ENVIRONET: A SPACE ENVIRONMENT DATA RESOURCE

Michael Lauriente
NASA Goddard Space Flight Center, Greenbelt, MD 20771

Henry Berry Garrett
Jet Propulsion Laboratory, Pasadena, CA 91109

ABSTRACT

This paper reviews the EnviroNET space data resource. This computerized data base provides rapid access to the latest information on a variety of environments and interactions of importance to the space community. Although primarily intended as a source for Space Shuttle users, the EnviroNET has information on spacecraft charging and the near-Earth charging environment of potential value to the conference attendees. These products, particularly as they relate to spacecraft charging and environmental interactions, are presented and the means for accessing them addressed.

INTRODUCTION

EnviroNET is a NASA service facility that can provide the spacecraft interactions community with on-line, dial-up technical information concerning environmental conditions likely to be encountered on station in a variety of orbital regimes. This information is intended to help scientists and engineers design equipment that will operate successfully in the possibly hostile spacecraft charging environments. Figure 1 illustrates the advantages of this system for the potential user. In particular, the system incorporates a combination of expository text and numerical tables and programs that currently model several natural environments required for spacecraft charging studies. The text is under continuous review by technical subpanels (each corresponding to the subject areas of the database) of experts who correct and augment the database to keep it accurate and current. A partial list of the current topics contained in EnviroNET is shown in Figure 2. Following a brief description of the data base as a whole and as an illustration of its contents, two areas of direct importance to this conference will be discussed in more detail: the subpanel on Surface Interactions which contains information on charging-related interactions with spacecraft and the Natural Environments subpanel. The paper concludes with a call for the conference attendees to review EnviroNET and to recommend changes so that it can better support the spacecraft charging community.

BACKGROUND

Early in the development of the Space Shuttle, payload planners recognized the need for a detailed description of the environmental interactions with Shuttle and its payloads. The extreme complexity and size of the Shuttle made it very difficult to characterize these environments by direct computation. At the urging of the NASA payload community, the Shuttle Program agreed to fly instruments (in early Orbital Flight Tests) that would measure various elements of payload environment. In the fall of 1982, NASA conducted its first Shuttle Environment Workshop *[Systematics Corp., Contract NAS5-27326, February 1983]* to describe what had been learned from these measurements. This led to concerns voiced with regard to the need for up-to-date information, on a continuing basis, about these and new concerns. To address the issues, NASA's Office of Space Science and Applications (OSSA) requested that a focal point be established for this environmental information, and that the activity be coordinated with other NASA centers, government agencies, and the user community. In mid-1983, Shuttle Payload Engineering Division asked that Goddard Space Flight Center (GSFC) lead an Agency-wide effort to identify Shuttle environment data that could be used by Shuttle payload planners and developers. It also suggested that the data obtained from this activity be put into an electronic database which could be accessed by any interested user. It is from this base that the current EnviroNET user resource grew.

A multi-center Shuttle Environment Working Group was organized through the efforts of OSSA and GSFC, with a Working Group established to prepare the charter and framework within which this group would function, Figure 3. The Working Group began organizing in late 1983. Three major panels were established with the functions and duties as follows:

- o The Natural and Induced Environments Panel, Figure 4, gathers and organizes data for input into the database
- o The User Panel, Figure 5, provides for interaction between disciplines and users.
- o The Information Management Panel, Figure 6, provides the database structure and manages the database.

The ultimate goal of the Working Group panels was to establish a comprehensive database of current information regarding the Shuttle Environment, readily accessible in a user-friendly format. Specific objectives for the Shuttle Environment Working Group (see

Figure 3), the working group relevant to this conference, included:

- o Assessing the user requirements for environmental data at all stages of experiment definition and development.
- o Obtaining and distilling the pertinent environmental data from available sources.
- o Working with the sources to obtain a common database that will be reviewed by experts in the specific areas.
- o Developing an information accessing system that is user-friendly.
- o Providing a network accessible by a wide variety of existing computer terminals and peripherals.
- o Coordinating these activities with other NASA centers, government agencies, and the user community.

Subpanels were created to address each of 10 environmental interactions identified as critical to the Shuttle program, Figure 4. These interaction areas were subsequently filled in at a series of workshops over the last 6 years (see later examples). Currently, more specific tailoring of the data base is underway, with models under development to provide tabular outputs to the screen or to files, and for plotting the resultant models. Orbit dosage models designed to allow the user to predict the radiation dosage for a given orbit or to predict densities and temperatures encountered along a given orbit are now available. Computer models are being expanded beyond the current models (thermosphere, ionosphere, energetic particles, magnetic field) to include gravity, radiation, meteoroids, space debris, and spacecraft anomalies. A simple spacecraft charging code will hopefully be available in the future for on-line use.

ENVIRONET AND SPACECRAFT CHARGING

The main EnviroNET topical areas of interest to spacecraft charging technology are found in Sections 8.0 and 11.0, Figure 2, Natural Environment and Surface Interactions respectively. A short summary and rationale for each of these chapters is presented in the following. As these sections contain a tremendous amount of data on the particular topics, it will only be possible to provide a brief overview of each (we urge the reader to actually try EnviroNET, don't just read about it!).

