in Table 1, the user inputs the correct values directly in the Planet Constants screen.

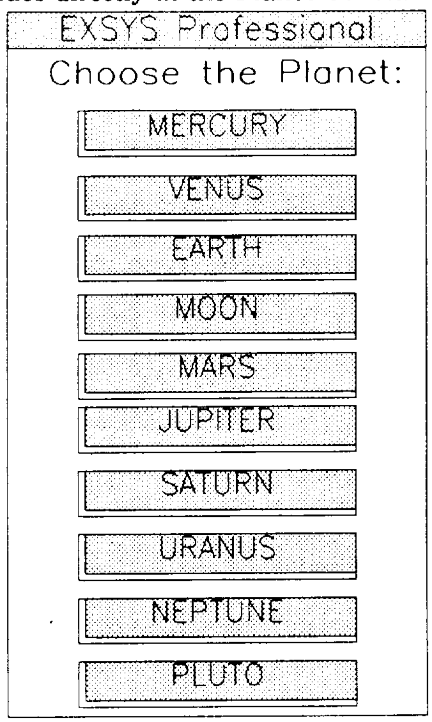

Figure 13 Planet Choice Screen

PLANET	PLANET_FLUX	SOLAR_FLUX	ALBEDO	RADIUS
MERCURY	4201	8920	.058	2487
VENUS	154.2	2570	.76	6187
EARTH	236.6	1352	.3	6378
MOON	603.25	1352	.047	1738
MARS	123	577.3	.140	3380
JUPITER	6.1	49.6	.51	71370
SATURN	1.8	14.7	.5	60400
URANUS	.31	3.65	.66	23530
NEPTUNE	.14	1.48	.62	22320
PLUTO	.0	0	.0	2284

Table 1: Different Planet Information

3.5.4 Surface Temperature and Heat Load

The user is asked to specify the temperature of the radiating surface in Kelvin (Figure 14).

A good initial approximation is the effective sink or environmental temperature of the surface. This can be found by running the Environmental Temperature option under the Surface Temperature selection from the main menu.

Another approximation is the desired temperature of the enclosure minus 5 K for each connection of the thermal carrier from the enclosure to the radiator (e.g. a heat pipe has two connections, one at the enclosure and one at the radiator).

The default is set at 273 Kelvin or 0° Celsius.

The default data file for this screen is "TEMPSCR.DAT".

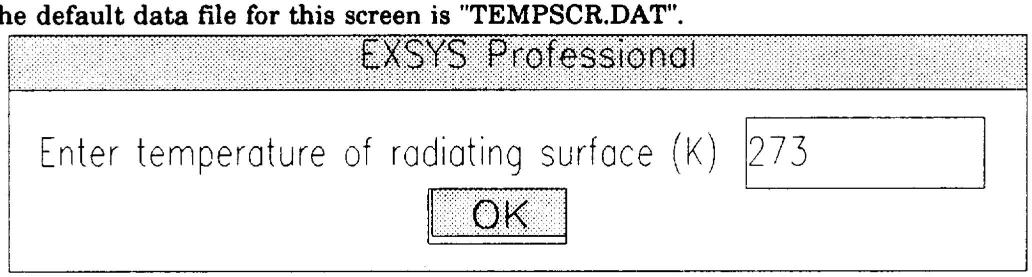

Figure 14 Surface Temperature Screen

3.5.5 Internal Heat Load

The user is asked to specify the internal heat load to dissipate (Figure 15). The heat load can be any internal heat supply that must be removed from the system, such as the heat generated by the electronic equipment inside the spacecraft. It is assumed that the heat is transferred out to the radiating surface by some process (undefined to Help Desk). Help Desk assumes that a transfer mechanism exists such as a heat pipe. The default heat load is 1.0 W.

The default data file for this screen is "QPSCR.DAT".

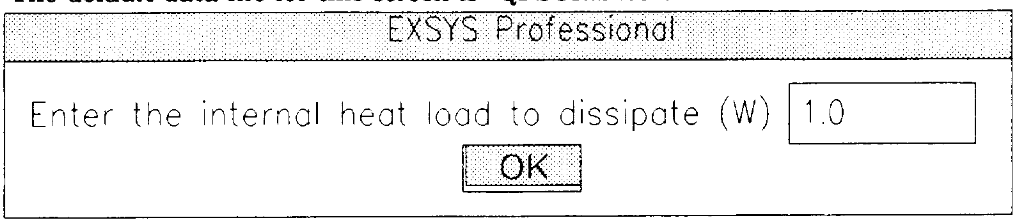

Figure 15 Internal Heat Load Screen

3.5.6 Enclosure Radiation

The enclosure radiation option is selected from the "Radiation Effects" screen (Figure 8, Page 11). This feature allows the user to size a radiator for an enclosure. It does not require the radiating surface to be part of the enclosure. Therefore the enclosure and the radiating surface can be influenced by different environments (e.g. the surface facing out into space and the enclosure internal to a spacecraft bus).

3.5.6.1 Enter value or Calculate?

The user is asked to enter the heat load to dissipate due to an attached enclosure. There are two options in defining the enclosure radiation effects. (Figure 16)

1) If the value is known the user can directly input the values and press the "OK" button.

2) If the value is not known the user can select the "calculate" button. Help Desk will lead the user through the enclosure analysis to determine the heat load on the surface of an instrument in an enclosure. Usually an enclosure contains an instrument that must be kept a constant temperature or within a specific temperature range. Help Desk calculates the amount of heat that must be rejected to maintain the required temperature.

The default data file is "QENCLSCR.DAT".

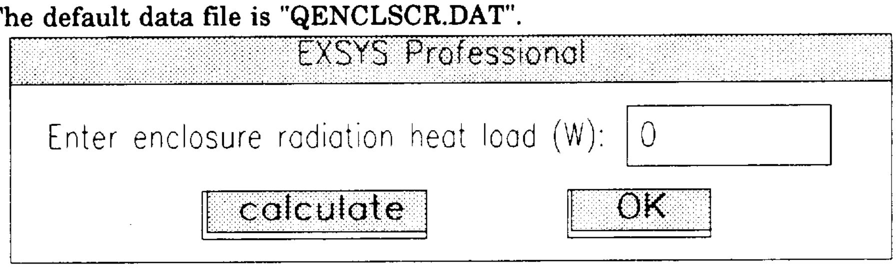

Figure 16 Enclosure Heat Load Screen

3.5.6.2 Calculate Enclosure Radiation Effects

To calculate the total heat load of an enclosure, the heat flux due to the enclosure radiation, must act on an area. In an enclosure, this is equivalent to the surface area of an instrument inside the enclosure. The instrument is assumed to be attached to a thermal carrier, which will transfer the heat to the radiating surface (Figure 2 in the introduction).

The user is asked to input the surface area and surface emissivity of the instrument inside the enclosure (Figure 17). The default value for the instrument surface area is .01 m^2 and the default value for the emissivity is 1 for a black surface.

The default data file is "AINSTSCR.DAT".

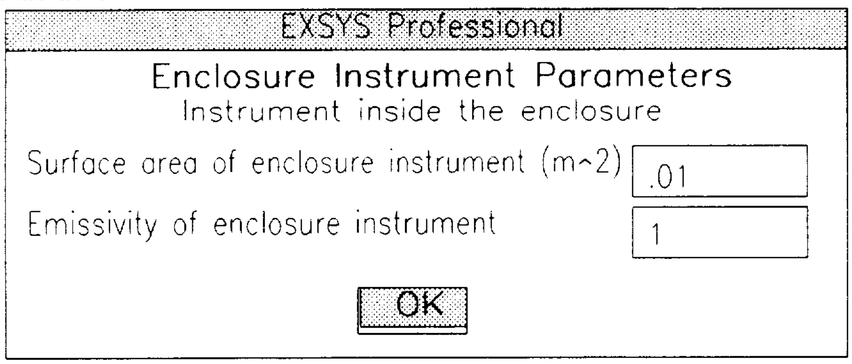

Figure 17 Enclosure Instrument Information Screen

3.5.6.3 Enclosure Analysis

Help Desk runs an entire enclosure analysis that is the same as the Enclosure Temperatures and Heat Loads option in the main menu. For further information on the enclosure radiation analysis see the "ENCLOSURE TEMPERATURE AND HEAT LOADS" section (section 3.8).

3.5.7 Surface Area Report Screens

At the end of the surface area analysis the expert system displays one of two report screens.

1) successful completion (Figure 18)
2) invalid results, negative area (Figure 19)

surface area	Calculated by Help Desk
surface temperature	Input by the user
radiation effects	Radiation effects selected by the user to include in the analysis
surface properties	User defined emissivity, absorptivity, solar flux, earth flux solar and planet view factors and albedo coefficient. Values not entered by the user are displayed with the default values.
heat loads	Calculated heat loads from each of the radiation sources (surface, sun, planet, albedo, enclosure and internal power). Heat load is the total heat on the surface over the entire area.

