DATA PROCESSING AND ANALYSIS FOR SPACE-BASED ASTRONOMY

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ABSTRACT

The sensors on a spacecraft, the spacecraft data handling system, the mission support ground data system, the experimenter's scientific data reduction and analysis system, the post-mission data storage and dissemination system all comprise elements of the data handling system for a space-based astronomy.

Primary treatement is given to the experimenter's scientific data system where the following aspects of astronomy missions are discussed: increasingly close operational contact of the experimenters with the sensors calls for moving data processing operations to the earliest possible point of the system. On the other hand, potential need for subsequent reprocessing of data would favor the central ground-based facility for initial processing with the open-end system philosophy.

One approach, extant and planned implementation of the scientific data analysis system for the zodiacal light experiment of the solar probe Helios, is presented in detail, taking into consideration experience from the various astronomy missions, in particular Pioneer and Skylab.

INTRODUCTION

The general space-astronomy data system, depicted in Figure 1, consists of five major components, each element reflecting different physical location.

C. Jaschek and G. A. Wilkins (eds.), Compilation, Critical Evaluation, and Distribution of Stellar Data. 61-68.

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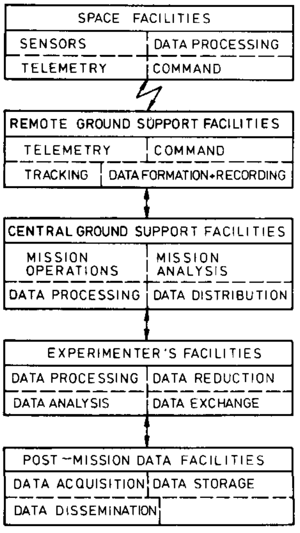

Figure 1 - General Space-Astronomy Data System

Electrical signal from various sensors of the spacecraft are initially conditioned and processed within individual experiment assemblies. The additional data processing may be done within the spacecraft data handling system performing functions such as raw data reduction without reducing information content, raw data reduction which reduces information content, data gathering, data compression or expansion, data storage, and data formatting and coding. This is followed by the telemetry link, which includes the transmitter, receiver, antennas and space path. The command link allows modifications of the spacecraft configuration [1].

The remote ground support facilities include the subsystems required to establish contact with the space facilities and to track their motions. Functions performed by these facilities include data acquisition, command, transmission, tracking and data preparation for communication lines.

The central ground support facilities perform the functions of mission operations support, mission planning and analysis, distribution of various data records produced at these facilities. There are three types of records coherently related to the preparation of permanent scientific data records: the system data record (SDR), the master data record (MDR) and the experimenter data record (EDR) [3]. The SDR is a log made at the central point of the system for each of the network systems (Tracking, Command, Telemetry, Monitor). The MDR has extraneous, and duplicate segments removed and the remainder is an organized, identified set of records, in digital forms. The EDR contains information of one particular experiment and supporting information such as orbit/attitude-, housekeeping-, and command-data.

The EDRs are further processed by the experimenter's facilities, consisting of subsystems performing the following functions: EDRs-processing, -monitoring, -displaying, and -converting, meta-processing, several phases of data reduction, data analysis and data preparation for scientific data exchange. The latter step supplies the World Data Center with the analysis and physics tape.

The post-mission data facilities, on the world-basis referred to as the World Data Center, disseminate data to the scientists upon request. More specifically this center, functioning as the integrated space science data center, is responsible for the active collection organization, storage announcement, retrieval, dissemination, and exchange of space science data.

EXPERIMENTER SCIENTIFIC DATA SYSTEM

Figure 2 shows various levels of processing connected with the experimenter's data system.

The straight forward operations level comprises various check-,

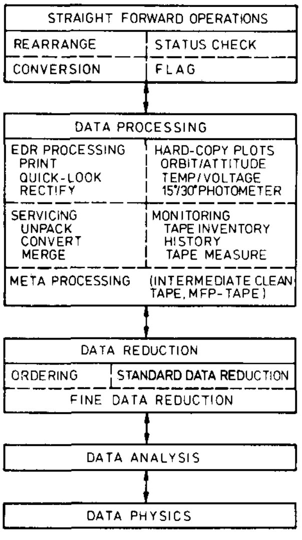

Figure 2 - Experimenter Data System-Processing Levels

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flagging-, conversion-, and rearranging-procedures. There is very important limitation implying that only those procedures will be performed for which data can be acessed sequentially i.e. no tape movements backwards or forwards.