Consider first the chapter on the Natural Environment. The purpose of this EnviroNET section is to describe the ambient natural environment that a vehicle will encounter while orbiting the earth. The natural environment includes neutral atmosphere, electromagnetic radiation (EMR), meteoroids, space debris, magnetic and gravitational fields, physical constants, and, of direct importance to spacecraft charging, plasma and charged particle radiation. Much of the content has been derived from JSC 30425, "Space Station Program Natural Environment Definition for Design." However, the material has been extensively edited and new material is continually being added to EnviroNET (it should always be kept in mind, however, that although EnviroNET is a NASA/AF product, it does not represent a contractually acceptable definition of the natural environment for payload design and development; it is provided only as a convenient information source to EnviroNET users).

The Natural Environment section (Figure 3) does not cover the induced environment or other effects resulting from the presence of the orbiting vehicle. Certain man-made factors were included, however, as part of the ambient natural environment (i.e., space debris and radio frequency (RF) noise generated on Earth), because they are not caused by the presence of the vehicle but form part of the ambient environment that it experiences. Each subsection contains an explanation and numerical description of the natural environment phenomena to which it is devoted. It was intended that these data would be sufficient for defining most preliminary hardware and experiment concepts. It is important to note that many of the natural environments discussed in EnviroNET are strong functions of time, varying with the solar cycle and the strength of the Earth's magnetic field, for example. Thus, for critical applications, it is important to use both an accurate model and the most up-to-date solar activity and field strength predictions. EnviroNET attempts to provide wherever possible specific instructions to the user on what is actually required and information on possible sources where day to day data are required.

As an example of the use of the Natural Environment section, consider Figure 7 and the path to it. This is part of the documentation material contained in EnviroNET on the MSIS model, a major code for predicting the neutral atmosphere. Figures 8 and 9 illustrate another part of the Natural Environment section--the modelling section. Figure 9 is an example of a user-friendly model for the 1986 Mass Spectrometer Incoherent Scatter Model (Hedin, 1987). The boundary conditions are shown above as input parameters. The output shown on the right is blank until the computer is asked to run the model (R) with keyed in values. A surface plot from the output of the model for atomic oxygen is shown in Figure 9. In this part of the data base, the user can thus obtain estimates of the atmospheric density and temperature from the MSIS model. Such information would be valuable for drag calculations or in estimating oxygen erosion. Note in particular this capability of the EnviroNET to provide graphical output in real time. For spacecraft charging studies, it is

planned to add models of the geosynchronous plasma and of the aurora that can be used to estimate the currents to the vehicle in these environments. Currently available is the IRI or International Reference Ionosphere model which is required for computing charging at low altitudes. As in the case of MSIS, help screens, a program description, and plotting capability are available.

The EnviroNET section on Surface Interactions contains the majority of the material of relevancy to this conference. As is well known to the attendees, the space environment at Shuttle altitudes can seriously affect spacecraft surfaces. Besides contamination and particle damage (covered by other sections), several such interactions with spacecraft surfaces have been observed in the last few years. The principle ones discussed in this section are:

1) spacecraft surface charging 2) V x B induced currents 3) High-voltage surface interactions 4) shuttle Ram/Wake plasma variations 5) shuttle surface glow 6) Atomic oxygen effects (spacecraft surface erosion)

Whereas at Shuttle altitudes, glow, surface erosion, and high-voltage surface interactions (resulting in power loss and increased surface arcing) are considered the most serious as they pose direct threats to operations, spacecraft charging is primarily a geosynchronous phenomenon--why then is it included in EnviroNET? The reasons for including spacecraft charging in EnviroNET should be obvious to the participants, however. Evidence from AF experiments on the Defense Meteorological Satellite Program (DMSP) have indicated that potentials as high as 1 kV may be observed in the auroral zone at low Earth orbit--hence, the justification for including spacecraft charging in the EnviroNET. Likewise, variations in the shuttle plasma sheath are tied to interactions with the shuttle surface potentials. These variations, and the regions of plasma enhancement and depletion and charging that they create, will greatly influence the environment around the Shuttle and therefore must also be included in a Shuttle data base and accurately characterized. V x B effects are probably the least serious of the "spacecraft charging" interactions included in EnviroNET. Even so, given the size of the Shuttle and some of the proposed shuttle-based systems such as the tether, the electric field induced by V x B may significantly affect operations. Thus, spacecraft charging and related phenomena are a critical component of the EnviroNET.

The data in the Surface Interaction section of EnviroNET are organized into the following subsections:

11.3 Spacecraft Charging (I. Katz and A. Rubin)

11.4 V x B (I. Katz and W. Raitt)
11.5 High Voltage (I. Katz)
11.6 Ram/Wake (A. Rubin, W. Denig, and W. Raitt)
11.7 Glow (H.B. Garrett, A. Chutjian, and S. Gabriel)
11.8 Atomic Oxygen Effects (L. Leger)

Each section is then broken down along the following lines:

1. Description
2. References
3. Key Players
4. Existing Data
5. Required Data
6. Possible Experiments
7. Mitigation

A sample screen from the "Description" part of the spacecraft charging subsection is presented in Figure 10. A list of "key players" from the data base is presented in Figure 11. Currently, the spacecraft charging section needs to be updated. The presentation of EnviroNET at this conference is intended to spur interest in this process and to allow us to provide you the user with the most up-to-date on this critical problem.

In addition to the obvious interest of the participants in this conference in sections on charging, V x B, Ram/Wake effects, and high voltage interactions, EnviroNET provides an additional service. Under the subsection on oxygen erosion, EnviroNET has stored up-to-date oxygen erosion rates for most common spacecraft surfaces. This information is critical in the selection of surface materials for charge control--materials subject to rapid oxygen erosion should not be used for conductive outer coatings (as an example, surfaces covered with ZOT paint for electrical and thermal control on Galileo were found to erode during a few days of exposure at Shuttle altitudes and loose their conductive properties). Although currently not available on EnviroNET, lists of secondary, photoelectron, and backscattering properties of common materials could be similarly provided if the attendees find this to be a useful addition.

