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EnviroNET: SPACE ENVIRONMENT FOR STRATEGIC DEFENSE INITIATIVE EXPERIMENTS

MICHAEL LAURIENTE
NASA GODDARD SPACE FLIGHT CENTER, MD 20771

INTRODUCTION

EnviroNET is a service/facility intended to provide users with on-line, dial-up technical information concerning environmental conditions likely to be encountered by instruments and experimental arrangements carried aboard the Space Shuttle and the Space Station Freedom. The database also has wider applicability for information on environments encountered by other satellites in both low altitude and high altitude (including geosynchronous) orbits. This information--which is DISTINCT FROM "REQUIREMENTS"--is intended to help scientists and engineers design equipment to operate successfully in the (somewhat hostile) space environment (fig .1).

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

EnviroNET incorporates at present a combination of expository text and numerical tables amounting to about two million characters (bytes), plus FORTRAN programs that model the neutral atmosphere, magnetic field and ionosphere. This text is under continuous review, correction, and augmentation by ten subpanels of technical experts: one for each of the database's main topics. The information contained in EnviroNET is shown in Figure 2. The aim is to keep information as accurate and current as possible. The EnviroNET files are stored on a MicroVAX II computer at GSFC and may be accessed on a 24 hour dial-up basis, at 1200 baud with ordinary telephone connections and at 9600 baud for users on the Space Physics Analysis Network, SPAN (ref. 1). SPAN is available via more than 1000 space science computer systems throughout the U.S.,Canada and Europe.

BACKGROUND

Early in the development of the Space Shuttle, payload planners recognized the need for a detailed picture of environmental impacts on Shuttle payloads. The extreme complexity and size of the Shuttle made it very difficult to characterize these environments by 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 (ref. 2) to describe what had been learned from these measurements. This led to concerns voiced with regard to the need for 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. As might be expected, initial tests did not answer all the questions and concerns raised by the payload 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.

ENVIRONET MAIN TOPICS

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Figure 2

THE WORKING GROUP

As a consequence, a multi-center Shuttle Environment Working Group was organized through the efforts of OSSA and GSFC, with the Working Group establishing the charter and framework within which this group would function (fig. 3).

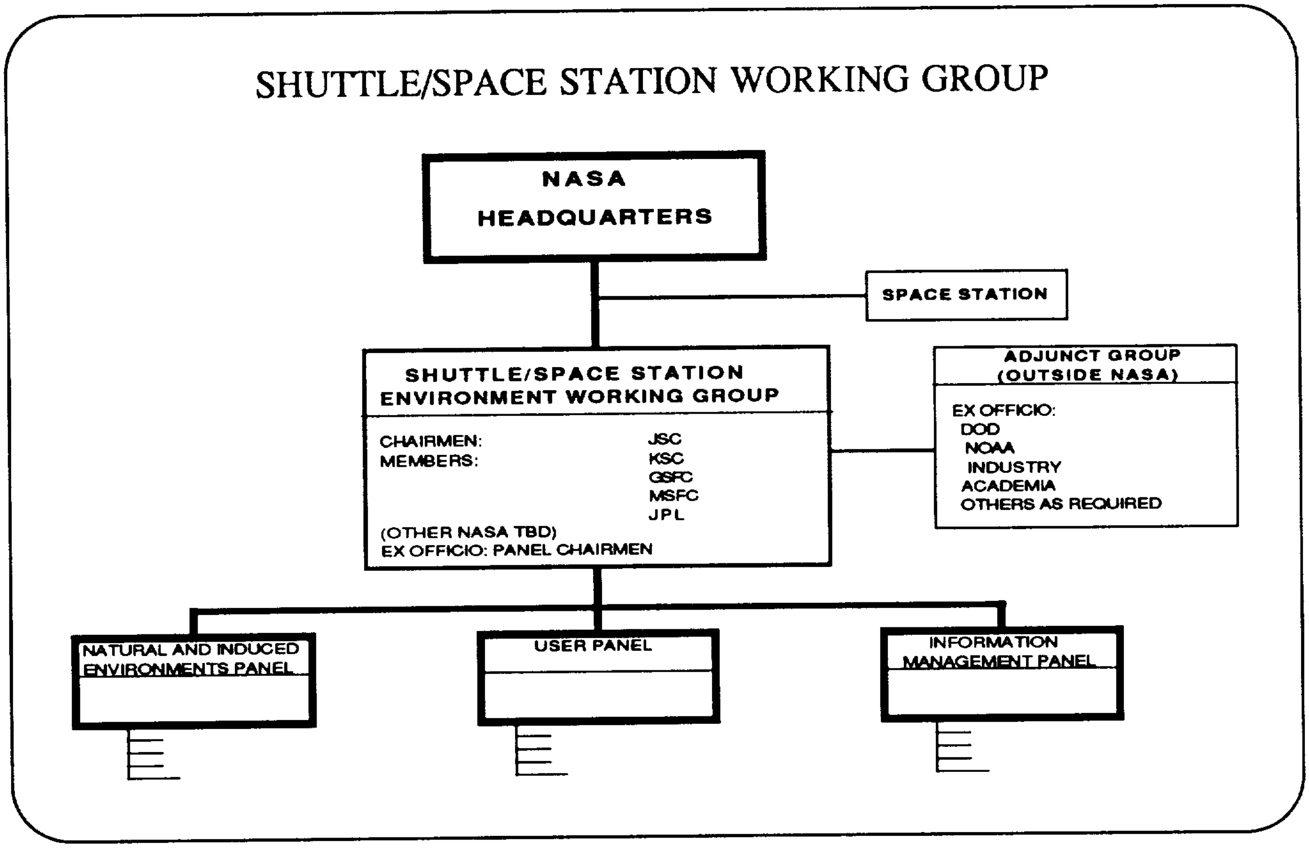

Figure 3

The goal of the Working Group was to have a comprehensive database established of current information regarding the Shuttle Environment, readily accessible in a user-friendly format. Specific objectives for the Shuttle Environment Working Group included:

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

With these objectives in mind, the Working Group began organizing in late 1983 and on into early 1984. A structure of panels and subcommittees was established and the task of staffing began. Three major panels were established with the functions and duties as follows:

1) The Natural and Induced Environments Panel (fig. 4) gathers and organizes data for input into the database. Duties: Make preliminary assessment of the reliability and traceablity of the data for the database; assess the state of the data and determine if it is directly useful to the user.
2) The User Panel (fig. 5) provides for interaction between disciplines and users. Duties: Identify user requirements and needed environmental data; provide an interface between the scientific community and the environmental data panel; and identify gaps in the information base, also noting the urgency of the requirements for this data.

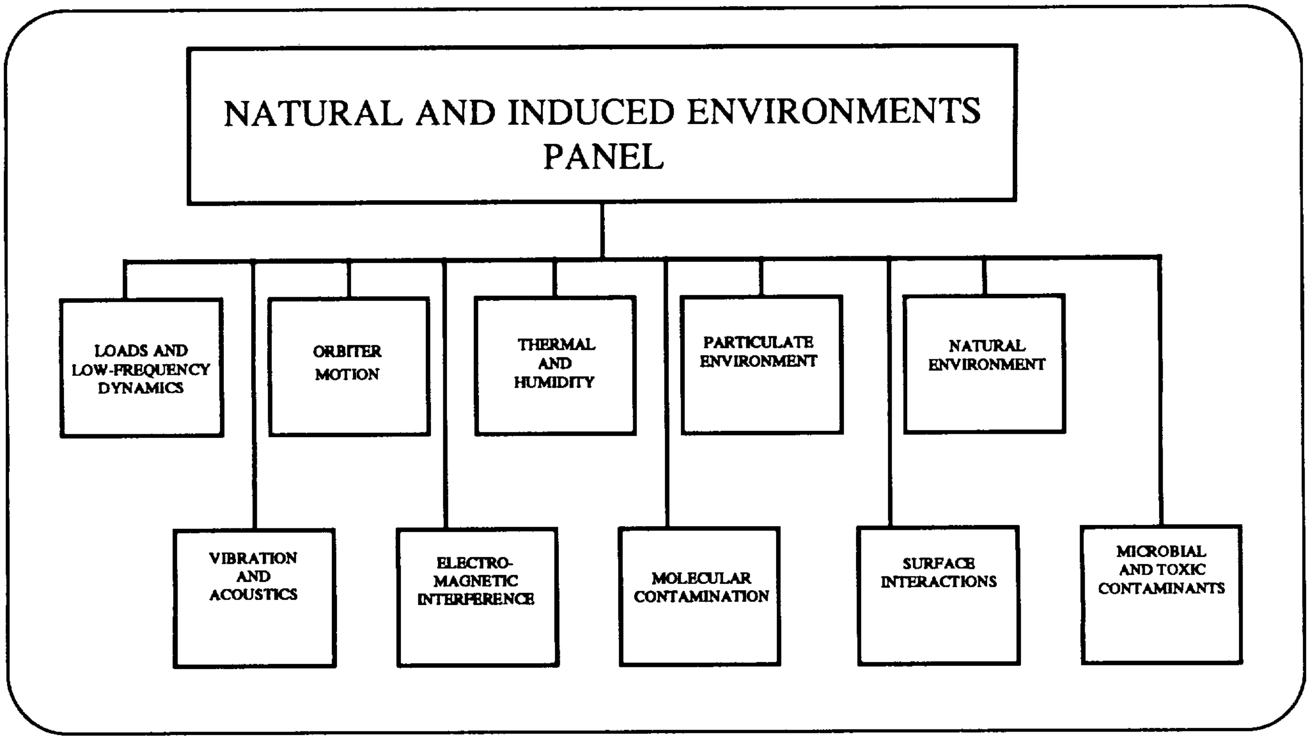

Figure 4

3) The Information Management Panel (fig. 6) provides the database structure and manages the database. Duties: Create a system for compiling, storing, and cataloging the information in the database; edit information; and coordinate network activities.

In August 1984, the Working Group, joined by the European Space Agency (ESA), sponsored its first Shuttle Environment Workshop, and the process of gathering data for the requested database began in earnest (ref. 3). The database was arranged by sections (or "chapters") along the key disciplines and named "EnviroNET." Also, database management procedures were outlined: The subpanels decide what data to collect; obtain and edit the data; and submit it to the Working Group for validation. Following validation, the Working Group gives the data to the Information Management Panel for inclusion in the electronic database. As a result of these considerable efforts, EnviroNET has evolved into a reasonable, mature and comprehensive database.