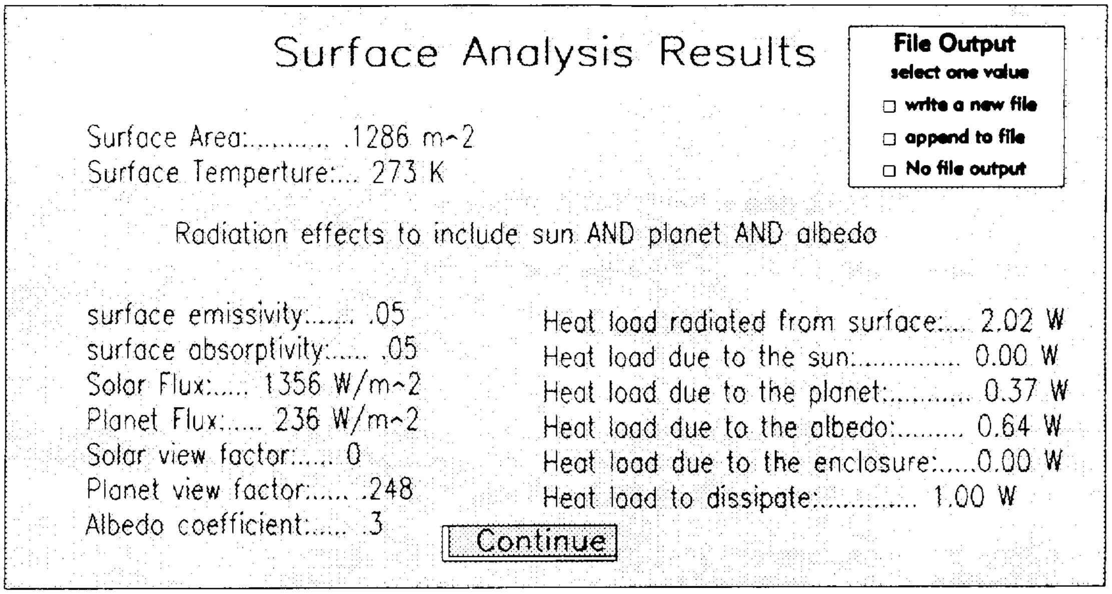

Figure 18 Surface Analysis Results Screen

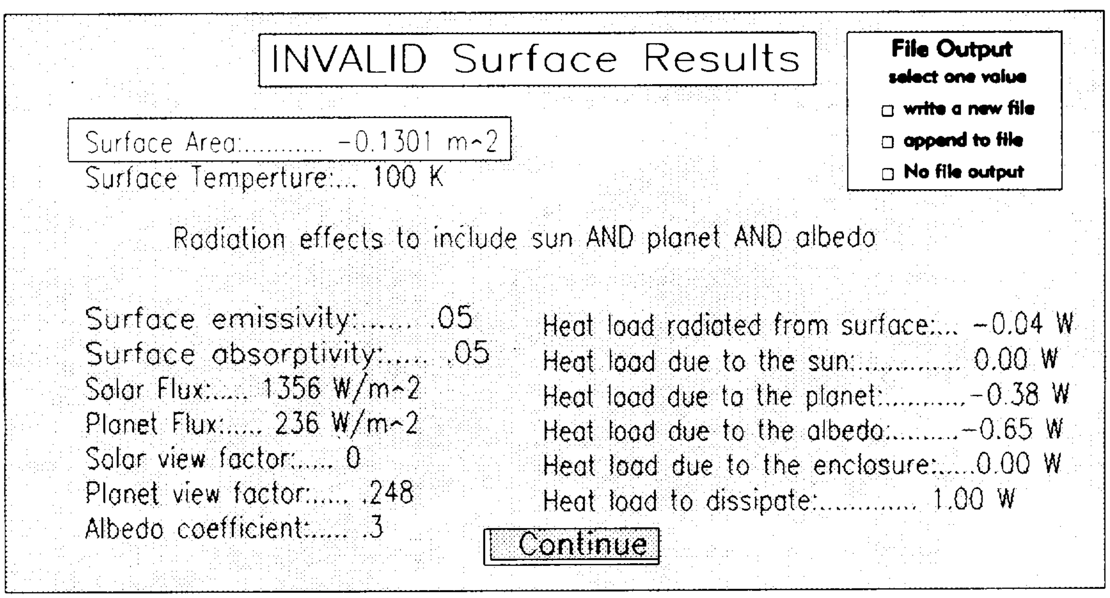

Figure 19 Invalid Surface Analysis Results Screen

file output
AREA.RPT

The user selects the form of file output.
- write a new file
- append to an old file
- no file output

A quick check to validate the heat loads can be performed by comparing the heat radiated from the surface to the sum of the heat loads on the surface.

For an invalid completion a slightly different screen is displayed. This screen has highlights to point out that the system has calculated a negative area.

Possible causes of a negative surface area result are:
- emissivity or absorptivity of the system that are too small
- a temperature that is too low to radiate all the heat.

See the technical manual for more information.

3.5.8 Report File

At the end of an analysis run, Help Desk can write the data to an ASCII file so that the user may access the information after the analysis session has ended. The menu selection appears on the final report screens shown in Figure 18 and Figure 19.

Help Desk allows the user to:
1) create a new file with the information
2) append the data to the existing file
3) produce no file output.

The information is written to the file AREA.RPT. It contains the same data that is displayed on the Surface Analysis Results screen.

The last few screens are EXSYS® generated. See section 2.5.1 and the EXSYS® manual for further details.

3.6 SURFACE TEMPERATURE

Determines the temperature of a single flat plate surface subjected to environmental and internal heat loads. The position of the surface in an orbit is defined by the user specified solar and planet view factors. The surface properties are either specified by the user or determined by Help Desk with information about the intended use or material composition. The environmental effects involved are selected by the user. The user may also specify that an enclosure is attached to the radiating surface.

3.6.1 Temperature Analysis Selection

The user has two options after selecting Surface Temperature analysis from the main menu:

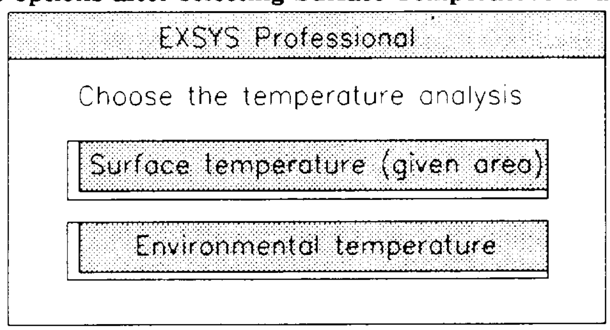

Figure 20 Temperature Analysis Selection Screen

Surface temperature (given area) calculates the temperature of the surface subjected to environmental heat loads and internal heat sources. The user must define the area of the surface.

Environmental temperature calculates the temperature of the surface subjected to environmental heat loads only. The resulting temperature is the effective equilibrium surface temperature or sink temperature. This analysis is independent of the total surface area.

These two analyses are very similar in procedure and inputs. They difference between the two is that:

1) Surface temperature requires the user to input an area
2) Environmental temperature does not use internal heat loads and enclosure radiations.

The difference is accommodated with the addition of several screens that are used only for Surface Temperature option. These screens have "*(surface temperature)*" specified in the headings in the following description.

3.6.2 Surface Area (*surface temperature*)

The user is asked for the area of the radiating surface (Figure 21). The user should input the total surface area rejecting the heat. The default value is 1 m^2.

The default data file is "AREASCR.DAT"

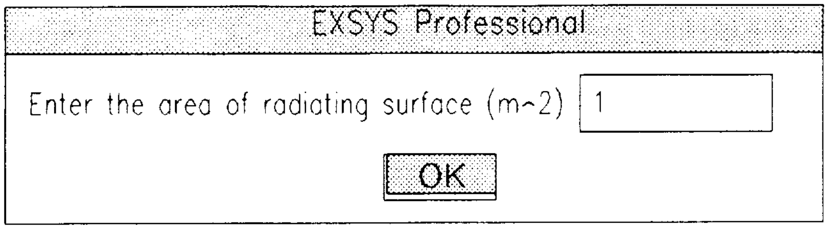

Figure 21 Surface Area Screen

3.6.3 Surface Constants

Figure 9, Page 12, shows the surface constants screen. These constants determine how the environment effects the surface. They determine the amount of heat absorbed into the surface, the heat radiated from the surface and the effective angle of the surface with respect to the sun and the planet.

Solar view factor — The fraction of the total radiation emitted by the sun that is directly incident on the surface. (e.g. 1: fully facing the sun, 0: parallel to the sun's rays, 0: facing away from the sun)

Planet view factor — The fraction of the total thermal radiation emitted by the planet that is directly incident on the surface. (e.g. for Low Earth Orbit: ~.88 for fully facing planet, .287 for perpendicular to the planet's surface, 0 for facing away from the planet)

Surface emissivity — Thermal emissivity of the radiating surface. The default value assumes the use of multilayered insulation (MLI). For assistance in determining emissivity, press the assistance button.

Surface absorptivity — Solar absorptivity of the radiating surface. The default value assumes the use of multilayered insulation (MLI). For assistance in determining absorptivity, press the assistance button.

Enter the appropriate values for the Solar and Planet view factors. **Remember do not press the return key**. Enter the values and move the cursor to the next field. For the surface emissivity and absorptivity, the user has two options. Either, enter the known values and press "OK", or ask Help Desk for assistance by pressing the "assistance" button.

The default data file for this screen is "ALPSCR.DAT".

3.6.3.1 Assistance Button

Before using the assistance button make sure view factor values are properly defined, because Help Desk does not ask for the values again.

The Assistance button is for assistance in determining the surface emissivity and absorptivity. It allows the user to run the same analysis as the "Surface Properties" option from the main menu as specified herein. The user is asked for the performance time, (Figure 41, Page 48) and the known surface information, (Figure 42, Page 48). Help Desk displays a list of valid material or application options for the user to choose.

3.6.3.2 Modify Assistance Results

Help Desk displays the results of the surface properties analysis, (Figure 10, Page 13). The report contains the surface application, surface material, performance time, emissivity and solar absorptivity. The screen also has two buttons:

1) continue
2) modify

The "continue" button places the calculated values into the variables for emmissivity and absorptivity and continues with the surface area analysis.

The "modify" button displays another surface properties screen which shows the current values of the emissivity and absorptivity (Figure 11, Page 13).

The user may change the values displayed and press the "OK" button when the values are correct. Help Desk uses the modified values for emissivity and absorptivity in the rest of the surface analysis.

3.6.4 Radiation Effects

The Radiation effects screen (Figure 8, Page 11) is where the user specifies the environmental and internal radiation effects to be included in the analysis. The user may choose any or all of the effects listed. These include solar radiation, planet radiation, albedo radiation, enclosure radiation on an instrument inside the enclosure and internal power to be dissipated.

sun	Radiation emitted by the sun.
planet	Radiation emitted by the planet.
albedo	Radiation reflected off the planet's surface due to clouds and the planet's reflectivity
enclosure radiation	Allows the user to specify an enclosure attached to the surface. Help Desk allows the user to input a value for heat load to dissipate due to the enclosure radiation, or ask the system to calculate the enclosure radiation effect.
internal power only	Heat from internal sources that is to be radiated from the surface. When calculating area or surface temperature, internal power is always radiated from the surface. This option allows the user to determine the surface area with only the internal power being rejected.

To choose any or all of the environmental effects, highlight the one(s) of interest then select the "CONTINUE" button.

NOTE: The surface temperature option with zero internal heat and zero enclosure radiation heat is the same as the environmental temperature option.

The environmental temperature option only needs the environmental radiation effects, (e.g. sun, planet, or albedo). It has no dependency on the internal heat or the enclosure radiation. If these are selected when performing an environmental analysis, they will be ignored.

3.6.5 Planet Constants screen

Figure 12, Page 14 shows the planet constants screen. These constants determine the environment in terms of solar radiation, planet radiation and reflected radiation that effects the surface.

The user has two options for entering these values.
1) enter the known values and press the "OK" button
2) for a planet other than the Earth, press the "different planet" button.

Albedo coefficient	Percentage of the total solar radiation incident on the planet that is reflected back to space. The default is for Earth ~ 0.3.
Solar Flux	Heat load per unit area on the surface due to the sun's radiation. The default is the yearly average for Earth ~1356 W/m^2.
Planet Flux	Heat load per unit area on the surface due to the planet's thermal radiation. The default is for Earth ~236 W/m^2.
Planet Radius	Radius of the planet under investigation. The default is for Earth ~ 6378 km

The default data file is "ABLSCR.DAT".

3.6.5.1 Different Planet Button

The different planet button allows the user to choose a planet other than the Earth for the analysis. Help Desk displays a list of the available planets for analysis (Figure 13, Page 15). For each planet, the values for Solar flux, Planet flux, Albedo coefficient and Planet radius are shown in the Table 1 on Page 16. If the values desired are different from those shown the user may input the correct values directly in the Planet Constants screen.

