DYNAMICS EXPLORER SCIENCE DATA PROCESSING SYSTEM

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Abstract. The Dynamics Explorer project has acquired the ground data processing system from the Atmosphere Explorer project to provide a central computer facility for the data processing, data management and data analysis activities of the investigators. Access to this system is via remote terminals at the investigators' facilities, which provide ready access to the data sets derived from groups of instruments on both spacecraft. The original system has been upgraded with both new hardware and enhanced software systems. These new systems include color and grey scale graphics terminals, an augmentation computer, micrographics facility, a versatile data base with a directory and data management system, and graphics display software packages.

1. Introduction

The Dynamics Explorer Science Data Processing System (SDPS) is a project dedicated computer data system in which the majority of the data processing, data management and data analysis activities are performed for the Dynamics Explorer (DE) program. The SDPS includes a central computer facility containing various data sets and a network of remote computer terminals through which DE scientists access the central facility.

The DE program has been developed to study the coupling of electric currents, energy, thermal plasma, electric field and electromagnetic radiation between the earth's magnetosphere, ionosphere and atmosphere [1]. Two spacecraft, instrumented with magnetic and electric field and electromagnetic wave sensors, charged and neutral particle detectors, and remote optical sensing instruments, will be launched simultaneously into coplanar polar orbits to acquire the data to be used in these studies [2]. The investigations to be performed by the DE scientists require that data sets derived from groups of instruments on both spacecraft be made readily available for processing, analysis and display. To fulfill this requirement, the ground data processing system developed for the Atmosphere Explorer program [3] has been acquired and both expanded and improved with new hardware and enhanced software systems. In addition, the SDPS will continue to support the Atmosphere Explorer investigators.

The SDPS provides seven services to the DE science community:

(1) direct access to telemetry, orbit and attitude data bases;

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(2) creation of common time-scale plots of abstracted data, called Summary Plots;

(3) processing of data to create a data base for analysis purposes, designated Mission Analysis Files (MAFs);

(4) storage of and access to the MAFs and query of a directory through a data base management system;

(5) interactive analysis of data;

(6) display of data on graphics terminals and generation of data plots on an off-line micrographics unit; and

(7) system support functions.

2. Investigation Approach

The activities associated with the acquisition of data from the instruments on-board the two spacecraft and the conversion of the telemetered data to quantities of geophysical significance are constrained by two basic system limitations, electric power duty cycles of the spacecraft [2] and computer capability within the SDPS. These two constraints coupled with the changing orbital configuration of the two spacecraft, which places them successively in a variety of interesting geophysical regions, has made imperative careful planning of data acquisition and preselection of subsets of acquired data for processing. The approach to these planning and selection activities is based on science investigations submitted by the DE investigators. A science investigation defines the purpose of a study, specifies the epoch of the mission for the data acquisition and the orbital criteria of the spacecraft during this period, selects the operational modes of the instruments and identifies any collaborative activities which should be performed with the spacecraft operations, such as simultaneous operations with a ground observatory. Each science investigation is initiated by a lead investigator. Spacecraft operations are planned

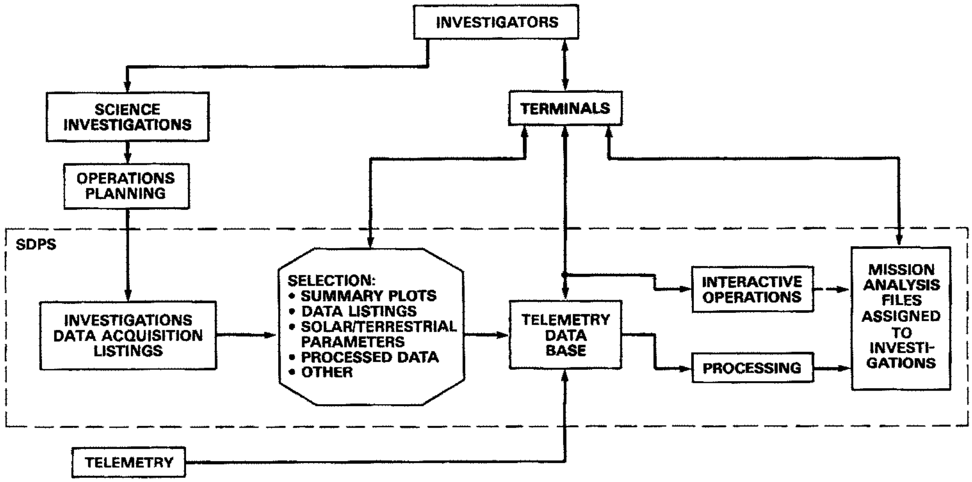

Fig. 1. Schematic diagram illustrating the use of a science investigation for operations planning and data processing accounting in the SDPS.