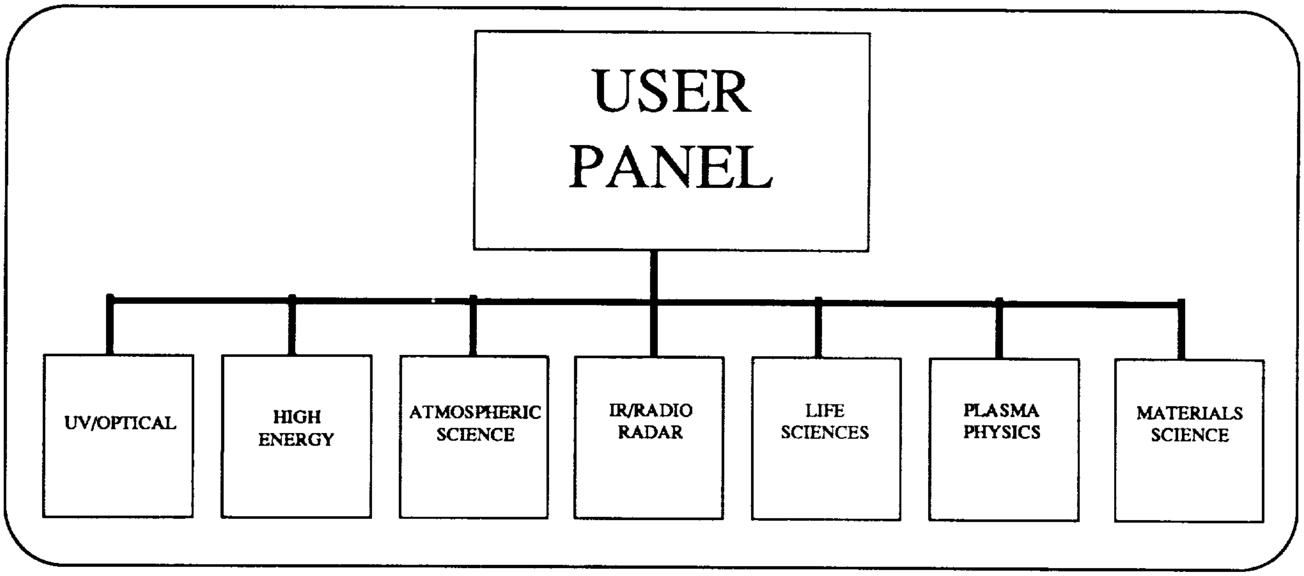

Figure 5

EnviroNET Displays

Plans for improving the services of EnviroNET are shown in Figure 7. Software from commercial sources are constantly evaluated for feasibility. Where necessary, in-house software is developed. The main menu system (ref. 4), 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 main menu (fig. 8) 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.

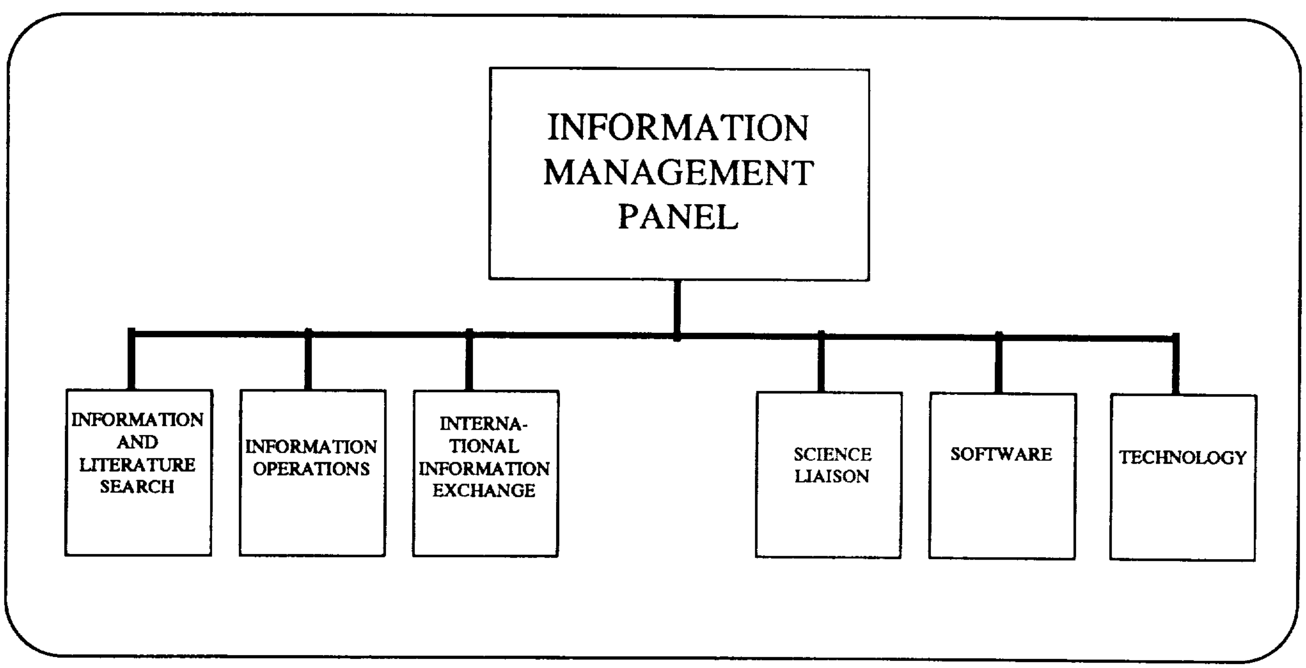

Figure 6

PLANS

- Consider options for improving service
  - -Software
  - -Graphics
  - -Modeling
  - -Network Servers (NSSDC, SPAN...)
- Newsletter
- Telescience
- Workshops

Figure 7

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                ENVIRONET MAIN MENU
                ===================

B  ->  BROWSE  -  Text Retrieval Subsystem (Requires VT100 emulation)

U  ->  User Message Service  -  Leave messages for other users

N  ->  Bulletin Board Notices  -  Changes to the database

D  ->  Download Specific Chapter

M  ->  Mail System  -  Mail us your comments about the system

F  ->  Function Calculation System  -  Natural Environment Models

G  ->  Graphics  -  Download high resolution graphs

L  ->  Logoff  -  End ENVIRONET session

Enter appropriate letter, followed by RETURN  :
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Figure 8

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 (fig. 9).