3.6.6 Internal Heat Load *(surface temperature)*

The user is asked to specify the internal heat load to dissipate (Figure 15, Page 17). The heat load can be any internal heat supply that must be removed from the system, such as the heat generated by the electronic equipment inside the spacecraft. It is assumed that the heat is transferred out to the radiating surface by some process (undefined to Help Desk). Help Desk assumes that a transfer mechanism exists such as a heat pipe. The default heat load is 1.0 W.

The default data file for this screen is "QPSCR.DAT".

3.6.7 Enclosure Radiation *(surface temperature)*

The enclosure radiation option is selected from the "Radiation Effects" screen (Figure 8, Page 11). This feature allows the user to size a radiator for an enclosure. It does not require the radiating surface to be part of the enclosure. Therefore the enclosure and the radiating surface can be influenced by different environments (e.g. the surface facing out into space and the enclosure internal to a spacecraft bus).

3.6.7.1 Enter value or Calculate? *(surface temperature)*

The user is asked to enter the heat load to dissipate due to an attached enclosure (Figure 16, Page 17). There are has two options in defining the enclosure radiation effects.

1) If the value is known the user can directly input the values and press the "OK" button.

2) If the value is not known the user can select the "calculate" button. Help Desk will lead the user through the enclosure analysis to determine the heat load on the surface of an instrument in an enclosure. Usually an enclosure contains any instrument that must be kept a constant temperature or within a specific temperature range. Help Desk calculates the amount of heat that must be rejected to maintain the required temperature.

The default data file is "QENCLSCR.DAT".

3.6.7.2 Calculate Enclosure Radiation Effects *(surface temperature)*

To calculate the heat load of an enclosure, the heat flux due to the enclosure radiation, must act on an area. In an enclosure, this is equivalent to the surface area of an instrument inside the enclosure. The instrument is assumed to be attached to a thermal carrier, which will transfer the heat to the radiating surface (Figure 2 in the introduction).

The user is asked to input the surface area and surface emissivity of the instrument inside the enclosure (Figure 17, Page 18). The default value for the instrument surface area is .01 m^2 and the default value for the emissivity is 1 for a black surface.

The default data file is "AINSTSCR.DAT".

3.6.7.3 Enclosure Analysis *(surface temperature)*

Help Desk runs an entire enclosure analysis that is the same as the Enclosure Temperatures and Heat Loads option in the main menu. For further information on the enclosure radiation analysis see the "ENCLOSURE TEMPERATURE AND HEAT LOADS" section (section 3.8).

3.6.8 Surface Temperature Results

The results screen is the same as in Figure 18 (Page 19). However, the surface area is specified by the user and the surface temperature is calculated.

surface area	Input by the user
surface temperature	Calculated by Help Desk
radiation effects	Radiation effects selected by the user
surface properties	User defined emissivity, absorptivity, solar flux, earth flux solar and planet view factors and albedo coefficient. Values not entered by the user are displayed with the default values.
heat loads	Calculated heat loads from each of the radiation sources (surface, sun, planet, albedo, enclosure and internal power). Heat load is the total heat on the surface over the entire area.

file output TEMP.RPT

The user selects the form of file output.

- write a new file
- append to an old file
- no file output

NOTE: A quick check to validate the heat loads: the heat radiated from the surface should be the sum of the heat loads on the surface.

3.6.9 Environment Temperature Results

The results screen is called "Temperature Results", (Figure 22).

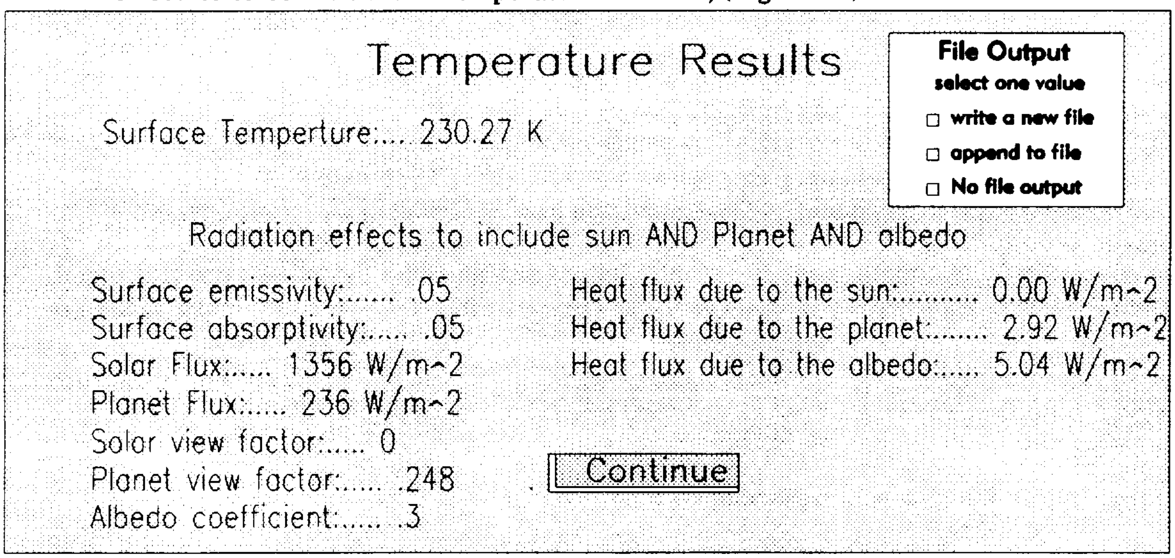

Figure 22 Environmental Temperature Results Screen

surface temperature — Calculated by Help Desk. This is the effective "sink" or equilibrium temperature. It is independent of area.

radiation effects — Radiation effects selected by the user

surface properties — User defined emissivity, absorptivity, solar flux, earth flux solar and planet view factors and albedo coefficient. Values not entered by the user are displayed with the default values.

heat fluxes — Calculated heat fluxes from each of the environmental radiation sources (sun, planet and albedo). Heat flux is the total heat on the surface per unit area.

file output
TEMP.RPT

The user selects the form of file output.

- write a new file
- append to an old file
- no file output

3.6.10 Report File

At the end of an analysis run, Help Desk can write the data to an ASCII file so the user may access the information after the analysis session has ended. The menu selection appears on the Report screen shown in Figure 22.

Help Desk allows the user to:
1) create a new file with the information
2) append the data to the existing file
3) produce no file output.

The information written to the file TEMP.RPT contains the same data that is displayed on the Temperature Results screen.

The last few screens are EXSYS® generated. See section 2.5.1 and the EXSYS® manual for further details.

3.7 ENCLOSURE ANALYSES

3.7.1 Assumptions

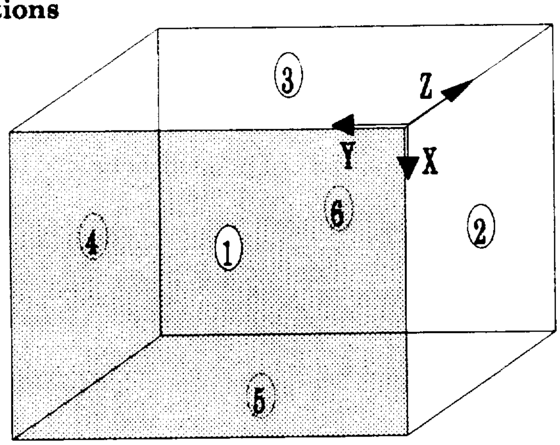

Figure 23 Enclosure Geometry

The enclosure analyses calculate the temperature and heat load on each side of an enclosure. Currently, the only enclosure geometry available is a simple rectangular box. The side numbers and local spacecraft coordinates are defined as shown in Figure 23. The side numbers and coordinates are assigned to the box as shown. They can be altered only by the knowledge engineer, not by the user.

Two enclosure analyses are available to the user:
1) calculate the temperatures and heat loads at a single point in an orbit
2) calculate the temperatures and heat loads at a user defined, equally spaced number of points in an orbit.

Enclosure Temperatures and Heat Loads allows the user to perform a detailed analysis at a single orbit point, such as the worst case point. This option has the ability to set a planet shield on one or more sides of the enclosure. It allows the user to manually specify the planet view factors.

Orbital Temperatures and Heat Loads gives the user all of the temperatures and heat loads for each of the six sides at multiple points in an orbit. The user can thus determine the best and worst case positions.

3.7.2 Coordinate axes conventions
The coordinate axes are chosen to be consistent with those defined in SDRC's Thermal Model Generator (TMG), +X Nadir, +Y in the direction of the velocity vector and +Z in the northern plane. Local coordinates are fixed to the body and rotate with the body. The local coordinates system is similar to a perifocal system with a 180° rotation about the local Z axis (Figure 24). Global coordinates are defined as +X Nadir, +Y in the direction of the velocity vector and +Z in the northern plane at vernal equinox. The global coordinate system is similar to the Geocentric coordinate system, with a 180° rotation about the global Z axis (Figure 25).

3.7.3 Shadowing
The effects of the planet shadowing the spacecraft are not calculated during the Enclosure

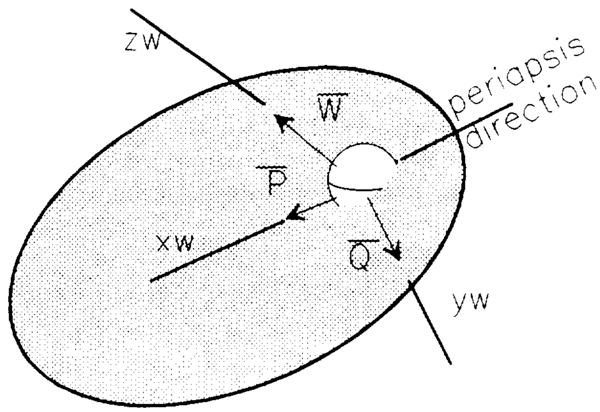

Figure 24 Local Spacecraft Coordinates

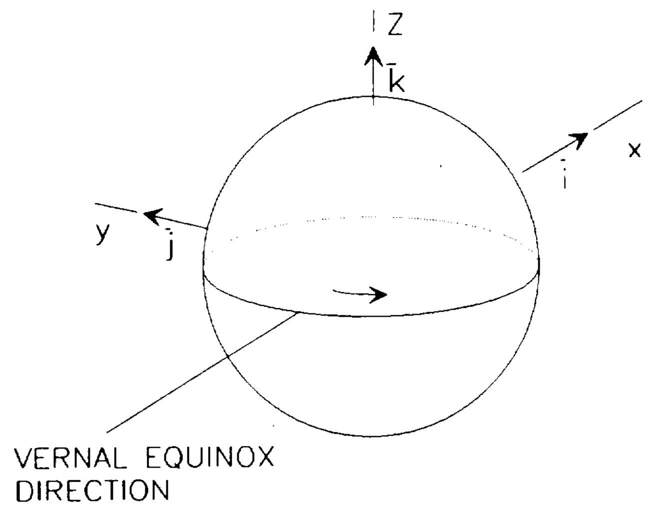

Figure 25 Global Coordinates

Temperature and Heat Loads analysis. The user must set the solar flux and albedo coefficient to zero when in the planet's shadow.