according to the science investigation requirements (see Figure 1). This scheduling activity, which results in the preparation of command sequences to operate the spacecraft and instruments, is performed using software systems within the SDPS [2]. These systems catalog an investigation and associate with it the corresponding periods of data acquisition.

To use the constrained computer facilities efficiently, the lead investigator selects the most promising periods of data for processing. A variety of aids are utilized in this selection (Figure 1), but primarily the Summary Plots, which are common time base plots of abstracted data from most of the instruments on both spacecraft designed to display the most salient features of the data. The succeeding data processing activities then decommutate the selected data from the telemetry format, and convert the data to geophysically meaningful quantities, which are then stored in Mission Analysis Files and identified with the appropriate science investigation. There the data sets are accessible to the investigators for higher level processing and analysis. Thus, the science investigation is the primary instrument for operations planning and data processing accounting in the SDPS.

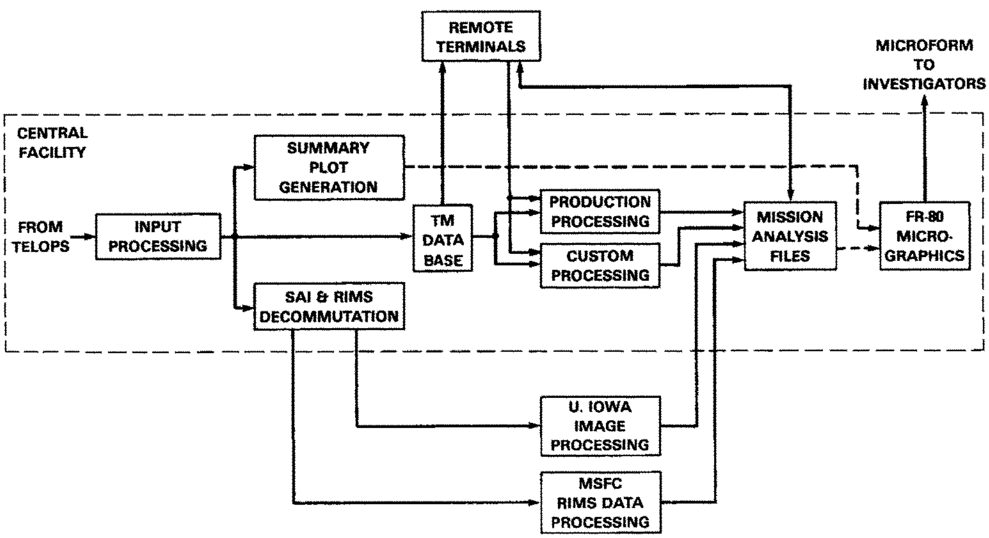

Fig. 2. Dynamics Explorer data system data flow.

The data flow itself is illustrated in Figure 2. Data from the NASA tracking stations (GSTDN) are captured in Telops (Telemetry On-Line Processing System) at the Goddard Space Flight Center (GSFC) and transferred in 24 hour batches each day to the SDPS. The SDPS serves as the input processor: assigning time to the telemetry frames of data, converting the raw telemetry data to time-smoothed data and stripping raw attitude data for transmission to other computers at the GSFC for spacecraft attitude determination. While the telemetry data are still on-line in the SDPS, instrument data from the Spin-Scan Auroral Imager and Retarding Ion Mass Spectrometer [1] are decommutated and sent to the instrumenters' facilities for special computationally intensive processing. The Summary Plots are also generated at this time and the plot files transferred to the micrographics unit via tape, where the data are displayed on microfiche. The telemetry data are then written onto magnetic tape to be included in the telemetry data base, which is used for future data processing and for archival purposes.

Upon selection by the lead investigator, data are promoted from the telemetry tape data base to the disks for processing, either automatically in a production mode controlled by the system operators, or under investigator control in a custom mode. The end result of either processing activity is the creation of a Mission Analysis File (MAF). The data processed off-line produce results that are also returned to the MAFs. Priorities for data to be processed are set by the Science Team [1].