UPDATING ENVIRONET

EnviroNET is a living document. Thus, workshops are conducted periodically for the panel leaders and subpanels. The results of these workshops are printed as informal documents for the purpose of feedback of information essential to the improvement of the services to users and to take advantage of the advancements in communications. These

documents are available upon request. As an example, at the mini-workshop held by the Natural Environment Panel, recommendations were made to add models that will generate energetic electron and proton environment values for a point in space, calculate orbital integrations of particle fluence, provide magnetic field traces and calculate ionospheric parameters. Besides now featuring interactive software, the system will eventually simplify space environment mission analysis. More recently, a mini-workshop was held on environmentally induced spacecraft anomalies *[Belmont Conference, 1989]*. The four main types of anomalies of concern are surface charging, bulk charging, single event upset, radiation dose. Plans are underway to develop a new chapter on this subject. A test bed is also planned for an expert system on spacecraft anomalies in cooperation with the Air Force.

CONCLUSION

EnviroNET is an operational system available to the scientists, engineers, satellite operators and users concerned with space environments who have access to a terminal or dial-up port. It is a tail node on SPAN accessible directly or through the national networks via NPSS. The EnviroNET staff welcomes comments and suggestions for how to improve this service. In particular, spacecraft charging is an area that would greatly benefit from the services that EnviroNET could provide--by serving as a source of computer models of the environment and charging, through lists of electrical properties of materials, and as a clearing house for the most recent papers and results. To summarize, the benefits to using EnviroNET include:

1) Validated NASA environmental information and interactive space models

2) Facilitating analysis of the natural space environment for missions

3) Easy access to expert assistance

Note: for EnviroNET to succeed, *user feed back is critical!*

APPENDIX: USING ENVIRONET

The following is intended as a very brief introduction to using EnviroNET and it structures (for details, the potential user is referred to the "EnviroNET User's Guide, 1989"). Specifically, the files, stored on a MicroVAX II computer at Goddard Space Flight Center (GSFC), can be accessed 24 hours a day by the user via modems or the NASA Space Physics Analysis Network (SPAN), (Green, 1988). SPAN is available via more than 1000 space science computer systems throughout the U.S. Canada and Europe. The database retrieval program features many user friendly options including transportability of data, software, and interactive computer modeling capability.

EnviroNET is accessed through the very well known SPAN system. SPAN uses Digital Equipment Corporation computers as network nodes (usually already paid for by NASA for a wide number of missions), and communicates over a combination of leased circuit switches and packet switching lines using the DECnet protocol. The SPAN topology, Figure 12, features four primary routing centers in the United States: Goddard Space Flight Center (GSFC), Johnson Space Flight Center (JSC), the Jet Propulsion Laboratory (JPL), and Marshall Space Flight Center, (MSFC), as well as one routing center at the European Space Operations Center (ESOC) in Darmstadt, Germany. There are approximately 1200 registered SPAN nodes. EnviroNET may be accessed via modem-equipped terminals, SPAN, or network servers at the routing centers.

The SPAN system allows the space scientific community to share information at speed of light. The network supports the transmission and reception of manuscripts. Data and Graphics files can be transferred between network nodes. The graphics bit map program written for EnviroNET has a transparent data compression program for speeding the transmission of the graph. SPAN now supports several types of network-to-network connections which provide access to SPAN.

Once the user reaches EnviroNET, he is presented with the "Main Menu". The Main Menu system (Environet User's Guide, 1989), Figure 13, which controls the EnviroNET activity on the MicroVAX II, is frequently updated in response to user suggestions and changing needs of the database activity. This menu allows one to run BROWSE, access the data files, download graphics and text, send mail to the system manager, read bulletin board notices, use the models or exit the system. The principal retrieval program, called BROWSE, is continually being updated in response to user and subpanel suggestions. With BROWSE, simple command choices allow one to page through the EnviroNET database sequentially, or jump to points of interest. To use BROWSE, one must have a VT100 compatible terminal or emulation. BROWSE has three menus: Main Topics, Data and Table of Contents/Index. One can move among the three menus to any part of the

database, or back to the EnviroNET main menu with a single keystroke. As you BROWSE about the database and change menus, the information on the terminal screen will change, but the basic layout of the screen will remain the same. Information is displayed in three windows: the page window at the top right, the data window at the center, and the option window at the bottom, Figure 14.

ACKNOWLEDGMENTS

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7. Solar-Geophysical Data Part I (prompt reports), issued monthly by National Geophysical Data Center, NOAA/NESDIS, E/GC2, 325 Broadway, Boulder, CO 80303.

8. Journal of Geophysical Research (Space Physics), issued monthly by American Geophysical Union, 2000 Florida Ave, N.W.,Washington, D.C. 20009.