The effects of the planet shadowing the spacecraft are calculated during the Orbital Temperature and Heat Loads analysis. Refer to Help Desk Technical Guide for details.

3.8 ENCLOSURE TEMPERATURE AND HEAT LOADS

Calculates the temperature and total heat loads on each of the enclosure sides that is subjected to environmental radiation effects. The analysis is performed at a single position in an orbit as defined by the user. The user must supply the enclosure thermal properties for each side, geometric dimensions along each coordinate axis and orbital information. Help Desk will assist the user in determining enclosure view factors, solar view factors and planet view factors.

3.8.1 Solar and Planet View Factors

The solar view factor for a surface is the fraction of the surface that "sees" the sun. For example in Earth orbit:

- 1 - fully facing the sun
- 0 - parallel to the sun's rays
- 0 - facing away from the sun

The planet view factor for a surface is the fraction of the surface that "sees" the planet. For example for a low Earth orbit:

- .88 - fully facing the planet
- .29 - perpendicular to the planet's surface
- 0 - facing away from the planet

Three variables effect the solar and planet view factors; the spacecraft orientation, the orbit and the position of the sun.

Help Desk has two choices for spacecraft orientation:

1) planet oriented
2) solar inertially oriented

When the spacecraft is planet oriented, side 5 of the enclosure always faces the planet. In this orientation all the surfaces rotate with respect to the sun. Therefore the planet view factors are relatively constant, while the solar view factors rotate with the spacecraft as it orbits the planet.

When the spacecraft is solar inertially oriented the same surface(s) always faces the sun. In this orientation all the surfaces rotate with respect to the planet. Therefore the planet view factors change as the spacecraft orbits the planet and the solar view factors are constant.

Help Desk has two choices for spacecraft orbit:

1) geosynchronous earth orbit (GEO)
2) low earth orbit (LEO).

GEO is defined with an orbital period equal to the daily rotational period of the planet. The planet view factors are effectively zero and are defaulted to zero, simplifying the number of calculations.

LEO is defined with a semi-major axis smaller than the GEO limiting case. The planet view factors are calculated at each orbit point.

The sun position can be defined:

1) in local coordinates
2) in global coordinates
3) with system defaults

Help Desk calculates the solar view factors by taking the dot product of the solar vector in local spacecraft coordinates and the local unit normals of each surface of the enclosure. The unit normals stay fixed with respect to the body.

When the sun position is entered in local coordinates, Help Desk immediately determines the solar view factors, independent of the spacecraft orientation.

When the sun vector is entered in global coordinates, Help Desk takes into consideration the spacecraft orientation when calculating solar view factors. If the *orientation is solar inertial*, Help Desk calculates the solar view factors at the line of nodes. It assumes that the orientation keeps the same side(s) facing the sun at all positions in the orbit. If the *orientation is planet*, Help Desk rotates the global vector to local coordinates. It then take the dot product of the local sun vector and the unit normals. Help Desk uses a FORTRAN executable DOS code SUNVECT.BAT to perform the rotation and the dot product. The screen blanks out when running a DOS routine in the WINDOWS$_{TM}$ background. When the screen reappears, Help Desk continues with the analysis using the calculated values. Help Desk does not display the results of these calculations until the final report screen.

When the user specifies the default values for sun position, the six solar view factors are predefined. The defaults are (0,0,1,0,0,0) for (side 1, side 2, side 3, side 4, side 5, side 6).

3.8.1.1 Sun Position

The user must specify the position of the enclosure with respect to the sun and planet, which is necessary for determining the solar view factors. The user has 4 methods to input the information (Figure 26) :

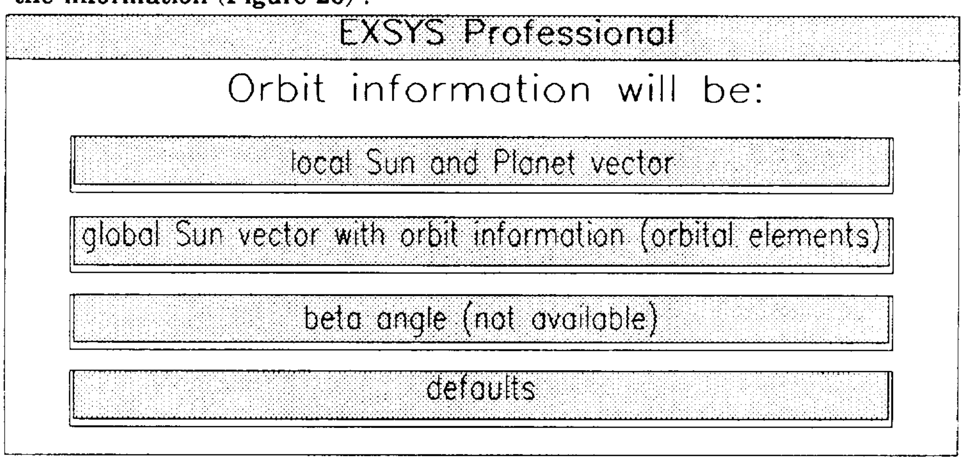

Figure 26 Orbit Information Screen

local Sun and Planet vector — The user defines the sun's position in local spacecraft coordinates.

global Sun vector with orbit information — The user defines the sun's position in global coordinates.

beta angle — This feature is currently not available. The screen will not change if this option is selected.

defaults

0° inclination
0° longitude of ascending node
0° argument of periapsis
0° true anomaly
6785 km semi-major axis (220 nmi above the surface of the Earth)
0 eccentricity (circular orbit)
sun vector is (1,0,0)

3.8.1.1.1 Local Sun and Planet Vector

The sun vector is the position of the sun, specified in local spacecraft coordinates (Figure 27). The local planet vector is currently not used in any analysis. However, the necessary input value boxes have been included to facilitate the addition of this feature in a future version of Help Desk.

The defaults are (-1,0,0) for the sun vector and (0,0,0) for the planet vector.

The default data file is "XSSCR.DAT".

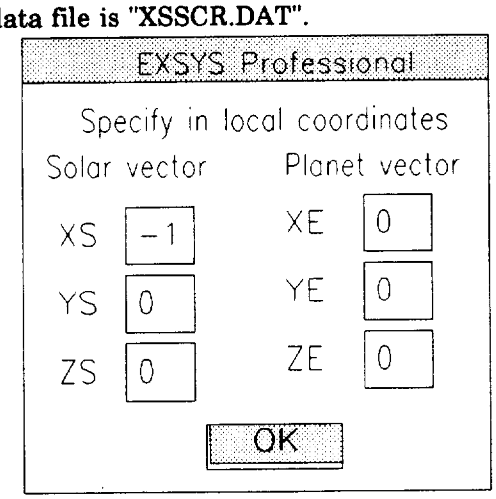

Figure 27 Local Sun and Planet Vectors Screen

3.8.1.1.2 Global Sun and Planet Vector

The sun vector is the position of the sun, specified in global spacecraft coordinates (Figure 28). The global planet vector is currently not used in any analysis. However, the capability to add this feature is enhanced by preparing the input screens.

Help Desk rotates the global sun vector into the local spacecraft coordinates using spacecraft position information. The spacecraft position is defined with the six classical orbital elements.

The defaults are (-1,0,0) for the sun vector and (0,0,0) for the planet vector.

The default data file is "GSSCR.DAT".

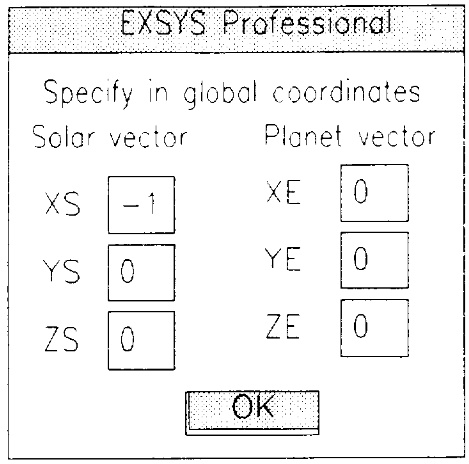

Figure 28 Global Sun and Planet Vectors Screen

3.8.1.2 Spacecraft Orientation

The user specifies the orientation of the spacecraft from two options (Figure 29):
1) planet
2) inertial

A geometric representation of each orientation is provided in Figure 30.

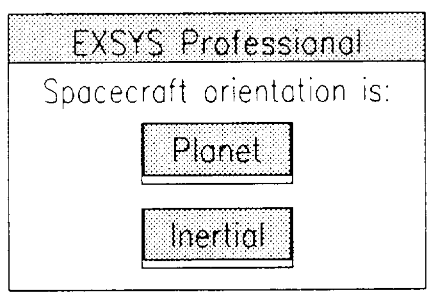

Figure 29 Spacecraft Orientation Screen

A planet oriented spacecraft always has one surface fixed with respect to the planet's surface. In Help Desk, side 5 is fixed with respect to the planet. A solar inertial oriented spacecraft always has the same surface(s) fixed with respect to the sun. See section 3.8.1 for more details.

3.8.1.3 Spacecraft orbit

The user must choose the type of orbit for the spacecraft (Figure 31). There are two options:
1) geosynchronous earth orbit (GEO)
2) low earth orbit (LEO).

GEO is defined with an orbit period equal to the daily rotation period of the planet. LEO is defined with a semi-major axis smaller than the GEO limiting case. The distinction is made because in GEO the planet view factors are effectively zero and the default value is zero when GEO is selected.