3. Hardware Description

The SDPS hardware consists of a Sigma-9 computer with associated peripherals and intercomputer channels located at the GSFC (Figure 3) and the remote terminal complex

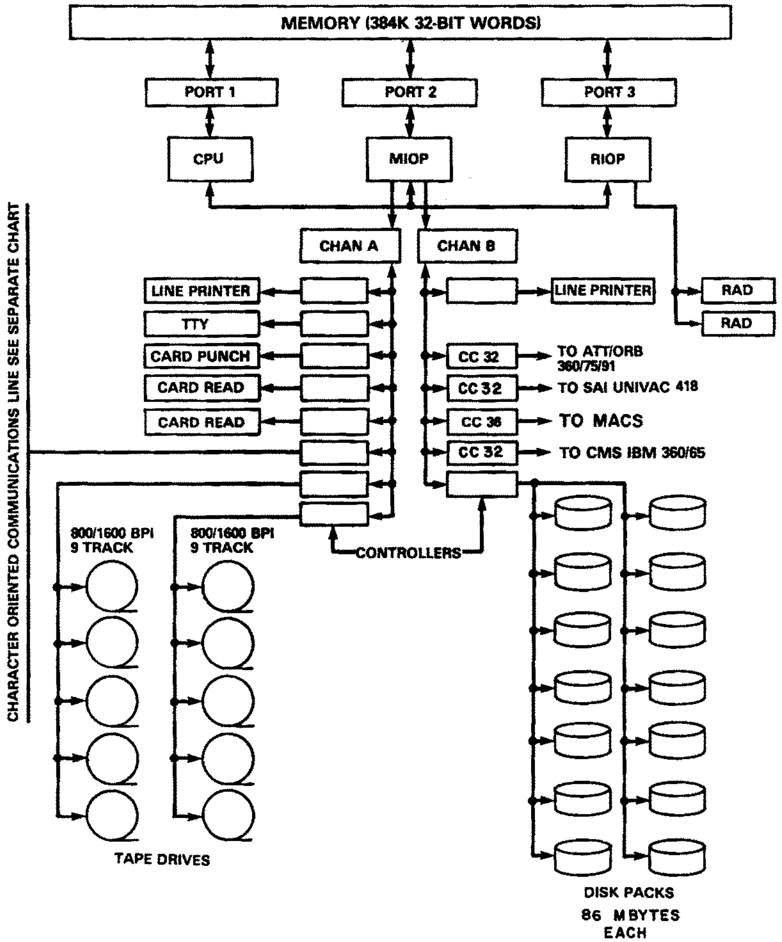

Fig. 3. Sigma-9 computer facility portion of the Science Data Processing System at the Goddard Space Flight Center. Links to computers involved in other tasks for the Dynamics Explorer project are shown.