The data processing level consists of the following: EDRs processing, production of hard-copy plots for science-, engineering-, and orbital-data, monitoring of all processing, meta-processing (producing intermediate tapes necessary for further processing) and various converting, packing-, and merging-routines servicing the experimenter's data system.

Functional steps within the data reduction level are: ordering, standard data reduction and fine data reduction. The objective of the ordering step is to produce a tape with ordered (according to increasing measurement cycle number) data blocks. The standard data reduction step produces a reduced tape with preliminary measurement results (brightness, polarization and color). This step comprises straight forward procedures only, dealing with quantitative characteristics of data. The fine data reduction step consists of procedures requiring feed-backs of processed data. Qualitative characteristics of data are becoming more obvious. It produces an analysis tape with final measurement results (brightness, polarization and color).

The data analysis level comprises separation of components phase and averaging individual results phase. It produces a physics tape with final measurement results of zodiacal light measurements.

The theoretical interpretation of final data is the objective of the data physics level.

LOCATIONS FOR PROCESSING FUNCTIONS

Some arguments, taking mainly operational costs into consideration, call for the performing of data processing functions as close to the sensors as possible. Benefits of this approach include reduced communications bandwidth between space facilities and ground stations, ground stations themselves, and ground stations and central facilities; simplified data handling; and reduced logistics support.

On the other hand, arguments calling for the accomplishment of data processing as late in the system as possible are considering increased scientific effectiveness as a most important factor. This approach allows to improve implied system uncertainty,to change portions of the system and to exploit unexpected phenomena.

The appropriate approach should take into consideration the both arguments. In general, the data processing for each of the operational functions mentioned earlier should be located according to the following criteria: degree of understanding of the system, state of knowledge of the physical phenomena being investigated, the experience of experimenters,and supporting personnel and operational costs. By evaluating criteria outlined earlier one should be able to choose the appropriate system in which the physical location for the data processing could eventually lean either toward spacecraft or toward experimenter's facilities. In many cases it should not be the closed-system. Basically, it should be possible to deliver essentially raw data to the experimenter if necessary to provide a high certainty that he can understand the data. Processing can later be moved progressively toward the spacecraft as that processing, the performance and the operations become more routine. Definately it should be possible to revert the earlier mode if circumstances require. It

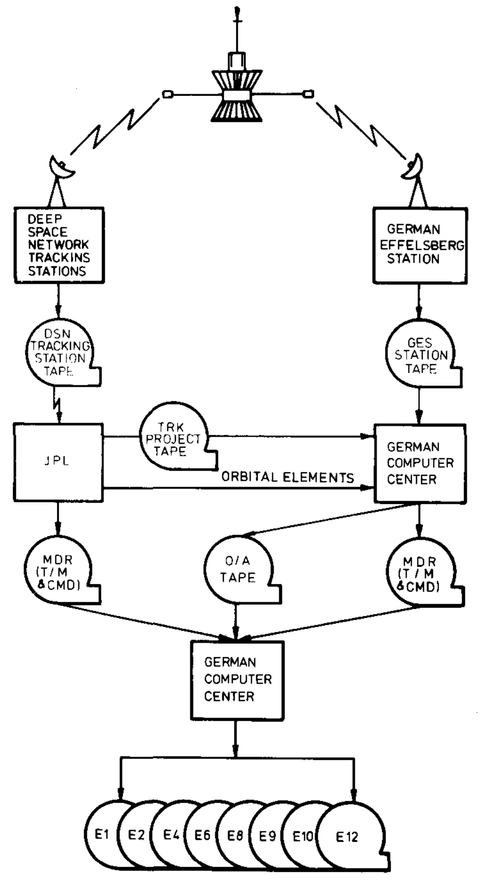

Figure 3 - Helios System Data Flow

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is also desirable to retain flexibility to perform many functions in more than one location to accomodate subsystems failures and other unexpected situations.

OPERATIONAL SYSTEMS

The operational system, implemented for the german experimenters of the solar probe Helios, is shown in Figure 3 [2]. The telemetry data are initially processed by the remote-processing facilities (German and/or American stations) producing digital tapes further processed by the central data processing facilities (Jet Propulsion Laboratory (JPL) and German Computer Center). These facilities are producing the following data records: tracking (TRK) tape, orbital elements, telemetry and command master data records (T/M and CMD) tape and orbit/attitude (O/A) tape. MDRs and O/A-tape are further processed by the german computer center producing the experimenter data record (EDR) tape for each experimenter.