3.8.1.4 Spacecraft Position

When the sun is entered in local spacecraft coordinates, the spacecraft is planet oriented

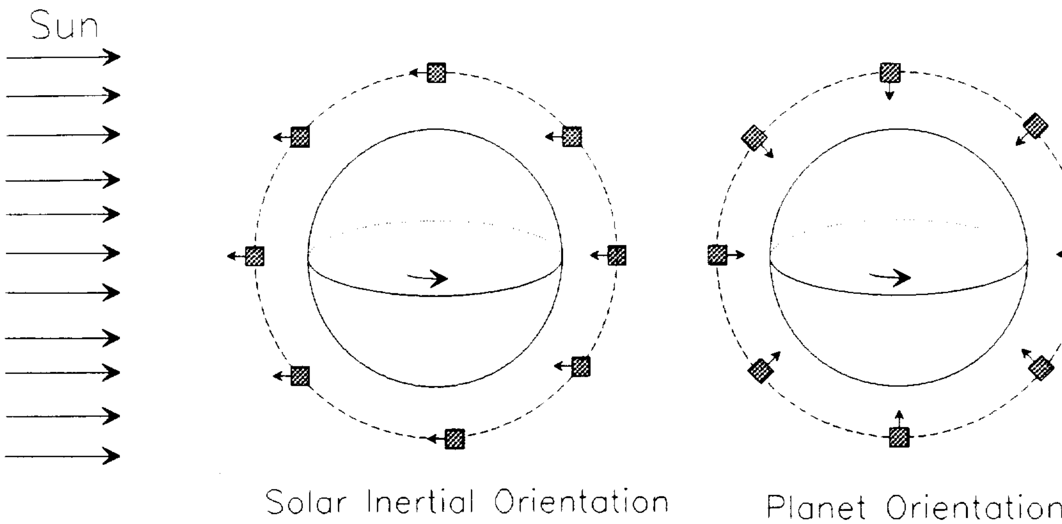

Figure 30 Orientation Geometry

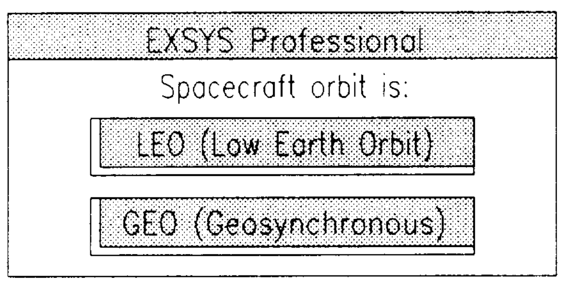

Figure 31 Orbit Selection Screen

and is in LEO, the user must specify the spacecraft position (Figure 32). Help Desk calculates the planet view factors normal and tangential to the planet's surface. Help Desk can accommodate any elliptical conic section with information about the spacecraft position without needing all the orbital elements.

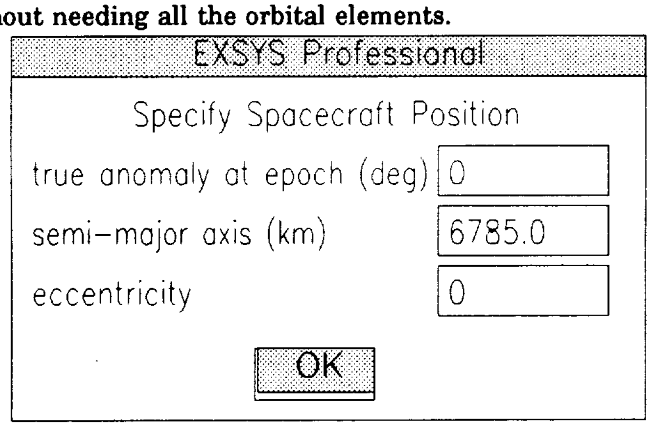

Figure 32 Spacecraft Position Screen

true anomaly at epoch The angle between the line of periapsis and the spacecraft position at a specific time. The default is 0°.

semi-major axis — Defines the size of the conic section. (2**a** is defined as the length of the cord passing through the foci connecting the end points of a conic section, where **a** is the semi-major axis). The default is 6785 km (220 nmi above the surface of the Earth).

eccentricity — Defines the shape of the conic section (0 for a circle; 0<1 for an ellipse; 1 for a parabola; >1 for a hyperbola). The default is 0°.

The default data file is "ECCSCR.DAT".

3.8.2 Orbital Elements

Help Desk determines the spacecraft position using the six classical orbital elements (Figure 33). The orbital elements are used to translate the global sun vector into the local spacecraft coordinates.

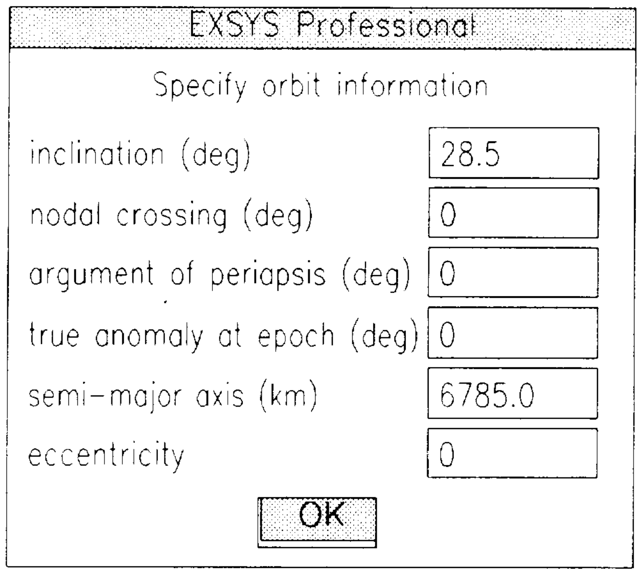

Figure 33 Orbital Elements Screen

inclination — Angle between the momentum vector and the global Z axis. The default is 0° inclination

nodal crossing — The angle between the vernal equinox direction and the line of nodes, in the equatorial plane (longitude of ascending node). The default is 0°.

argument of periapsis — The angle in the orbit plane between the line of nodes and the direction of periapsis. The default is 0°.

true anomaly at epoch — The angle between the line of periapsis and the spacecraft position at a specific time. The default is 0°.

semi-major axis — Defines the size of the conic section. (**2a** is defined as the length of the cord passing through the foci connecting the end points of a conic section, where **a** is the semi-major axis). The default is 6785 km (220 nmi above the surface of the Earth).

eccentricity — Defines the shape of the conic section (0 for a circle; 0<1 for an ellipse; 1 for a parabola; >1 for a hyperbola). The default is 0°.

The default data file is "INCSCR.DAT".

3.8.3 Modify Planet View Factors

When Help Desk finishes calculating the planet view factors, the user is asked if the planet view factors are to be modified (Figure 34).
The user has two options:

1) no — Help Desk continues the analysis using the current planet view factors.
2) yes — Help Desk displays the current planet view factors and allows the user to change them.

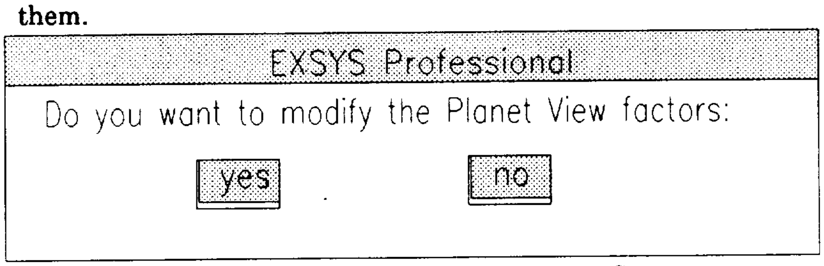

Figure 34 Modify Planet View Factors Screen

3.8.3.1 Manual Planet View Factors

The calculated planet view factors are returned to an input screen for the user's inspection and modifications (Figure 35).

One purpose of this screen is to allow the user to model a planet shield on one or more sides of the enclosure. The user can manually change the planet view factor, effectively shielding the side from the planet's radiation.

Press the "OK" button when the planet view factors are properly defined.

3.8.4 Planet Constants

The expert system displays the planet constants screen for the enclosure analysis (Figure 12, Page 14). These constants define the environment effecting the surface.

The user has two options for entering these values.

1) enter the known values and press the "OK" button
2) for a planet other than the Earth, press the "different planet" button.

Albedo coefficient — Percentage of the total solar radiation incident on the planet that is reflected back to space. The default is for Earth ~ 0.3.

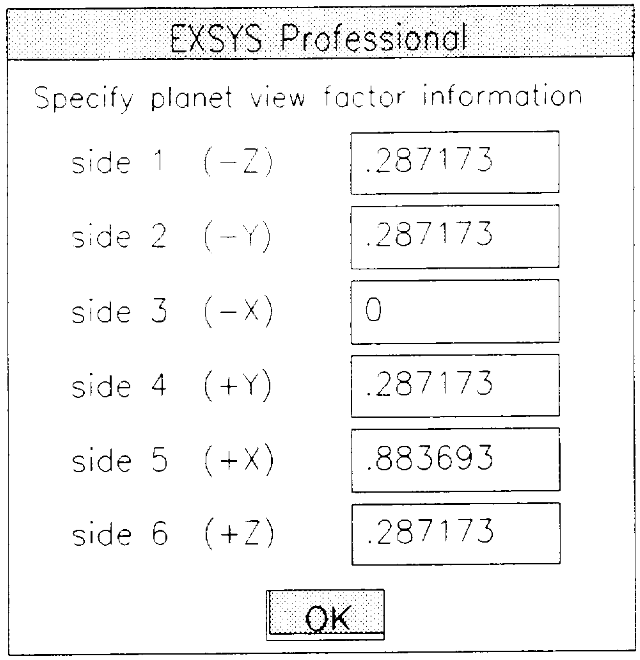

Figure 35 Manual Planet View Factors Screen

Solar Flux	Heat load per unit area due to the sun's radiation. The default is the yearly average for Earth ~1356 W/m^2.
Planet Flux	Heat load per unit area on the surface due to the planet's thermal radiation. The default is for Earth ~236 W/m^2.
Planet Radius	Radius of the planet under investigation. The default is for Earth ~ 6378 km

The default data file is "ABLSCR.DAT".

3.8.4.1 Different Planet Button

The different planet button allows the user to choose a planet other than the Earth for the analysis. Help Desk displays a list of the available planets for analysis (Figure 13, Page 15). For each planet, the values for Solar flux, Planet flux, Albedo coefficient and Planet radius are shown in the Table 1 on Page 16. If the values desired are different from those shown the user inputs the correct value directly in the Planet Constants screen.

3.8.5 Enclosure Property Screen

The enclosure property screen contains all of the physical enclosure properties (Figure 36).

enclosure dimension	The dimension along each of the three axes (m).
solar absorptivity	Absorptivity on each of the six sides. The user specifies each of the six sides independently
emissivity	Emissivity (or infrared absorptivity) on each of the six sides. The user specifies each of the six sides independently.