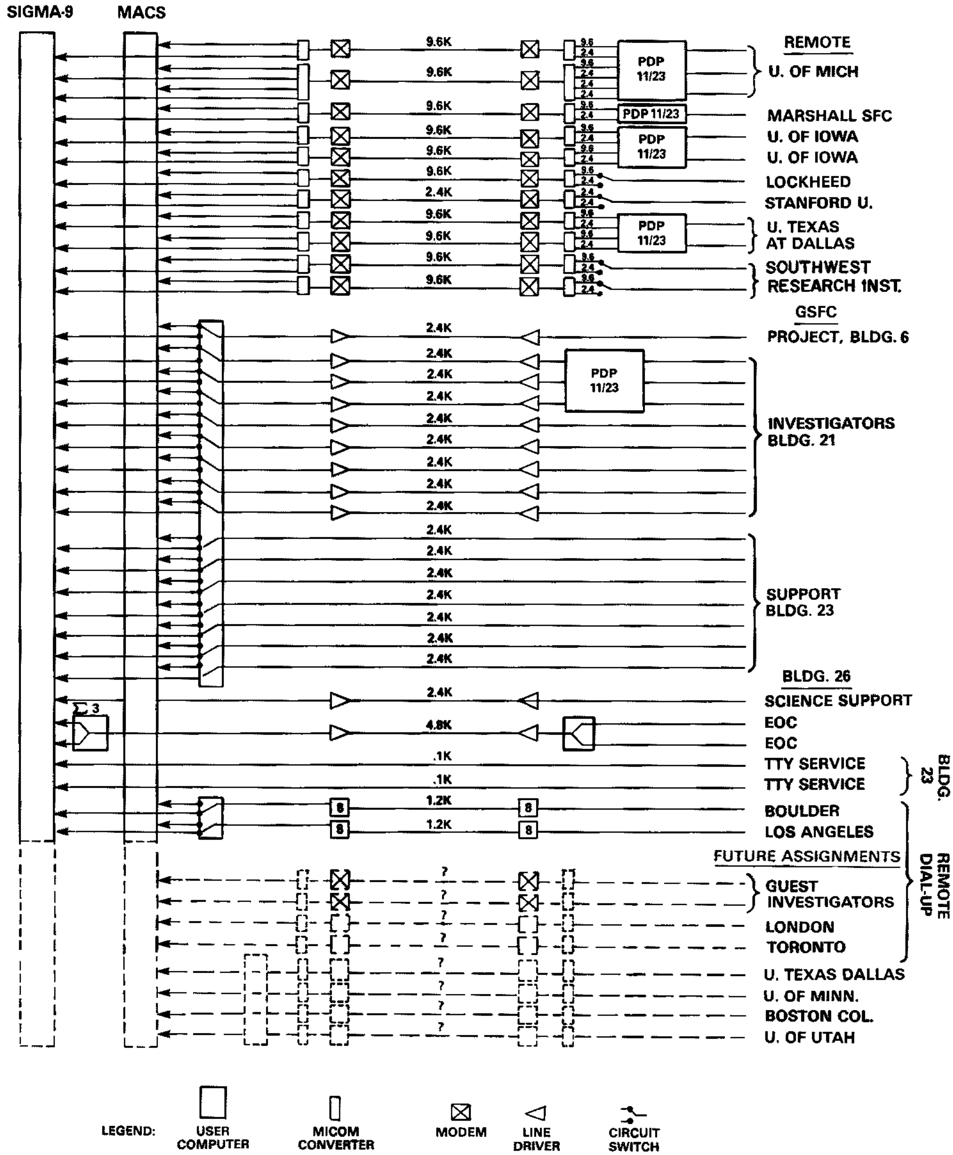

Fig. 4. Dynamics Explorer communications system to remote terminals.

for the scientists (Figure 4). The Sigma-9 facility will be augmented with an IBM 4341 computer, which will become operational about six months after launch.

3.1. Sigma-9 computer facility

The Sigma-9 computer facility is composed of a Xerox/Honeywell Sigma-9 with the configuration illustrated in Figure 3.

The intercomputer channels link the Sigma-9 with a variety of other computers [2] for the acquisition and transmission of telemetry, attitude data, decommutated instrument data, instrument command sequences, and files to the augmentation computer after it becomes operational.

3.2. Remote terminal complex

The DE investigators access the data with remote terminals located at their respective facilities using 7-bit ASCII asynchronous communications protocol (Figure 4). The terminals are used for initiating data processing activities on the central facility, for query and retrieval of data, for communication between the investigators and with the production personnel, and especially for displaying data. Due to the emphasis on graphical displays within the DE program, the alphanumeric terminals previously used by the Atmosphere Explorer program were replaced with graphics devices. Depending on the needs of the investigators each site contains a selection of equipment from the list in Table I. Many of the investigators are supplying additional hardware which is easily attached to the terminal facilities to supplement their analysis capabilities.

TABLE I

Terminal equipment

Type	Product
Grey scale terminal	Princeton electronics products 8500 M
Color terminal	Tektronix 4027
Vector graphics terminal	Tektronix 4014 and 4012
Alphanumeric terminal	Digital Equipment corporation VT-100
Hardcopy devices	Tektronix 4631 and 4632
Printer plotter	Varian 4211
Minicomputer	Digital Equipment corporation 11/23 128 K bytes of memory, and local disk storage

Dedicated communication lines at 2.4 k baud between the terminals and the central facility are provided (Figure 4). Communication lines to the augmentation computer will be changed to 9.6 k baud for investigators having instrument responsibility when the augmentation computer becomes operational. A number of dial-up lines of 300 baud and 1200 baud are available to investigators, including non-U.S. scientists.