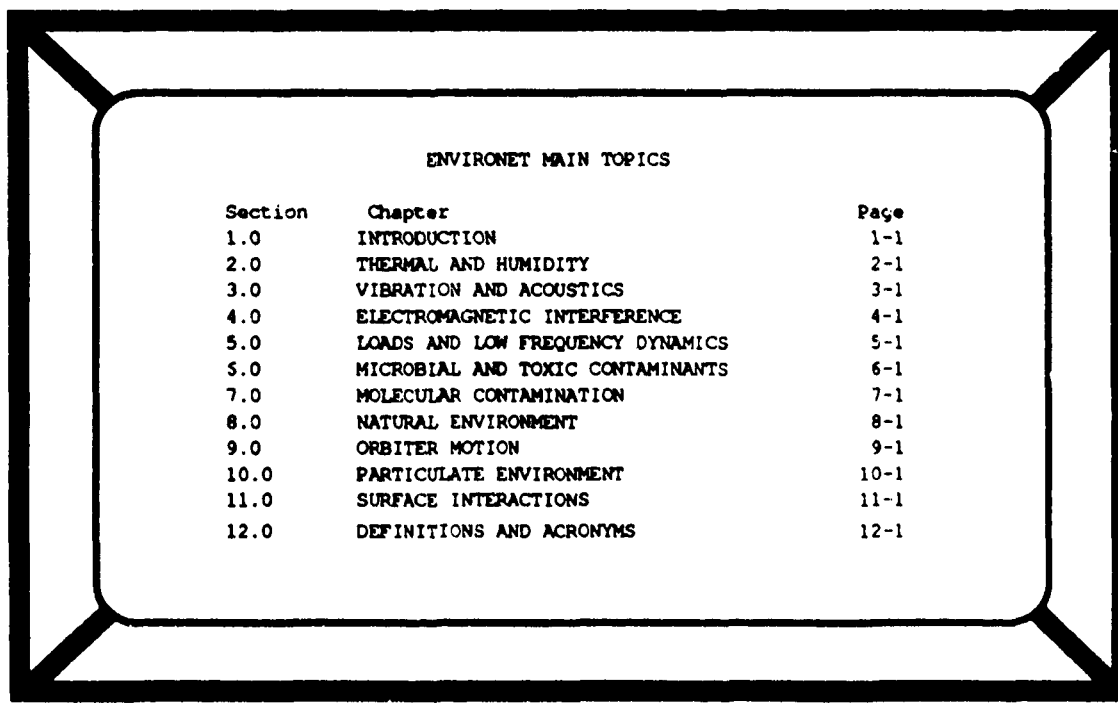
9. Accessing SPAN From Non-SPAN Nodes, National Space Science Center (NSSDC)/Work Data Center-A for Rockets and Satellites (WDC-A-R&S), NASA GSFC, Greenbelt, MD 20771.

FIGURES

ENVIRONET

- CENTRALIZED COMPUTER-BASED INFORMATION ON NATURAL AND INDUCED ENVIRONMENTS OF SHUTTLE AND SPACE STATION
- BASED ON MEASURED DATA (SHUTTLE) AND EMPIRICAL MODEL VALIDATED BY DISCIPLINE PANELS
- FOR SCIENTISTS AND ENGINEERS USE IN THE DESIGN AND DATA ANALYSIS OF FLIGHT HARDWARE
- MAINTAINED CURRENT BY NASA THROUGH COOPERATIVE EFFORTS OF INDUSTRY, OTHER GOVERNMENT AGENCIES, THE EUROPEAN SPACE AGENCY, ACADEMIA, AND THE NASA COMMUNITY

Figure 1: Advantages of EnviroNET



ENVIRONET MAIN TOPICS

Section	Chapter	Page
1.0	INTRODUCTION	1-1
2.0	THERMAL AND HUMIDITY	2-1
3.0	VIBRATION AND ACOUSTICS	3-1
4.0	ELECTROMAGNETIC INTERFERENCE	4-1
5.0	LOADS AND LOW FREQUENCY DYNAMICS	5-1
5.0	MICROBIAL AND TOXIC CONTAMINANTS	6-1
7.0	MOLECULAR CONTAMINATION	7-1
8.0	NATURAL ENVIRONMENT	8-1
9.0	ORBITER MOTION	9-1
10.0	PARTICULATE ENVIRONMENT	10-1
11.0	SURFACE INTERACTIONS	11-1
12.0	DEFINITIONS AND ACRONYMS	12-1