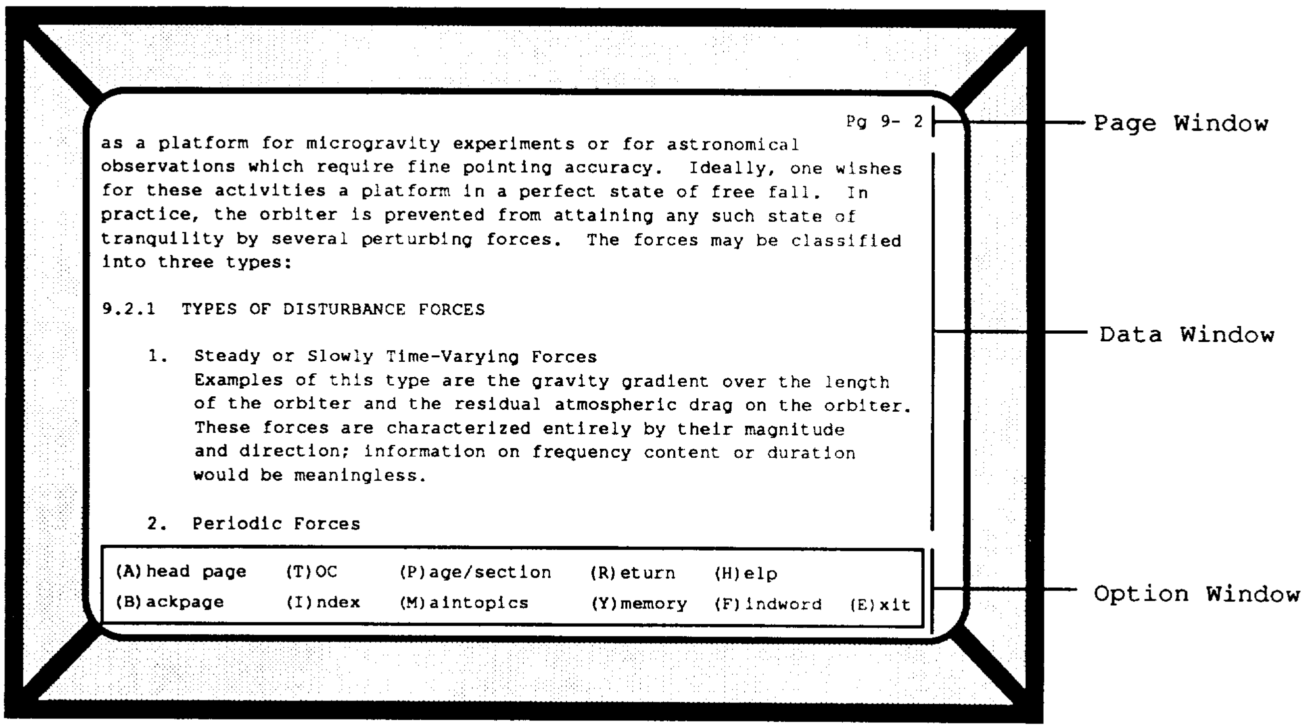

Figure 9

GRAPHICS

Graphics display of database figures is slowed because of the high number of bits in the bit map and the 1200 baud rate of the communication system. All possible avenues for circumventing or coping with this problem are under continuing investigation. In the interim, the text is designed for minimal dependence upon graphics, although "text graphics" are displayed when suitable. The immediate graphics effort is to deliver high resolution graphical data accompanied with textual data to the user with a minimum of user effort and familiarity with the system. A near-term goal is to provide graphical data in an easy and convenient format. To accomplish this objective, certain components—such as POPGRAPH—are being developed. POPGRAPH is a user friendly program being written in-house to facilitate easier access to the graphical data while viewing the textual data. It resides in memory and can be invoked instantly by pressing a sequence of three keys. When finished viewing the graphical data, the user can immediately return to the text with a single keystroke.

The Enhanced Graphics Adapter (EGA) is a standard high-resolution graphics adapter used on the IBM PC and compatibles. It provides a resolution of 640 pixels by 350 pixels. Since the Color Graphics Adapter (CGA), has a resolution of 640 pixels by 200 pixels, which is not always sufficient for some of the more detailed graphs, there is a need to upgrade to the EGA. Currently, the EGA image size is 28 kilobytes. Downloading one of the images from the MicroVAX to a PC will require an average of 1 second per kilobyte at 9600 baud.