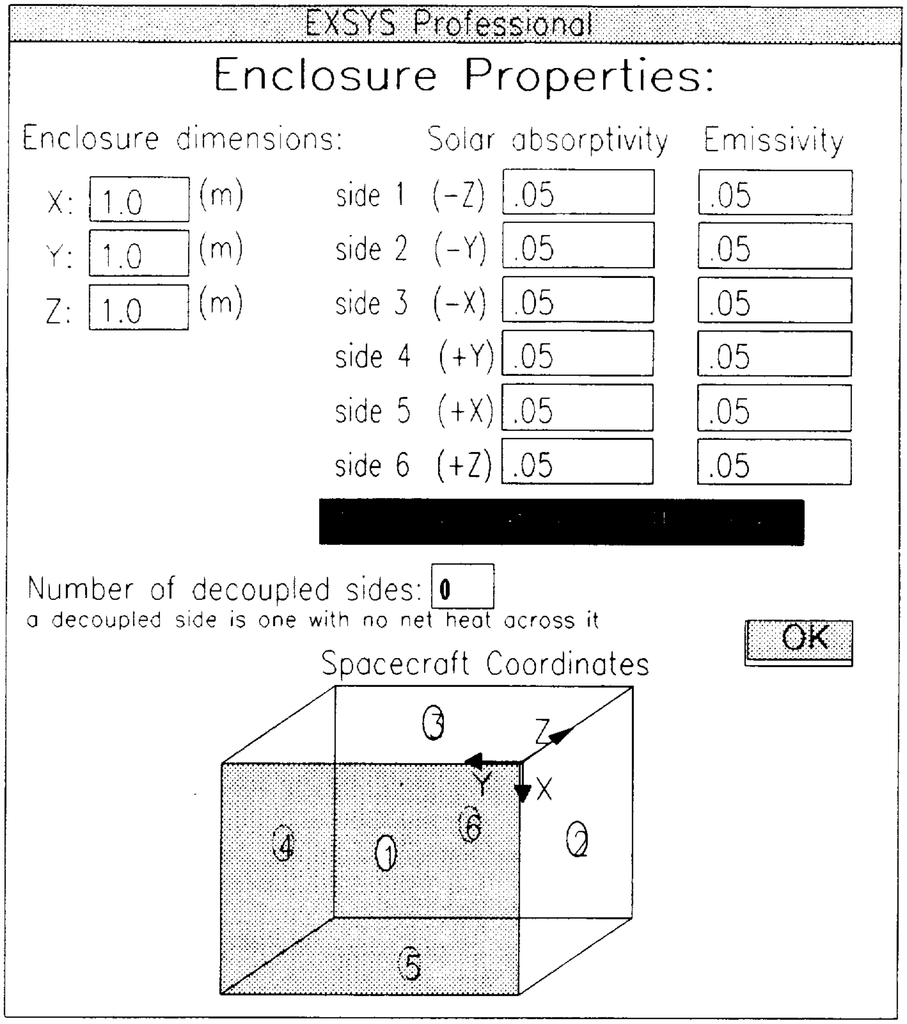

Figure 36 Enclosure Properties Screen

decoupled sides — The number of sides that are decoupled from the enclosure. A decoupled side is one with no net heat flux across it. Physically this is when one side is insulated from the outside environment (see section 3.8.5.1 below).

internal surface — The internal surface is black to promote isothermality.

spacecraft coordinate — A figure shows the spacecraft local coordinates and displays the surface numbers.

The default data file is "XSCR.DAT"

3.8.5.1 Decoupled Sides

A decoupled side is one with no net heat flux across it. An example is the side of an enclosure (or spacecraft bus) that has the thermal radiator attached to it. There is no net heat flux from the enclosure through the side with the radiator, so the side is effectively decoupled from the enclosure. When building a spacecraft, this is accomplished with insulation between the radiator and enclosure surface.

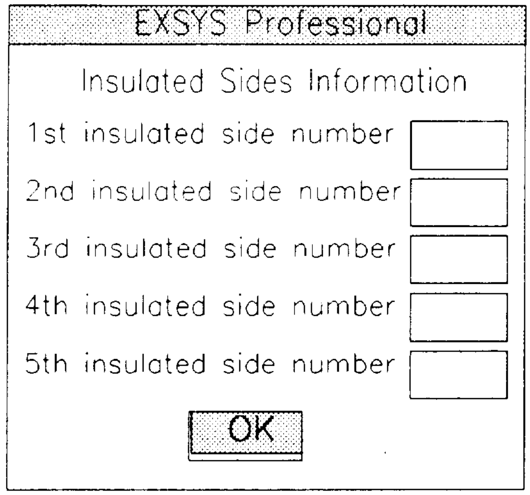

Figure 37 Insulated Sides Screen

If the user specifies more than 0 decoupled sides, Help Desk will request which of the sides are decoupled (Figure 37). The side numbers are displayed with the spacecraft coordinates on the bottom of the enclosure property screen. The side numbers can not be changed relative to the spacecraft coordinates.

Place the cursor in the box for the first insulated side number and type the side that is decoupled (e.g. if side 4 has the radiator, in the first insulated side number box type the number 4.)

3.8.6 Enclosure Results Screen

The enclosure analysis results screen is shown in Figure 38.

surface temperatures	On each of the six sides
net surface heat loads	On each of the six sides. Heat load is the total heat on the entire area of the surface.
orbit information	Specified by the user including orbital elements, orientation and orbit.
external surface properties	Specified by the user

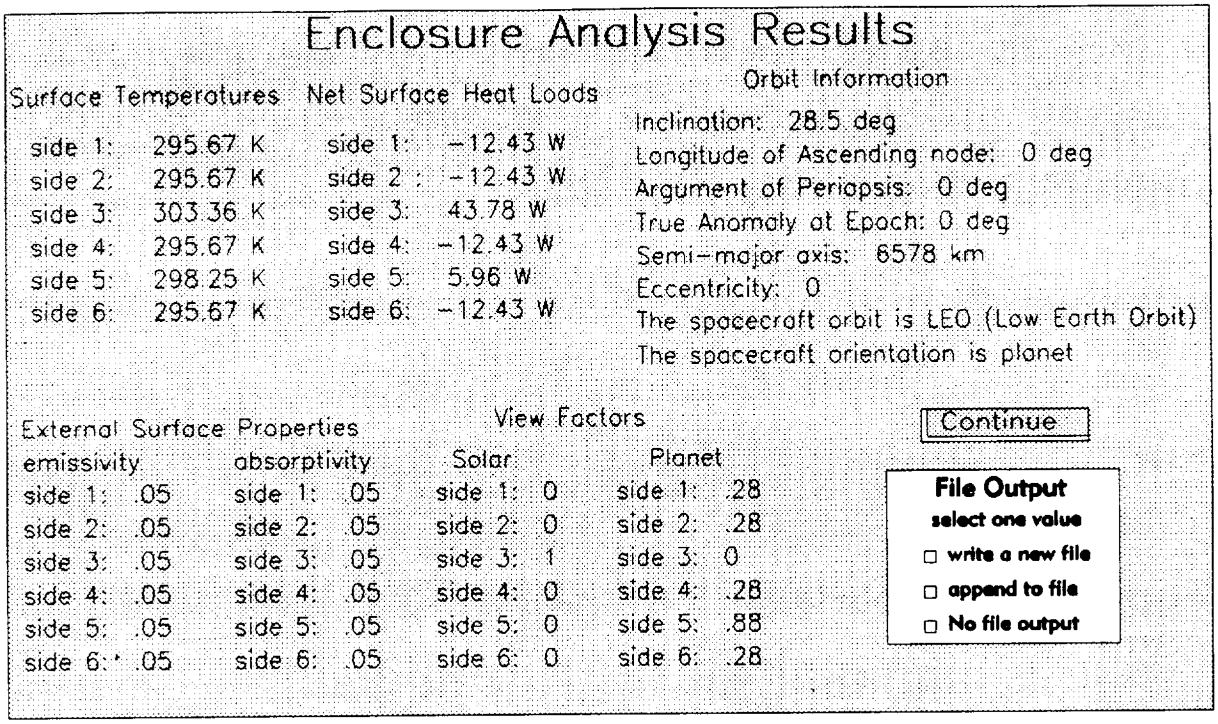

Figure 38 Enclosure Analysis Results Screen

solar view factors	Calculated by the expert system using the sun vector and the orbital information.
planet view factors	Calculated by the expert system and reviewed and modified by the user.
file output ENCL.RPT	The user selects the form of file output. • write a new file • append to an old file • no file output

3.8.7 Report File

At the end of an analysis run, Help Desk can write the data to an ASCII file so that the user may access the information after the analysis session has ended. The menu selection appears on the report screens shown in Figure 38.

Help Desk allows the user to:
1) create a new file with the information
2) append the data to the existing file
3) produce no file output.

The information written to the file ENCL.RPT. It contains the same data that is displayed on the Enclosure Analysis Results screen.

The last few screens are EXSYS® generated. See section 2.5.1 and the EXSYS® manual for further details.

3.9 ORBITAL TEMPERATURE AND HEAT LOADS

The Orbital Temperatures and Heat Loads analysis is similar to the Enclosure Temperatures and Heat Loads analysis option. Both codes use the same FORTRAN DOS codes to calculate solutions.

There are two major differences between the enclosure analysis and the orbital analysis.

1) the orbital analysis is calculated over an entire orbit instead of at a single point. The user specifies the number of orbit points to be analyzed.
2) the user cannot manually specify the planet view factor for any of the six sides, as in the enclosure analysis.

3.9.1 Shadowing

The orbital analysis and heat loads section calculates when the spacecraft is in the shadow of the planet. It changes the solar flux and solar view factors to zero when in the shadow. See the Technical guide for more details.

3.9.2 Solar and Planet View Factors

The solar view factor for a surface is the fraction of the surface that "sees" the sun For example, in Earth orbit:

- 1 - fully facing the sun
- 0 - parallel to the sun's rays
- 0 - facing away from the sun

The planet view factor for a surface is the fraction of the surface that "sees" the planet. For example, in low Earth orbit:

- .88 - fully facing the planet
- .29 - perpendicular to the planet's surface
- 0 - facing away from the planet

Three variables effect the solar and planet view factors, the spacecraft orientation, the orbit and the position of the sun.

Help Desk has two choices for spacecraft orientation:

1) planet oriented
2) solar inertially oriented

When the spacecraft is planet oriented, side 5 of the enclosure always faces the planet. In this orientation all the surfaces rotate with respect to the sun. Therefore the planet view factors are relatively constant, while the solar view factors rotate with the spacecraft as it orbits the planet.

When the spacecraft is in a solar inertial orientation the same surface(s) always faces the sun. In this orientation all the surfaces rotate with respect to the planet. Therefore, the planet view factors change as the spacecraft orbits the planet and the solar view factors are constant.

Help Desk has two choices for spacecraft orbit:

1) geosynchronous earth orbit (GEO)
2) low earth orbit (LEO).

GEO is defined with an orbital period equal to the daily rotation period of the planet. The planet view factors are effectively zero and are defaulted to zero, simplifying the number of calculations.

LEO is defined with a semi-major axis smaller than the GEO limiting case. The planet view factors are calculated at each orbit point.

The sun position can only be entered in global coordinates.
Help Desk calculates the solar view factors by taking the dot product of the solar vector in local spacecraft coordinates with the local unit normals for the enclosure. The unit normals are fixed with respect to the body. The sun vector is entered in global coordinates, Help Desk must take into consideration the spacecraft orientation when calculating solar view factors.

If the *orientation is solar inertial*, Help Desk calculates the solar view factors at the line of nodes. It assumes the orientation keeps the same side(s) facing the sun at all positions in the orbit. If the *orientation is planet*, Help Desk rotates the global vector to local coordinates. It then take the dot product of the local sun vector and the unit normals. Help Desk uses a FORTRAN executable DOS code to perform most of the orbital temperature and heat load calculations.