Figure 4 illustrates the operational data processing and analysis system for the zodiacal light experiment (E9) of Helios probe. The Max-Planck-Institute (MPI) Computer Center merges EDRs for the period of one month into ordered tape, having extraneous and duplicate elements removed, and data reorganized into meaningful logical units. The ordered tape is the principal input for the scientific data reduction and analysis system. After the reduction phase the analysis tape is produced and further processed by the data analysis system producing the physics tape. This system is supported by the microfilm information system of the German Society for Mathematics and Data Processing (GMD), putting data on microfilm in graphic-, and/or alphameric-form. The microfilm is primary medium for the experimenters data exchange. The reduced-, and analysis-tape are due to the National Space Science Data Center (NSSDC), taking care of the further dissemination of experimental-data, and/or-results to the scientific community.

CONCLUSION

With respect to the previous experience with the data processing for the space-based astronomy missions, in particular Pioneer, Skylab and Helios, the following approach seems to be favored by the principal investigatiors [4]: the development of the scientific data reduction and analysis modules strictly at the experimenter's facility, preferably under his close supervision; the centralized (with good back-ups) routine processing and data handling; the possibility to use general software packages (e.g. integrated graphics system, file manipulation system)

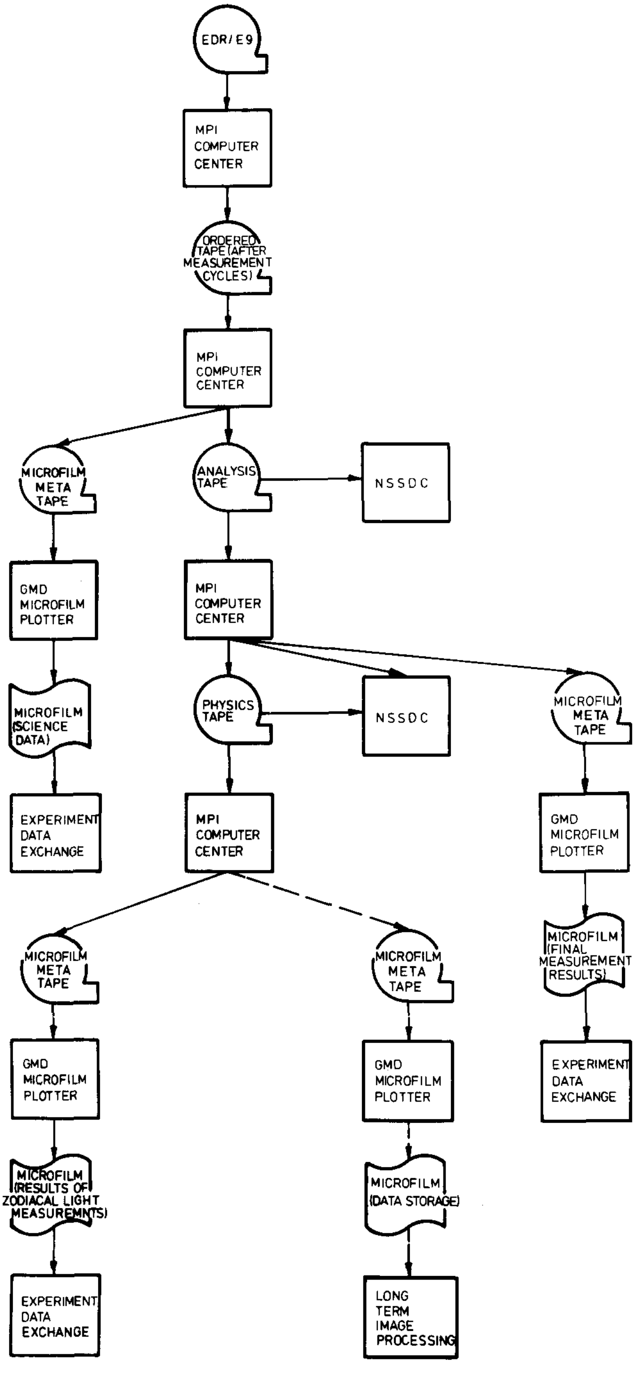

Figure 4 - Zodiacal Light Experiment System Data Flow

on service basis at the central processing facility (e.g. NASA-Center).

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