3.3. Mission analysis computing system (MACS)

Initially all activities at the central facility will be supported by the Sigma-9. When the augmentation computer becomes operational the Sigma-9 will be used primarily for data processing (creation of MAFs), and the augmentation computer for analysis and graphics, and especially to service the MAFs. For this reason the augmentation computer facility has been designated the Mission Analysis Computer System (MACS). In identifying the tasks for the MACS, an effort was made to minimize both disruption of services and software conversion.

The MACS functional requirements include:

- receive, catalog and archive a large, on-line data base of MAFs, orbit/attitude data, and solar-terrestrial parameters;
- provide routines for the interrogation, retrieval and update of the files;
- support graphics packages for the terminals and microform unit;
- provide prompt response under the expected terminal I/O load in accessing data and developing programs;
- provide computational capabilities for various analysis programs and other mathematical operations.

A large increase in on-line data storage was sought to provide a responsive system. Table II lists an estimate of the contents expected on-line at the end of the first year of the mission. The MACS will also provide an increase of a factor of two in CPU power.

TABLE II

On-line data storage capabilities (up to 5.6 G bytes)

Function	Quantity
Directory of data	Life of mission
Current MAF data	2 month equiv.
User requested MAFs	1 month equiv.
Orbit/attitude data	1 yr
Solar-terrestrial parameters	1 yr
Collaborative program data	To be determined

Thirty-eight terminal ports including those from graphics and intelligent terminals will be supported, many with the 9.6 k baud line rates. The system will also maintain commonality of software interfaces for the MAFs and graphics with the Sigma-9.

The configuration of the IBM 4341 computer system selected for MACS is illustrated in Figure 5. Because of the separation of functions, coupling between the two computer systems is minimal. Data files created on the Sigma-9 will be transferred over a 230 k baud line to the MACS. Communication in the reverse direction is not required. The investigators will be able to communicate directly with either computer system from their remote terminals.

3.4. Micrographics

An Information International Incorporated FR-80 recorder/plotter will be used for microform output. The FR-80 consists of a high-speed computer that accepts digital data from magnetic tape, a translator to process the data, and a precision electro-optical system that records data as alphanumeric and/or graphic information on a high resolution CRT. The CRT is photographed onto appropriate microform products. Interchangeable camera and film transport systems provide grey scale images on microfiche and microfilm or in movie format, or color microfilm.