3.9.2.1 Spacecraft orientation

The user specifies the orientation of the spacecraft from two options (Figure 29, Page 33):
1) planet
2) inertial

A geometric representation of each orientation is provided in Figure 30, Page 34.

A planet oriented spacecraft always has one surface fixed with respect to the planet's surface. In Help Desk, side 5 is fixed with respect to the planet. A solar inertial oriented spacecraft always has the same surface(s) fixed with respect to the sun. See section 3.9.2 for more details.

3.9.2.2 Planet Constants screen

Figure 12, Page 14 shows the planet constants screen. These constants determine the environment effecting the surface.

The user has two options for entering these values.
1) enter the known values and press the "OK" button
2) for a planet other than the Earth, press the "different planet" button.

Albedo coefficient	Percentage of the total solar radiation incident on the planet that is reflected back to space. The default is for Earth ~ 0.3.
Solar Flux	Heat load per unit area on the surface due to the sun's radiation. The default is the yearly average for Earth ~1356 W/m^2.
Planet Flux	Heat load per unit area on the surface due to the planet's thermal radiation. The default is for Earth ~236 W/m^2.
Planet Radius	Radius of the planet under investigation. The default is for Earth ~ 6378 km

The default data file is "ALBSCR.DAT".

3.9.2.2.1 Different Planet Button

The different planet button allows the user to choose a planet other than the Earth for the analysis. Help Desk displays a list of the available planets for analysis (Figure 13, Page 15). Once a planet is selected, the values for Solar flux, Planet flux, Albedo coefficient and Planet radius are taken from the Table 1. If the values desired are different from those shown in Table 1 on Page 16, the user may input the correct values directly in the Planet Constants screen.

3.9.2.3 Global Sun and Planet Vector

The sun vector is the position of the sun, specified in global spacecraft coordinates (Figure 28, Page 33). The global planet vector is currently not used in any analysis. However, the necessary input value boxes have been included to facilitate the addition of this feature in a future version of Help Desk.

Help Desk uses the spacecraft position information and rotates the global sun vector into the local spacecraft coordinates at each of the user defined points in the orbit.

The defaults are (-1,0,0) for the sun vector and (0,0,0) for the planet vector.

The default data file is "GSSCR.DAT".

3.9.3 Orbital Elements

Help Desk determines the spacecraft position using the six classical orbital elements (Figure 33, Page 35). The orbital elements are used to translate the global vector into the local spacecraft coordinate, at every orbit position.

inclination	Angle between the momentum vector and the global Z axis. The default is 0° inclination
nodal crossing	The angle between the vernal equinox direction and the line of nodes, in the equatorial plane (longitude of ascending node). The default is 0°.
argument of periapsis	The angle in the orbit plane between the line of nodes and the direction of periapsis. The default is 0°.
true anomaly at epoch	The angle between the line of periapsis and the spacecraft position at a specific time. The default is 0°.
semi-major axis	Defines the size of the conic section. (2**a** is defined as the length of the cord passing through the foci connecting the end points of a conic section, where **a** is the semi-major axis). The default is 6785 km (220 nmi above the surface of the Earth).
eccentricity	Defines the shape of the conic section (0 for a circle; 0<1 for an ellipse; 1 for a parabola; >1 for a hyperbola). The default is 0°.

The default data file is "INCSCR.DAT".

3.9.4 Enclosure Property Screen

The enclosure property screen contains all of the physical enclosure properties (Figure 36, Page 37).

enclosure dimension	The dimension along each of the three axes (m).
solar absorptivity	Absorptivity on each of the six sides. The user specifies each of the six sides independently
emissivity	(or infrared absorptivity) Emissivity on each of the six sides. The user specifies each of the six sides independently.
decoupled sides	How many sides are decoupled from the enclosure. A decoupled side is one with no net heat flux across it. Physically this is when one side is insulated from the outside environment (see section 3.9.4.1 below).
internal surface	The internal surface is black to promote isothermality.
spacecraft coordinate	A figure shows the spacecraft local coordinates and displays the surface numbers.

The default data file is "XSCR.DAT"

3.9.4.1 Decoupled Sides

A decoupled side is one with no net heat flux across it. An example is the side of an enclosure (or spacecraft bus) that has the thermal radiator attached to it. There is no net heat flux from the enclosure through the side with the radiator, so that the side is effectively decoupled from the enclosure. When building a spacecraft, this is accomplished with insulation between the radiator and enclosure surface.

If the user specifies more than 0 decoupled sides, Help Desk will request which of the sides are decoupled (Figure 37, Page 39). The side numbers are displayed with the spacecraft coordinates on the bottom of the enclosure property screen. The side numbers can not be changed relative to the spacecraft coordinates.

Place the cursor in the box for the 1st insulated side number and type the side that is decoupled (e.g. if side 4 has the radiator, in the 1st insulated side number box type the number 4.)

3.9.5 Number of Orbit Points

The user defines the number of points around an orbit at which the temperatures and heat loads are calculated (Figure 39). Default is 12 points, such that the orbit will be analyzed every 30°, (e.g. 360/12 = 30).

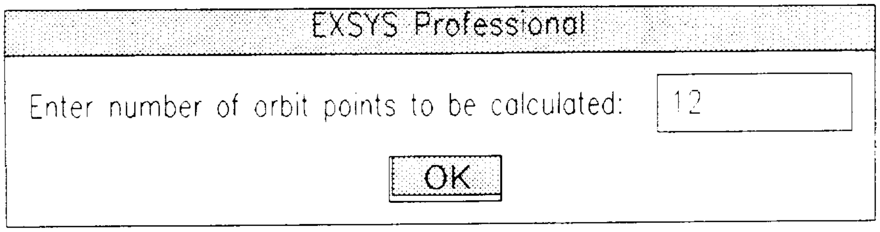

Figure 39 Number of Orbit Points Screen

3.9.6 Orbit Analysis Results Screen

The orbit analysis results screen shows many of the worst case (hottest side, highest temperature delta between two sides) and best case (most isothermal) results from the orbital analysis run (Figure 40).

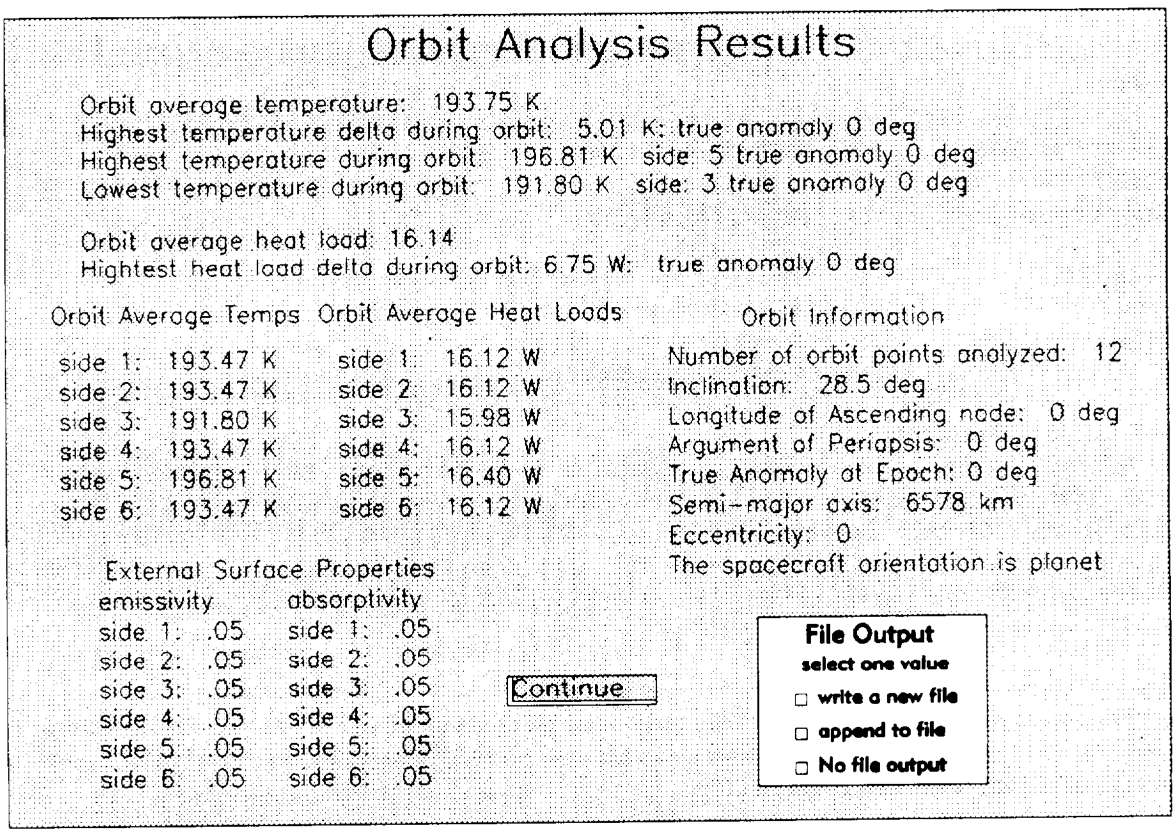

Figure 40 Orbital Analysis Results Screen

Orbit average temperature The average of all six sides averaged over the entire orbit.

highest temperature delta The highest temperature delta between any two sides and the true anomaly where it occurs.

highest temperature of any side	The highest temperature of any side during the entire orbit, the side number and the true anomaly where it occurs.
lowest temperature of any side	The lowest temperature of any side during the entire orbit, the side number and the true anomaly where it occurs.
orbit average heat load	The average heat load of all six sides averaged over the entire orbit.
highest heat load delta	The highest heat load delta between any two sides at one position in the orbit and the true anomaly of the position where it occurs.
orbit average temperatures	Average temperature for each of the six sides over the entire orbit.
orbit average heat loads	Average heat load for each of the six sides over the entire orbit.
external surface properties	Defined by the user
orbit information	defined by the user.
file output ORBIT.RPT	The user selects the form of file output. • write a new file • append to an old file • no file output

3.9.7 Orbit Data File

The information on the orbital analysis results screen is stored in an ASCII data file called "RAD_ORB.DAT". It contains all the temperatures and heat loads for each point in the orbit. The user can determine the worst case orbital positions(s) and find all of the information for a specific point in the data file. The enclosure analysis can then be used for a more in-depth thermal analysis at a specific point in the orbit. For example the addition of a planet shield and determination of the environmental temperatures.

3.9.8 Report File

At the end of an analysis run, Help Desk can write the data to an ASCII file so the user may access the information after the analysis session has ended. The menu selection appears on the report screen shown in Figure 40.

Help Desk allows the user to:
1) create a new file with the information
2) append the data to the existing file
3) produce no file output.

The information is written to the file ORBIT.RPT. It contains the same data that is displayed on the Orbital Analysis Results screen.

The last few screens are EXSYS® generated. See section 2.5.1 and the EXSYS® manual for further details.