Figure 2: Current Topics

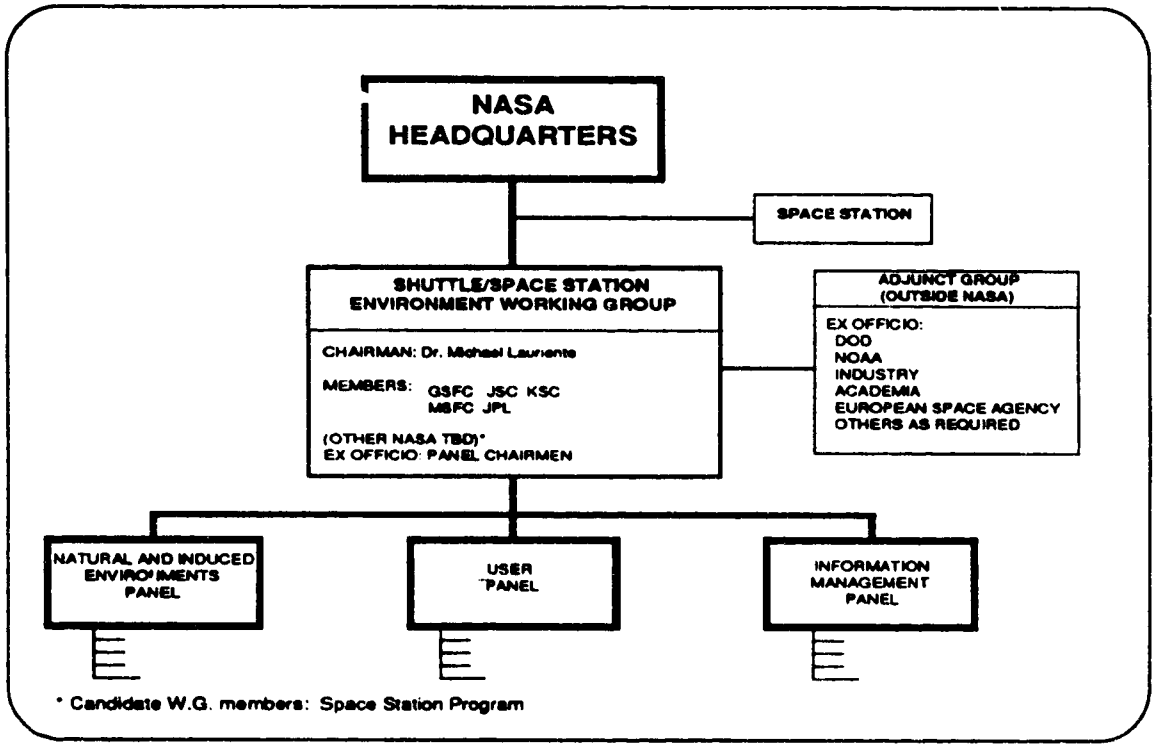


Figure 3

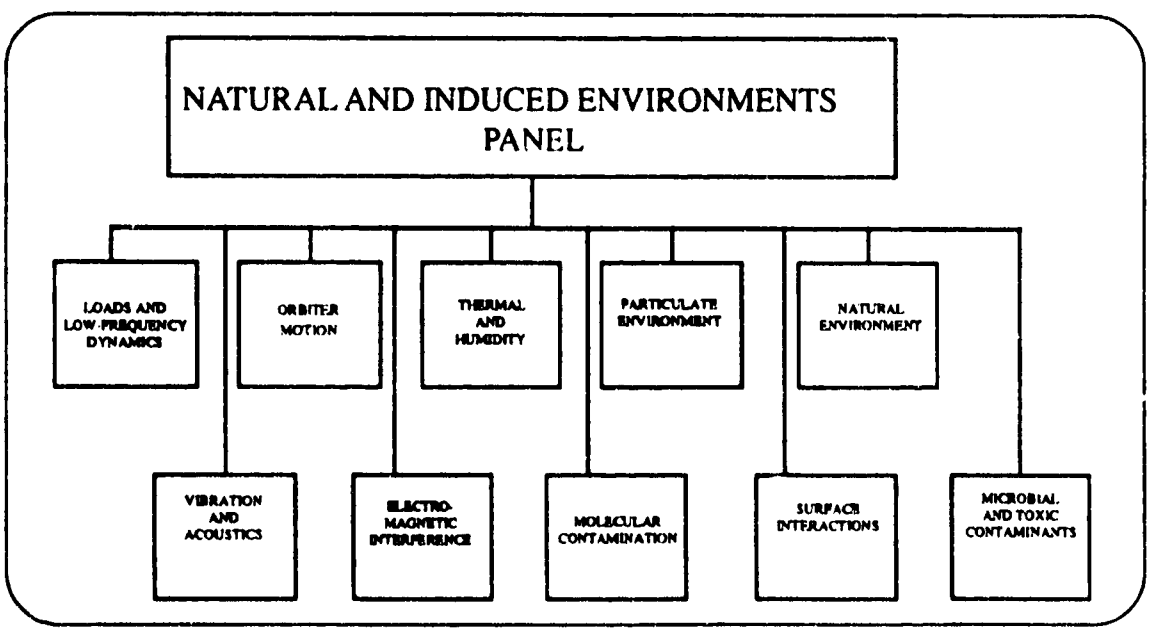


Figure 4

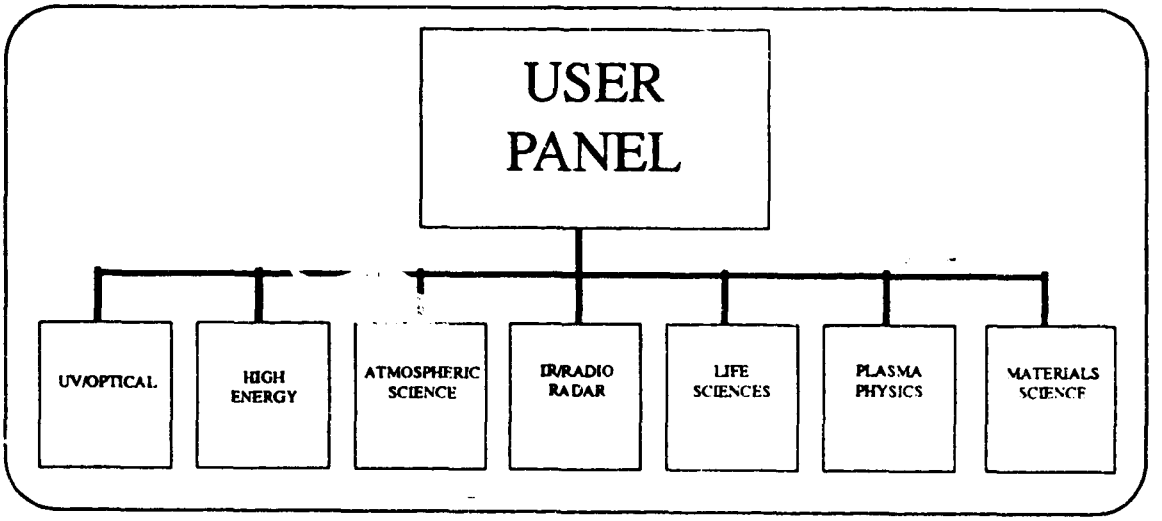


Figure 5

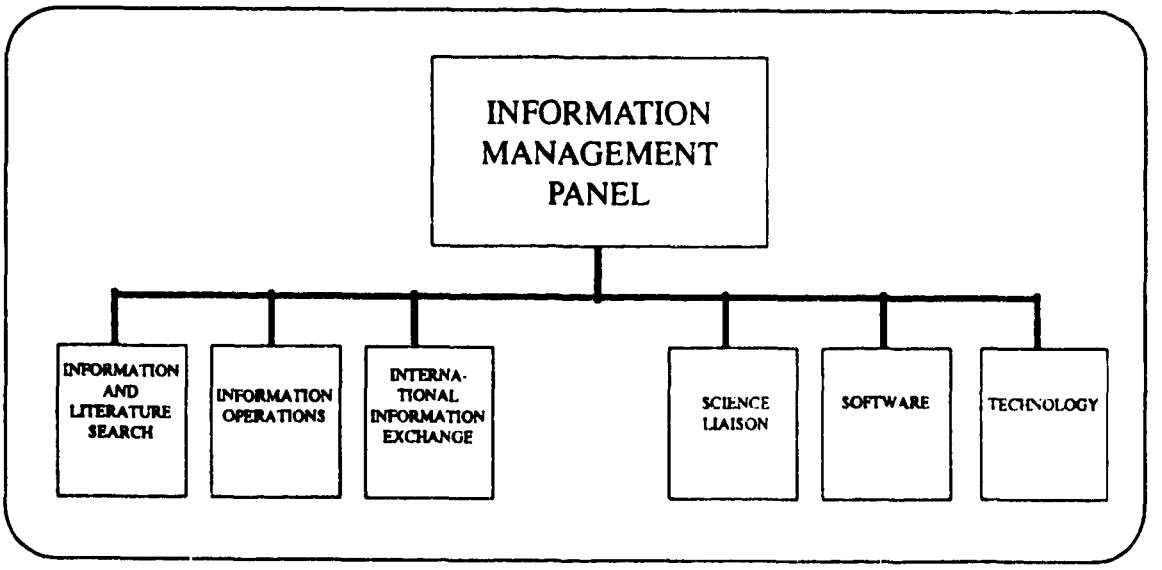


Figure 6

8.3.2.4 MSIS86 MODEL

The neutral model, MSIS-86 (The MSIS-86 Thermospheric Model by A.E.Hedin, J. Geophys. Res., Vol 92, pp. 4648-4662, 1987), which can now be accessed through the EnviroNET menu, was chosen for the 1986 COSPAR International Reference Atmosphere. This model is based primarily on in-situ (mass spectrometer) composition and temperature measurements and ground based radar measurements. MSIS provides densities of individual constituents and is based on data covering periods from low to high solar activity.

8.3.3 SOLAR ACTIVITY DATA

Table 3-1 lists the 13-month smoothed values of the 10.7 centimeter solar radio flux (F10.7) and the Ap throughout an eleven year solar cycle. The values in the table are based on a statistical analysis

Figure 7

MSIS MODEL

Input Ranges

Day number	1 to 365	Local solar time (hrs)	0 to 24
Altitude (km)	85 to 1000	Average F10.7 flux	65 to 300
Geodetic latitude (deg)	-90 to 90	Current F10.7 flux	65 to 300
Geodetic longitude (deg)	-180 to 180	Magnetic index AP	0 to 400

Input Parameters		Output Values	
1) Day of year	44	H (Number/cm³)	1.41E+07
2) Altitude	100	N (Number/cm³)	6.54E+05
3) Latitude	40	HE (Number/cm³)	9.64E+07
4) Longitude	-75	O (Number/cm³)	4.03E+11
5) Local time	12	N2 (Number/cm³)	7.85E+12
6) Average F10.7	100	O2 (Number/cm³)	2.02E+12
7) Current F10.7	200	AR (Number/cm³)	1.19E+11
8) Magnetic index AP	300	Total (gm/cm³)	4.91E-10
		TN(INF) (deg K)	1300.8
		TN (deg K)	194.3

Do you want to (R)un the model with the current values, change some (1 through 8) or (A)ll the values, or (Q)uit?