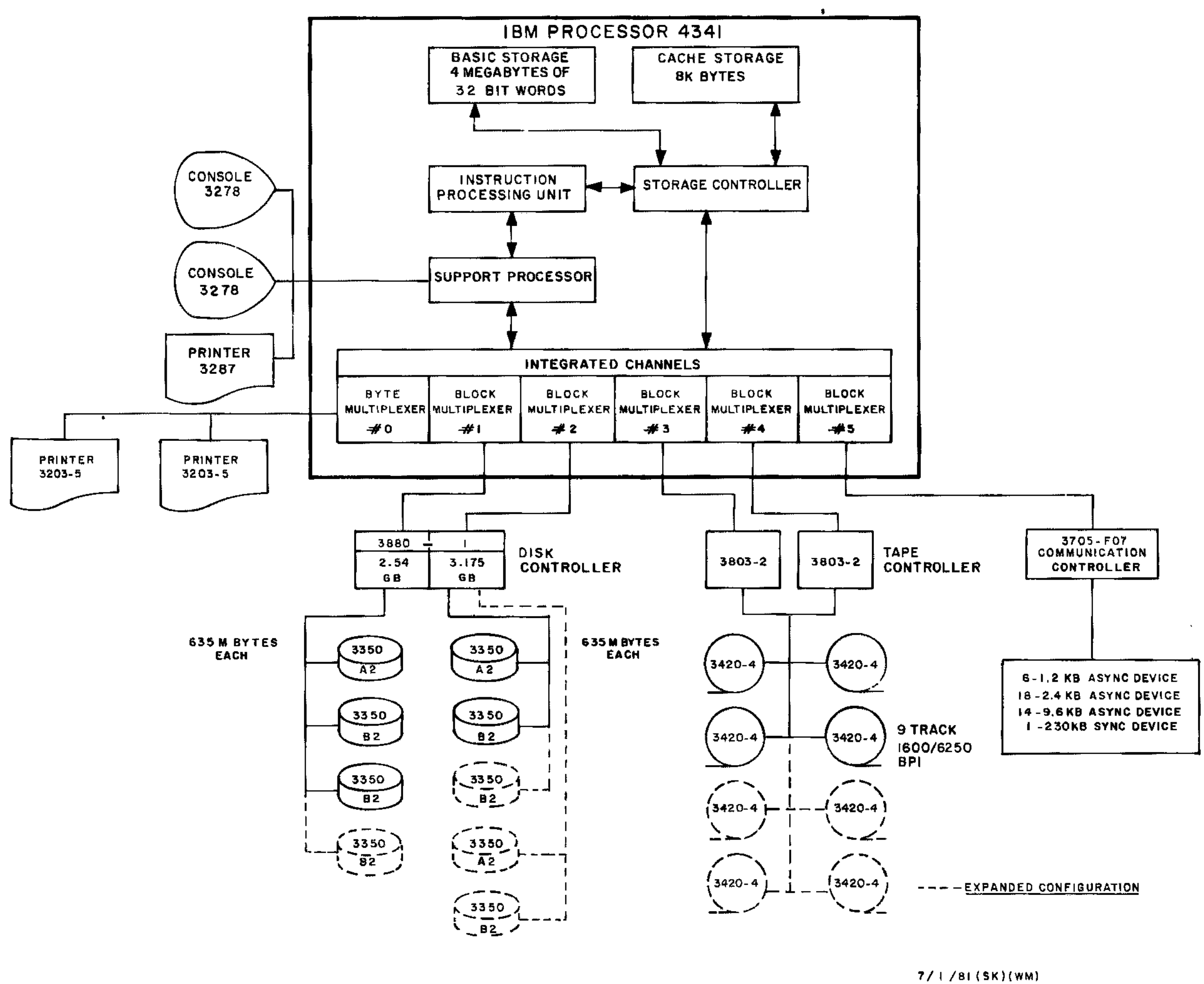

Fig. 5. Mission Analysis Computer System (MACS) which will augment the Sigma-9 facility to provide increased analysis and graphics capabilities.

4. Data Processing

Data processing programs are written by the investigators and use systems programs to access the various data bases, archive data, and generate outputs to the various graphical devices. Processing of data is done routinely on all telemetry data in the summary plot mode and on selected subsets in production and custom modes.

4.1. Summary plots

Summary plot generation involves the extraction of a subset of the telemetry data and conversion to key geophysical parameters using simple algorithms. The results are summarized in plot form and displayed by the FR-80 on microfiche, which are duplicated and sent to the investigators within a few days. Data from all acquisition periods will be processed in summary plot form. An example of a microfiche frame for DE-B appears in Figure 6. Four frame types are used to plot the data from DE-A, each on a common time scale of one hour per frame. One additional frame is used for a full orbit summary of a subset of the data. Data from the DE-B spacecraft are plotted in five frame types, each on a common time scale of 10 min per frame. For each spacecraft one orbit of data will be displayed on one fiche.