At 1200 baud, the download time will increase proportionately, thus compaction protocol to squeeze the 28 kilobyte image down to about 10 kilobytes will be undertaken to cut the down load time by as much as 60%. A typical high-resolution graph available for viewing (fig. 10) shows contamination during ascent. The long-term goals are first, to accommodate more users by expanding to different graphics cards on the IBM PCs, and by expanding to different machines, such as Macintosh computers; and second, to integrate textual data and graphical data into one format so that a user will not have to switch from one to the other as at present. To sum up: most IBM PCs and compatibles use one of the three following graphics cards. They either have a Color Graphics Adapter (CGA), an Enhanced Graphics Adapter (EGA), or a Video Graphics Array card (VGA), or compatibles of these adapters. Currently, only CGA and EGA users are

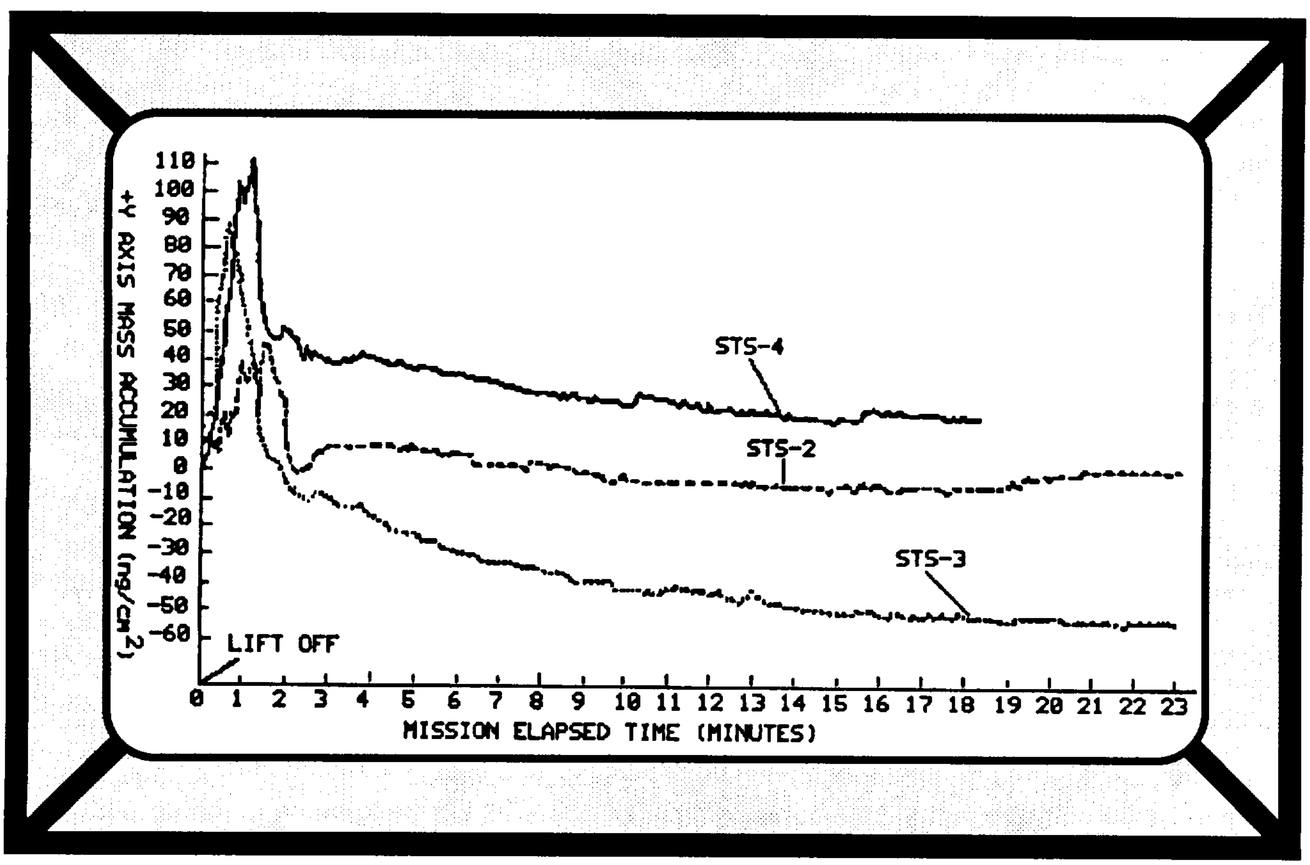

Figure 10

supported. Eventually, the system will support users of the VGA adapters as well as users of the Macintosh computer. Currently, if a user of EnviroNET is reading textual data, and he sees a reference to a piece of graphical data, he must log off, run the display program to view the graphical data, and log in again to continue viewing textual data. This is a very inconvenient and time-consuming process. POPGRAPH makes things easier by allowing the user to switch between textual data and graphical data and vice versa.

MODELS

EnviroNET has expanded its activity by adding interactive models of the natural environment. The models include neutral atmosphere density and temperature(refs. 5, 6), ionosphere, electron temperature and density, the magnetic field vector, and energetic particle or radiation flux. These models are based on data from satellites which orbit the Earth in the thermospheric and exospheric regions of the atmosphere. The thermosphere is the region above approximately 85 km (depending on season and other factors) where temperature increases sharply with altitude, turbulent mixing of different molecular species ceases, and ultraviolet (UV) and extreme ultraviolet (EUV) flux from the sun dissociate the molecules and ionize the constituents to form the ionosphere. Above roughly 500 km, the thermosphere gradually merges into the exosphere where the mean free path of molecules is longer than the vertical scale height. The temperature in the upper thermosphere and lower exosphere approaches an asymptote called the exospheric temperature. The ineffectiveness of mixing processes above about 105 km results in a situation called diffusive equilibrium, where the individual atmospheric constituents decrease with a scale height inversely proportional to their individual molecular weights, and the mean molecular weight decreases monotonically with altitude. Atomic oxygen is a major constituent of the upper thermosphere along with molecular nitrogen and helium. Hydrogen becomes a major constituent in the exosphere. Argon, molecular oxygen, and atomic nitrogen are minor constituents in the upper thermosphere. The structure of the thermosphere has been determined by a number of satellite, rocket, and ground based techniques and the data summarized in various empirical models. The density, temperature, and composition of the thermosphere are found to depend on time (year, day of year, and time of day), position (latitude, longitude, and altitude), solar generated or triggered energy inputs (solar UV and EUV, magnetospheric particles, and magnetospheric electric fields and currents), and to some degree on the state of the lower atmosphere upon which the thermosphere rests.