Figure 8

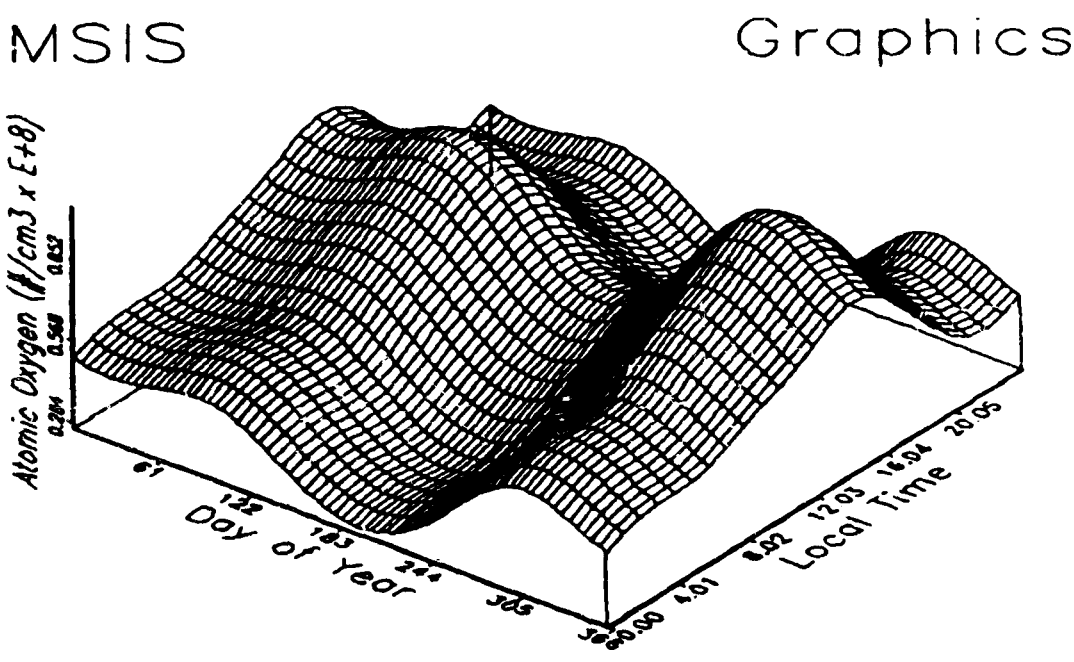


Figure 9: An example surface plot from the output of the MSIS-86 Model
F10.7 = 150; Ap = 200; Lat = Long = 0; Alt = 500

11.1 SPACECRAFT CHARGING
(By I. Katz and A. Rubin)

11.1.1 DESCRIPTION

Spacecraft charging occurs at geosynchronous orbit during magnetic substorms, when dense clouds of kiloelectron volt plasma envelop spacecraft. These kilovolt plasma clouds charge up the spacecraft surfaces to potentials which range up to 19 kilovolts. Surface potentials of many kilovolts lead to arc discharges, with accompanying currents of up to 1000 amps, which radiate rf power into the spacecraft electronics, and have led to false commands, upsets and, in one case, complete loss of a spacecraft.

At Shuttle Orbiter altitudes of 200 to 500 km, the ionospheric plasma is cold and dense, a state which ordinarily would not support charging. Special conditions must exist to permit spacecraft charging, and these special conditions exist in polar orbit, when the

Figure 10

11.1.3 EXPERT CONTACTS

Dr. William F. Denig
AFGL/PHK
Hanscom AFB
Bedford
MA 01731 USA
(617) 861-3989

Dr. Carolyn K. Purvis
Lewis National Research Center MS77-4
21000 Brookpark Road
Cleveland
OH 44135 USA
(216) 433-4000

Dr. George Inouye
TRW STGM21145
1 Space Park
Redondo Beach
CA 90278 USA
(213) 535-8448