3.10 SURFACE PROPERTIES

The SURFACE PROPERTIES option and the ASSISTANCE Button (Figure 9), help the user to select the appropriate surface emissivity and solar absorptivity. The user must input the surface material or the surface application.

This analysis uses the frame "SURFACE.TXT". A frame is a small database of information that the expert system can access. When the expert system accesses the frame, it returns the first occurrence that satisfies the inquiry. The values in the frame are taken from a table, "Thermal Properties of Surfaces" published in Reference 1. The frame file SURFACE.TXT is located in the directory with the expert system and the other data files. The entire frame "SURFACE.TXT" is shown below.

Surface	Typical_application	Solar_absorptance		Emittance	
		BOL	EOL	BOL	EOL
black paint	interior structure	0.90	0.90	0.90	0.90
white paint	antenna reflector	0.20	0.60	0.90	0.90
optical solar reflector	north panel radiator	0.08	0.21	0.80	0.80
optical solar reflector	south panel radiator	0.08	0.21	0.80	0.80
graphite/epoxy	solar panel	0.84	0.84	0.85	0.85
graphite/epoxy	antenna structure	0.84	0.84	0.85	0.85
aluminized kapton	thermal insulation	0.35	0.50	0.60	0.60
tiodized titanium	apogee motor thermal shield	0.60	0.60	0.60	0.60
aluminum	propellant insulation	0.12	0.18	0.06	0.06
aluminum tape	propellant insulation	0.12	0.18	0.06	0.06
deposited aluminum	propellant insulation	0.12	0.18	0.06	0.06
anodized aluminum	interior structure	0.20	0.60	0.80	0.80
solar cells	solar panels	0.70	0.70	0.82	0.82
gold		0.25	0.25	0.05	0.05
multilayered insulation	surface insulation	0.05	0.05	0.05	0.05
BOL, Beginning of Life; EOL, End of Life, 7 years					
surface data taken from Reference 1, page 275					

Table 2: Surface Properties

3.10.1 Performance Time

The user is asked if the performance time is beginning of life (BOL) or end of life (EOL) (Figure 41).

BOL returns the values for the maximum capabilities of the thermal control system.

EOL returns the values for the degraded capabilities at 7 years. All surfaces degrade somewhat over time due to the ultraviolet solar radiation.

3.10.2 Surface Material/ Surface Application

The user is asked if the known information is the surface material or the application of the surface (Figure 42).

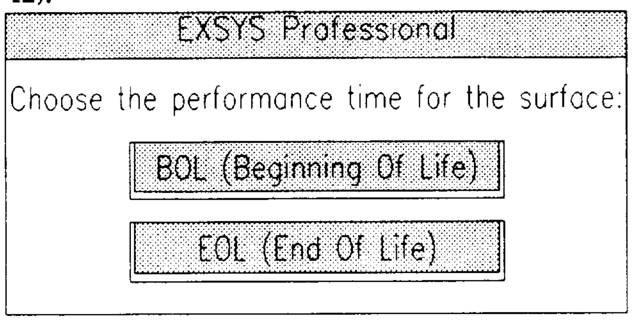

Figure 41 Performance Information Screen

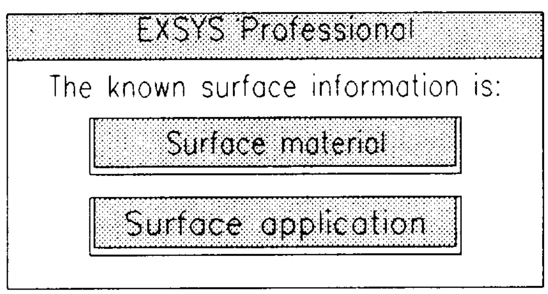

Figure 42 Known Surface Information Screen

Surface material The material composition of the surface (e.g. black paint). Help Desk shows a list of surface materials (Figure 43) for the user to choose from. The user must select one of the displayed options. Help Desk searches the frame for the first occurrence that matches the user's request. The values for emissivity, absorptivity and surface application are placed in the variables [EPSILON], [ALPHA] and [APPLICATION].

Surface Application The use of the surface (e.g. reflector). Help Desk shows a list of surface applications (Figure 44) for the user to choose from. The user must select one of the displayed options. Help Desk searches the frame for the first occurrence that matches the user's request. The values for emissivity, absorptivity and surface material are assigned to the variables [EPSILON], [ALPHA] and [MATERIAL].

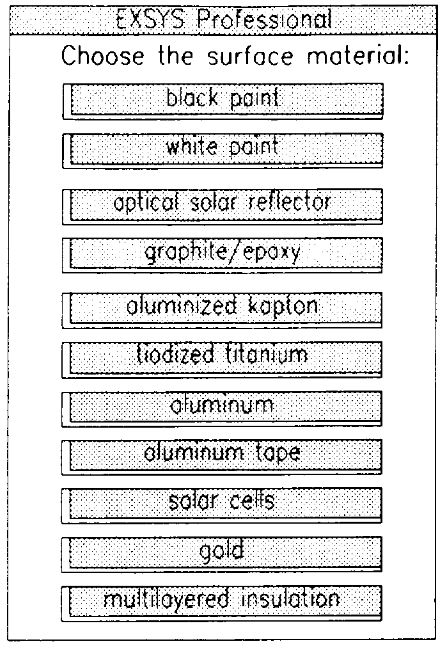

Figure 43 Surface Material Screen

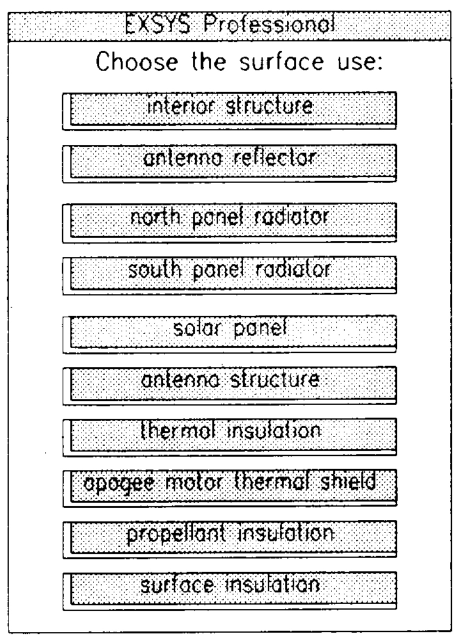

Figure 44 Surface Application Screen

3.10.3 Surface Properties Results

The surface properties results screen is shown in Figure 45.

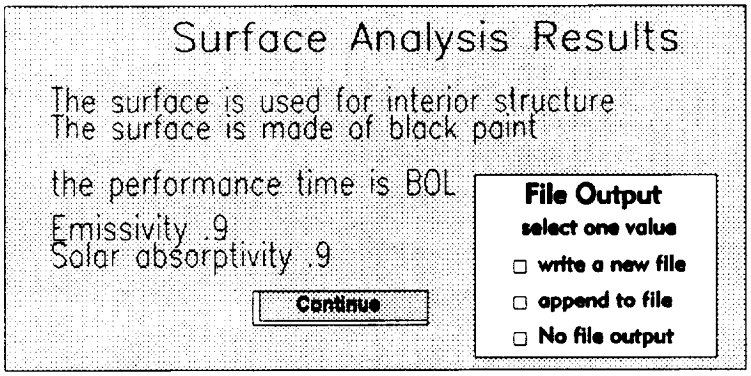

Figure 45 Surface Properties Results Screen

surface application	Application of the surface
surface material	Material composition of the surface
performance time	The time at which the analysis is being performed, either the beginning or the end of the instruments life.
emissivity	Surface emissivity or infrared absorptivity
absorptivity	Surface solar absorptivity
file output SURF.RPT	The user selects the form of file output. • write a new file • append to an old file • no file output

The emissivities and absorptivities can be used for future analysis with any of the other options on the Main Menu.

If the Surface Properties option was accessed with the ASSISTANCE Button, the system will continue with the appropriate analysis using the emmissivity and absorptivity as shown in the results screen.

3.10.4 Report File

At the end of an analysis run, Help Desk can write the data to an ASCII file so the user may access the information after the analysis session has ended. The menu selection appears on the Report screens shown in Figure 45.

Help Desk allows the user to:
1) create a new file with the information
2) append the data to the existing file
3) produce no file output.

The information written to the file SURF.RPT. It contains the same data that is displayed on the Surface Analysis Results screen.

The last few screens are EXSYS® generated. See section 2.5.1 and the EXSYS® manual for further details.

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Glossary

fired rules	when a THEN clause is executed
heat load	total heat on a surface (W)
heat flux	heat on a surface per unit area (W/m^2)
surface	single flat plate (Figure 46)

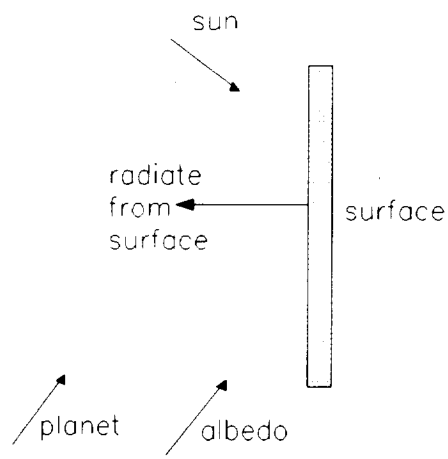

Figure 46 Surface Analysis Geometry

enclosure	rectangular box (Figure 47)

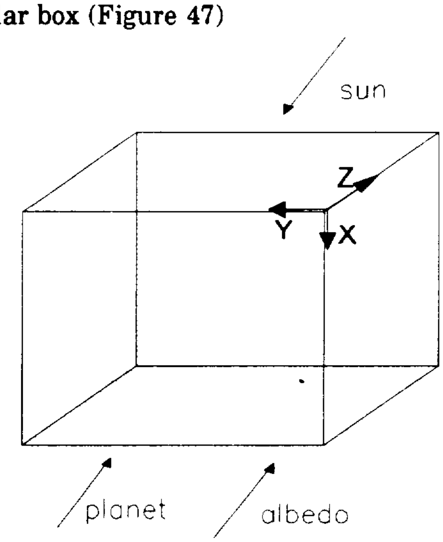

Figure 47 Enclosure Analysis Geometry

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13. ABSTRACT (Maximum 200 words)

This document is a guide for users of the Thermal Analyst's Help Desk. Help Desk is an expert system that runs on a DOS based personal computer and operates within the EXSYS℠ expert system shell. Help Desk is an analysis tool designed to provide users having various degrees of experience with the capability to determine first approximations of thermal capacity for spacecraft and instruments. The five analyses supported in Help Desk are: (1) surface area required for a radiating surface, (2) equilibrium temperature of a surface, (3) enclosure temperature and heat loads for a defined position in orbit, (4) enclosure temperature and heat loads over a complete orbit, and (5) selection of appropriate surface properties. The two geometries supported by Help Desk are a single flat plate and a rectangular box enclosure.

14. SUBJECT TERMS
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