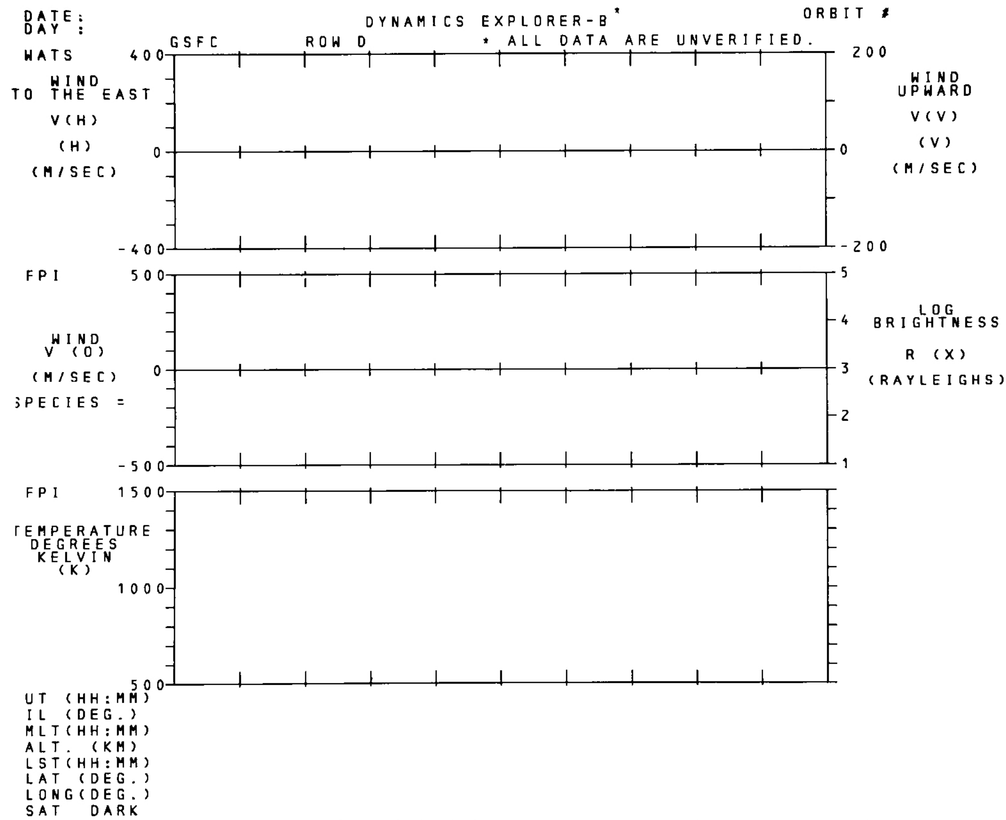

Fig. 6. Example microfiche frame into which will be plotted summary data from the Wind and Temperature Spectrometer and Fabry-Perot Interferometer on DE-B.

The summary plots will be used by the investigators to select events and time periods which are likely to produce the most promising results upon detailed analysis. They will also serve as an initial monitor of data quality from most of the instruments and provide information for subsequent operations planning.

4.2. Production processing

Production processing is executed by the staff at the central facility using programs supplied by those investigators with instrument responsibilities. No investigator interaction in the processing is required except to select which acquisition periods should be processed. The output from this level of processing is generally in geophysically meaningful units, although an intermediate file may be produced for later higher level processing. Results produced in this process are stored in the MAF and entries are made in the directory describing the file contents. When MACS is operational, the file and directory entry will be transferred from the Sigma-9 to the MACS. Production processing will generally be performed during the night.

4.3. Custom processing

Custom processing is performed generally during the daytime by the investigators primarily on an interactive basis from their terminals. This processing allows the investigator to selectively process and display the data on the graphics terminals and to rapidly inspect the processed data for its validity. Modifications to the processing algorithms can be made interactively and tested in this manner. Custom processing also produces MAFs, and may provide higher level processing of intermediate files or the generation of additional derived products which are then inserted into the MAFs.

5. Data Bases

To provide easy access to the data bases in the public files and to simplify development of programs which access the data bases, standardized data base files have been established that are accessible by using FORTRAN-callable system interface routines. The data files available to the investigators are described below:

5.1 Telemetry data

The telemetry (TM) files, containing the time-smoothed and edited telemetry data after the input processing functions are performed, reside in the telemetry tape data base. The entire process of telemetry data management is transparent to the user. Requested telemetry data will be automatically promoted from the tape data base and put on-line for the user. The arguments in a FORTRAN-callable routine specify which telemetry words from the main frame of telemetry are required, as well as spacecraft identification, date and time. The telemetry data base will exist only on the Sigma-9.

5.2. Orbit/attitude files

Definitive orbit/attitude data for each satellite will be kept on disk. The basic format of both orbit and attitude data consists of a set of parameters maintained at specific time intervals. When a request is made for a parameter at a particular time, the parameter is either extracted from the file or calculated from stored parameters. Numerical interpolation over time is used to provide the parameter at the requested time.

5.3. Mission analysis files

The Mission Analysis Files (MAFs) contain processed data which are provided primarily by the investigators responsible for instruments as a result of either production or custom processing, and are maintained for common access in the MAF data base. All investigators have 'read access' to any MAF data maintained by this system (Figure 1).