Dr. Al Rubin
AFGL/PHK
Hanscom AFB
Bedford
MA 01731 USA
(617) 861-2933

Figure 11

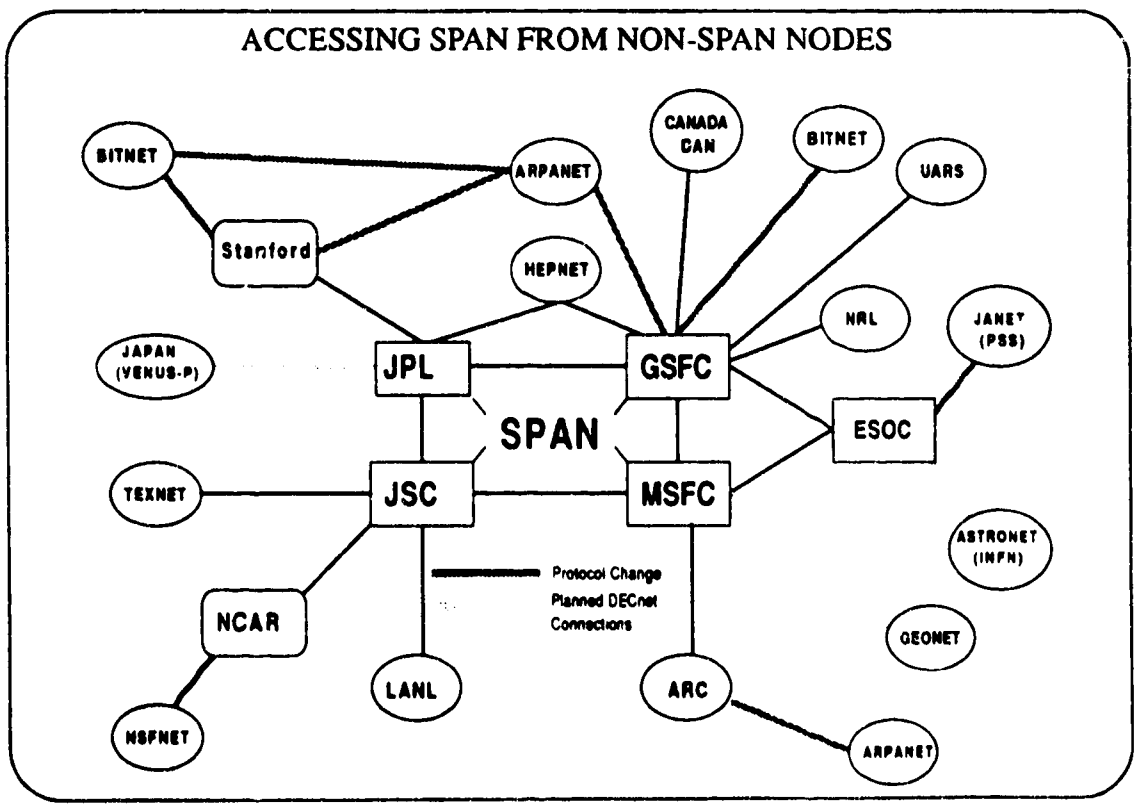


Figure 12

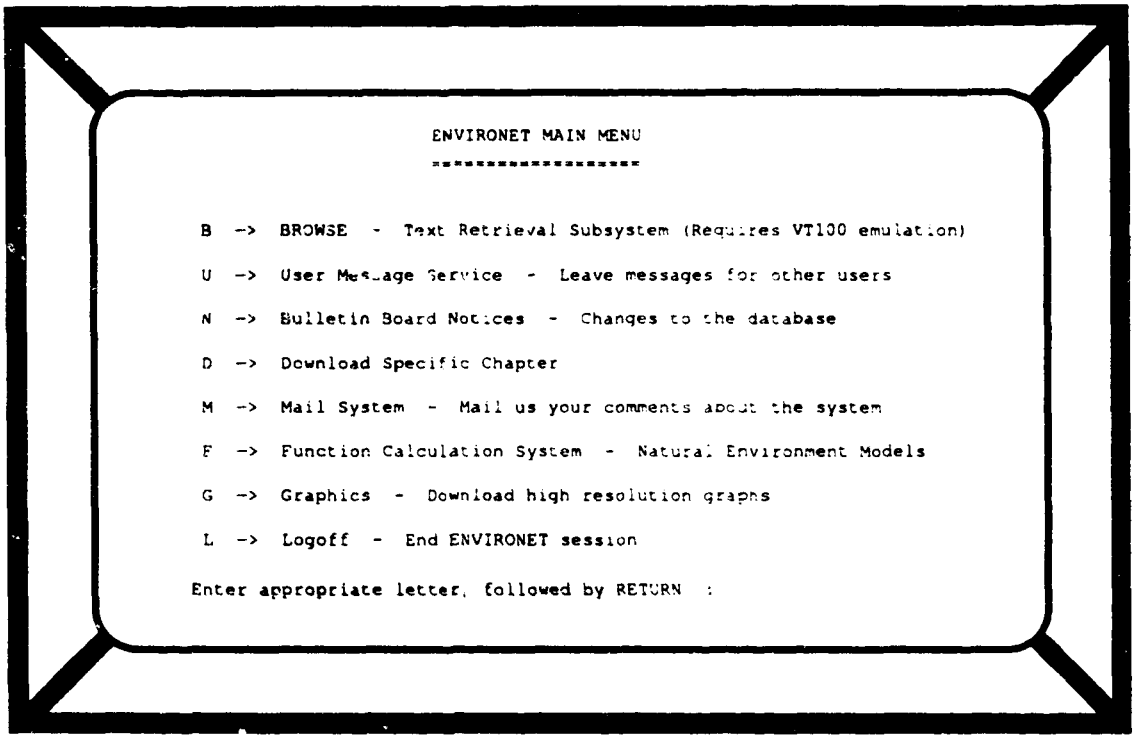


Figure 13

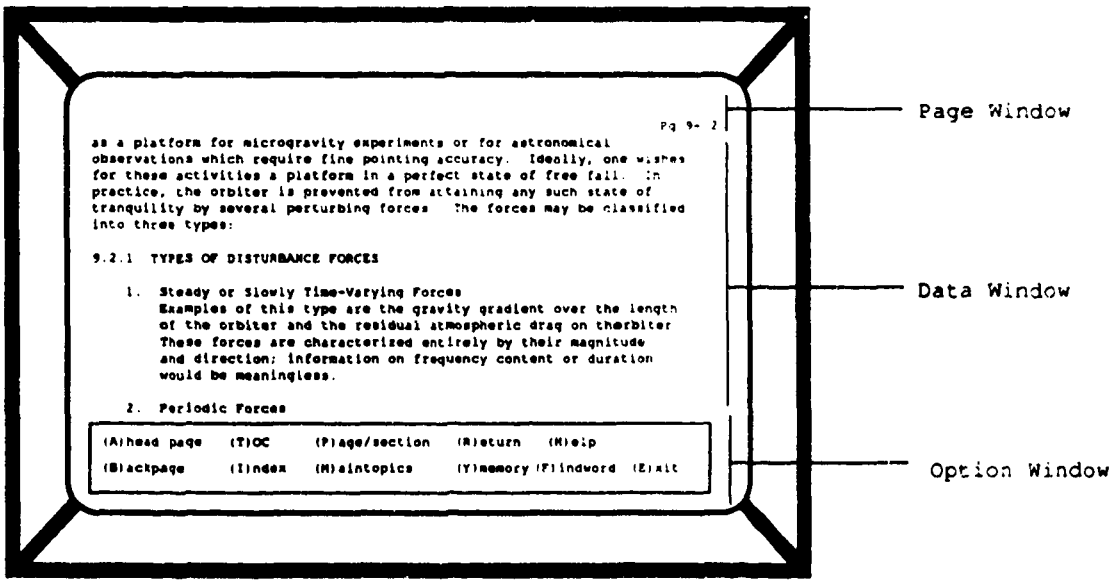


Figure 14