Winds are an important part of the environment at orbital altitudes. Wind speeds may reach 1000 meters per second at high latitudes, driven indirectly by magnetospheric electric fields, but are usually less than 100 meters per second at low latitudes. Wind measurements have only recently been summarized in the same fashion as density and temperature measurements. There are five major types of variations in the thermosphere at orbital altitudes. The temperature and densities of all the constituents except hydrogen increase strongly with increases in solar EUV flux. Total density has a diurnal maximum in the early afternoon, but temperature and the various constituents all have diurnal maxima at different times of the day. The temperature and individual constituents have strong seasonal variations which are out of phase for the heavier and lighter constituents, resulting in only a minor seasonal variation for total density. A significant global semiannual variation, with density maxima near the equinoxes, is present for all constituents and varies from year to year for unknown reasons. Magnetospheric energy input in the auroral regions (magnetic storms) increases total density and temperature over the whole globe, but preferentially at high latitudes, while the lighter constituents decrease at high latitudes.

Wave activity originating in the auroral zone and also the lower atmosphere is present everywhere in the thermosphere, but primarily at high latitudes with density variations up to 15%. The occurrence of waves can only be described statistically and limits the accuracy of model predictions. The solar 10.7 cm radio flux, which can be measured from the ground, is used as an index of solar UV and EUV flux. The 10.7 cm flux correlates quite well with major EUV emissions, but less well with other EUV emissions and UV wavelengths. The EUV and radio flux vary from day to day with major periods of 27 days and 11 years. Both the daily value of the 10.7 cm flux and a several month average of the flux have proved useful in empirical models. Energy input from the magnetosphere, which can change rapidly in less than an hour, not only heats the atmosphere (particularly at high latitudes), but also causes variations in the magnetic field measured at the ground (magnetic storm). These variations are summarized in a number of magnetic indices. The three hourly ap or kp planetary magnetic indices (kp is derived from ap by a pseudo-logarithmic transformation) and their daily averages (ap and kp) are used by most empirical models as their index for magnetospheric energy input. The prediction of either the 10.7 cm flux or magnetic indices for future times is subject to large errors because it depends on the meteorology of the sun and nonlinear processes in the magnetosphere, and constitutes the major uncertainty in predicting the future state of the thermosphere.

Historical values of the 10.7 cm flux and magnetic indices can be found in standard references (ref. 7 and ref. 8). For rough estimates, the 10.7 cm flux index can be taken as 70, 150, or 230 for low, medium, and high solar activity respectively and the Ap (Kp) index can be taken as 4 (1), 27 (4), or 400 (9) for low, medium, and extremely high magnetic activity respectively.

Two empirical models can be accessed through the EnviroNET menu and allow calculation of density, temperature, and composition based on user specifications for time, position, and energy input, as discussed above. The first is the MSFC/J70 model (ref. 4) chosen as the design standard for Shuttle and Space Station. This model is based directly on total densities derived from changes in satellite orbits as a result of atmospheric drag. However, the data were gathered before 1970 and do not provide unique information about temperature or composition. The second model is the MSIS-86 model (ref. 5) chosen for the 1976 Committee on Space Research (COSPAR) International Reference Atmosphere. This model is based primarily on in situ mass spectrometer composition and temperature measurements, and ground-based radar temperature measurements. Total densities of the MSIS model basically agree with drag models, while providing more accurate predictions for the temperature and individual constituents. The models generally have an accuracy for total density on the order of 15% to 20%. The natural atmosphere models, which are run from the EnviroNET main menu, will be expanded to include topics such as gravity, radiation, and meteoroids. In addition, a model is being developed to provide parameters at given points along a space shuttle or space station orbit as well as integrated doses. Graphics display of the model parameters along given orbits will also be developed. The computer screen display for the MSIS model is shown in Figure 11. After input parameters (left) are entered, the computer calculates the output displayed on the right.

NETWORK SERVERS

SPAN (ref. 1) 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, (fig. 12) features four primary routing centers in the