The MAF system consists of (a) a directory, (b) member data sets, and (c) accompanying utility software for accessing and manipulating the data sets. The member data sets with user-defined time resolution may be composed of data from a single instrument, or data from groups of instruments. The key to the usefulness and flexibility of the MAFs lies primarily with the MAF directory. The investigator can obtain from the directory the time periods of data related to specific science investigations, or the directory can be searched for data sets that are available from specific instruments. In addition, the directory can supply the operational mode of an instrument, the quality of data in the MAF, the temporal resolution of the data, and a variety of other information which the investigator responsible for creating the MAF chooses to insert. Thus the MAF directory can be used to select and choose subsets of the entire data base. Upon selection of data periods, the data can be accessed and displayed using the utility programs available from the responsible investigator, or special data groups can be assembled by collecting together useful MAF member data sets. The utility programs appropriate for the particular data set are also identified in the directory.

5.4. Solar-terrestrial parameters

The Solar-Terrestrial Parameter data base is a special MAF containing common parameters associated with solar-terrestrial conditions, including sunspot number, the 2800 MHz solar radiation flux, the Kp and Dst indices, solar wind and interplanetary magnetic field parameters, and possibly other derived parameters, such as ε, the magnetospheric energy input parameter [4] and $v \cdot B_s$, the dawn-dusk component of the interplanetary electric field [5]. These parameters will be especially useful for assisting in the selection of time periods for processing data, as well as for correlation studies.

6. Graphic Packages

Three graphics packages are provided for displaying data on the variety of graphics devices contained within the SDPS (see Figure 7). The plot files for the FR-80 appear in SD-4060 Meta-language format. From the Sigma-9 these are produced by EGS (Extended Graphics System), an upgrade of IGS (Interactive Graphics System). Should an investigator wish to debug his plot routine with a more rapid turn-around, he can display the plots prepared for the FR-80 on his graphics terminal, using the conversion system MICROSYM between SD-4060 Meta-language and Tektronix 4010-series ter-

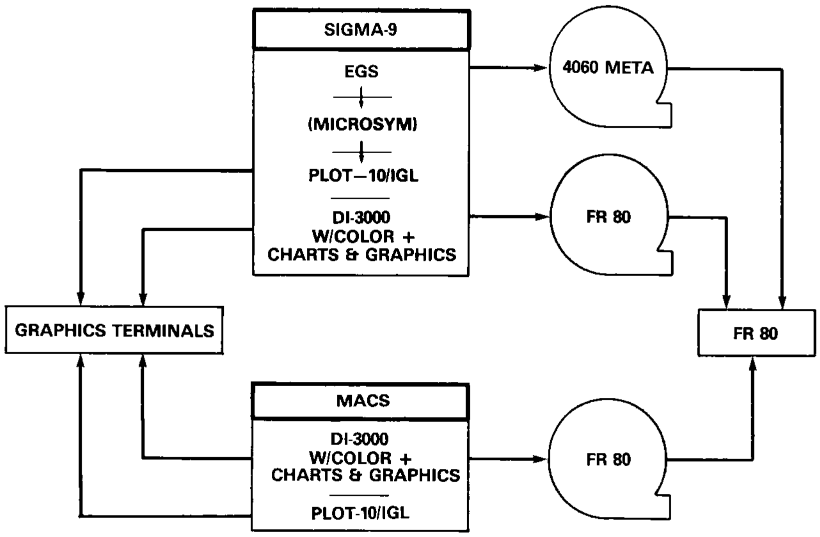

Fig. 7. Graphics packages on the SDPS for displaying data on a variety of graphics devices.

minal commands. The Tektronix PLOT-10/IGL (Interactive Graphics Library) software has been modified to drive both the Tektronix terminals and the Princeton Electronics Products 8500 M grey scale terminals in an interactive mode from the Sigma-9. A more versatile machine-and-device-independent plot package, DI-3000 from Precision Visuals, Inc., has been installed in the Sigma-9 and will be included in the MACS.

7. Conclusions

The Dynamics Explorer program has acquired the Sigma-9 central computer system as the core of an SDPS to perform data processing, data management and data analysis functions for the investigators associated with the program. At the same time the Sigma-9 computer system will continue to support the Atmosphere Explorer investigators. The system has been enhanced in a number of important ways to provide extensive graphics capabilities both at remote terminal sites and at the central facility, increased computational power, and vastly increased on-line storage. Summary plots of all data periods will be provided to the investigators associated with the program in microfiche format. The data base of processed data and the associated directory has been made more versatile and accessible to the user community.

Acknowledgments

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