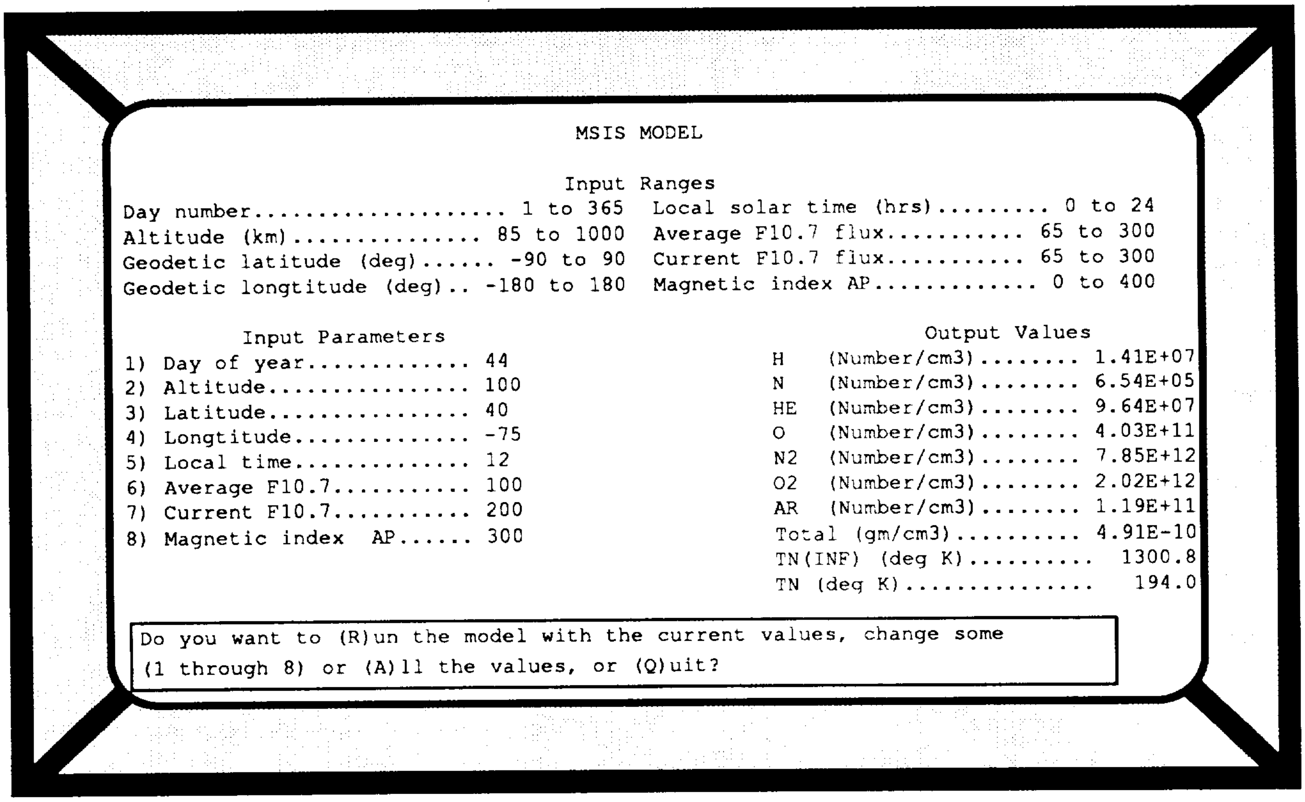

Figure 11

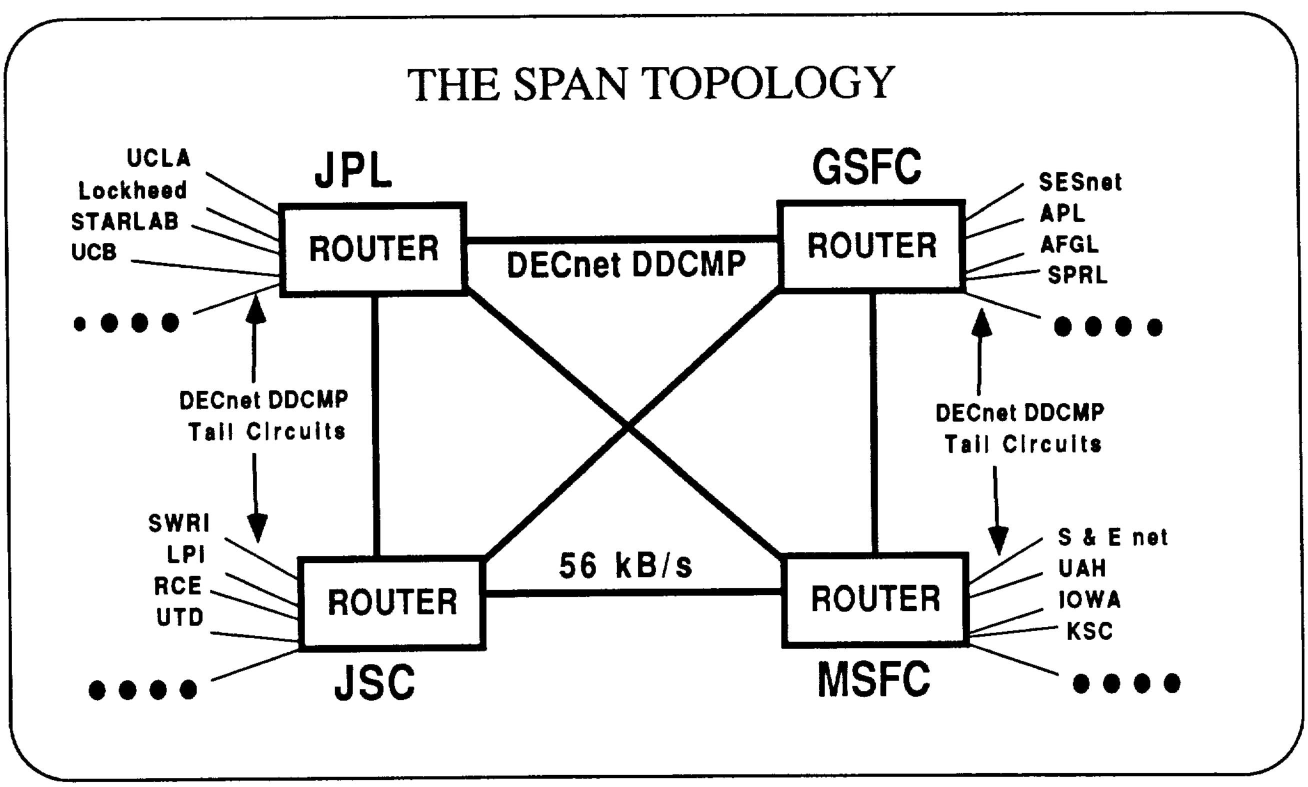

Figure 12

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 brings the space scientific community together in a common working environment. The network supports the transmission and reception of manuscripts. Data and Graphics files can be transferred between network nodes. SPAN now supports several types of network-to-network connections which provide access to SPAN (ref 9). These are shown in Figure 13. Each oval represents an entire network of computer nodes (ref. 1).

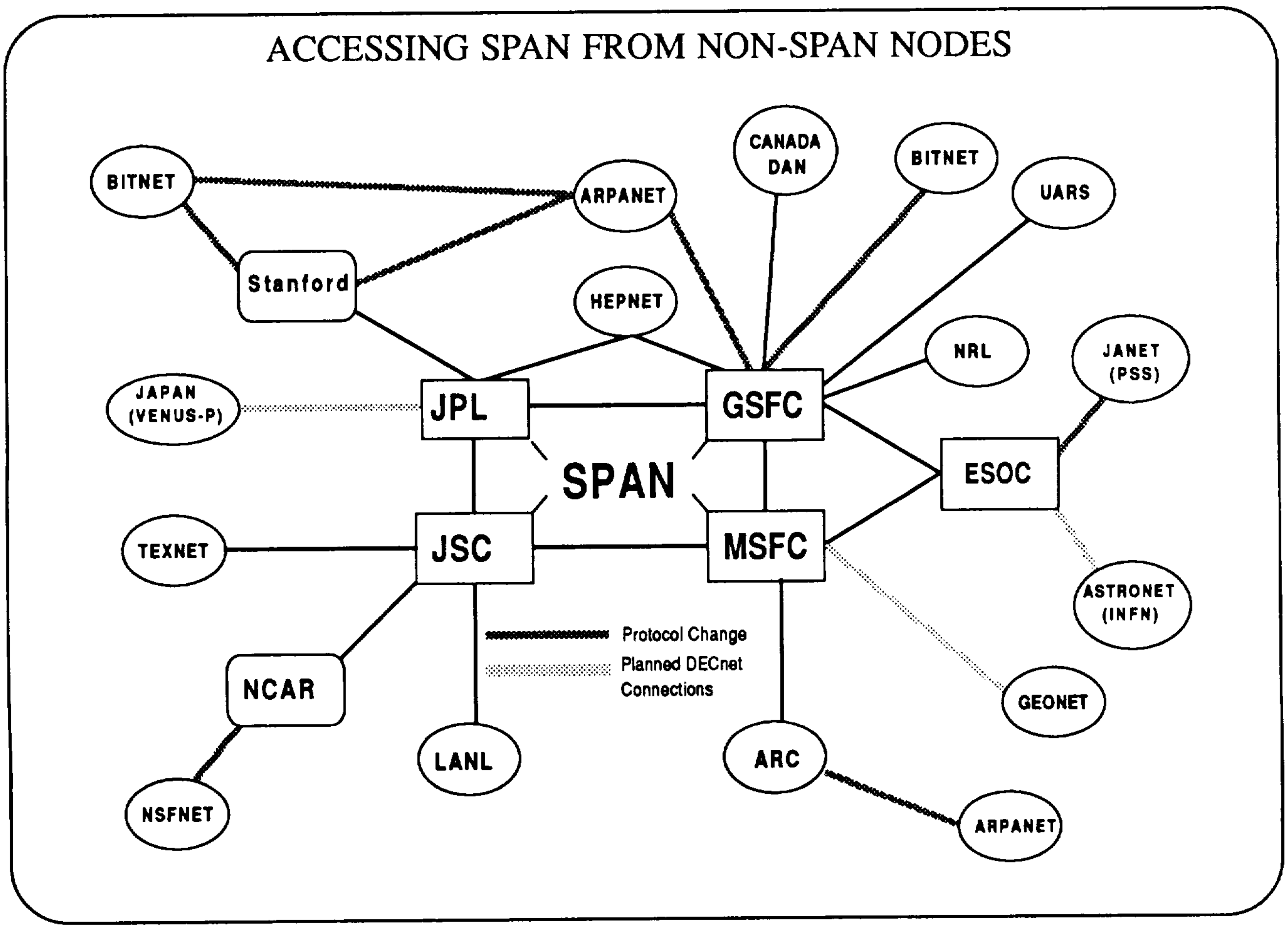

Figure 13

TELESCIENCE

EnviroNET is ideally suited for investigators to cooperate from their "remote" home laboratories and computers with their colleagues by computer networking. This is an expansion of the concept started with the Atmosphere Explorer and Dynamics Explorer programs when many scientists were connected over dedicated phone lines to a central "remote" computer site containing their data and computer programs. With the advent of SPAN, the remote Dynamics Explorer scientists could communicate with one another directly and offload calculations and data analysis to their home systems, thereby improving productivity with simultaneous analysis on remote, distributed computer systems. EnviroNET is being upgraded to permit the users to conduct teleanalysis, i.e., perform analyses using Space Shuttle/Space Station environment data and the models on computers at remote institutions. EnviroNET has always drawn on the NASA centers, other government laboratories, industry, and universities. The academic community is especially involved because it provides important opportunities for testing and evaluating new ideas, techniques and concepts before they have reached the state of maturity considered by contractors and project mangers suitable for implementation. A testbed program like EnviroNET provides a valuable way of training graduate students who represent the future scientists and engineers of the nation, and who need to be at the leading edge of our SPAN technology.

WORKSHOPS

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.

CONCLUSION

EnviroNET is an operational system available to the SDI experimenters 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.

Some of the benefits to using EnviroNET include:

1) Validated NASA environmental information and interactive space models
2) Facilitating the payload integration process
3) Easy access to expert assistance
4) Potential for time and cost savings

ACKNOWLEDGMENTS

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