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SPACE SCIENCES DATA PROCESSING

by George H. Ludwig

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Greenbelt, Md.

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ABSTRACT

Spacecraft carrying large numbers of scientific instruments presently transmit data at the rate of approximately 150 million data points per day which must be converted from raw digital form into a conceptually meaningful form for analysis. The task of processing these data rapidly and accurately is a large one, done in several steps. The first step involves converting the raw receiver output signals into computer compatible digital form, including signal clean-up, establishment of synchronization, and time decoding. In the newest processing lines, this first step also includes a moderate amount of editing and quality checking. The remaining steps employ large-scale computers for further editing, establishing accurate timing, computing spacecraft attitude, and sorting to provide data tapes for individual experimenters. The experimenters are responsible, at present, for further reduction to a more meaningful form. These operations include additional sorting, storage, compilation, computation, and display. There is a great need for additional development of analysis and display programs, techniques, and equipment to assist in this work.

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INTRODUCTION

This paper deals with the problems of data collection and data processing from space sciences satellites which produce large volumes of data over periods of months to years. These data are subjected to systematic detailed analyses to ascertain the characteristics of space phenomena. Space sciences satellites are distinguished from the manned, lunar, planetary, meteorological, and communications spacecraft, which are not discussed here. These latter types of spacecraft have larger requirements for real-time and near-real-time processing because of operational demands, and because of the more volatile nature of their data.

In the pre-satellite 1950's, experiments flown on sounding rockets and balloons produced from a few minutes to a few hours of data which were analyzed during the next several years by experimenters and groups of graduate students at universities. Even the first satellites greatly expanded the data base by providing data for months of operating lifetime. Since then, the data rate has increased rapidly from a few bits per second to as much as 64,000 bits per second, in the case of the Orbiting Geophysical Observatory (OGO) series. Furthermore, operating lifetimes have increased from a few weeks to several years. Figure 1 illustrates data volume growth from 1961 to the present; included are data points for the Explorer, Interplanetary Monitoring Platforms (IMP), Orbiting Solar Observatory (OSO), OGO, Orbiting Astronomical Observatory (OAO), Applications Technology Satellites (ATS), and Biological Satellites (BIOS) series. Excluded are data for the international satellites (for which data processing services are normally provided by the experimenters' countries), NIMBUS satellites (which do, in fact, contain a number of scientific experiments),

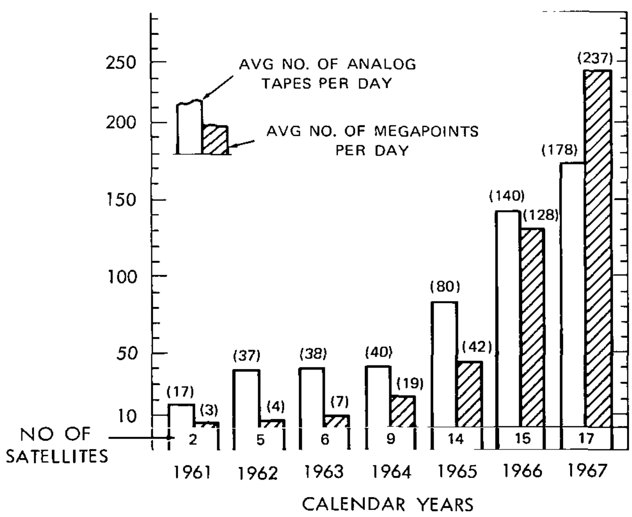

Figure 1—Growth in space sciences data volume, in millions of data points per day. A data point is a measurement (temperature, voltage, etc.) generally corresponding to 8 to 10 binary digits.

TIROS, Environmental Sciences Service Administration (ESSA), Department of Defense (DOD), and the University Satellite series. The distinction between spacecraft included and those not included in this discussion reflects the separation of projects whose data processing is performed within the large scale Goddard Space Flight Center (GSFC) Central Processing Facility (CPF) and those whose data processing is performed elsewhere.

THE INFORMATION SYSTEM

The "information system" refers to those portions of the electronic system that collect outputs from the experiment sensors on the spacecraft, process these data on the spacecraft, transfer them to the ground receiving stations, and prepare the information for the experimenters so that they may reach conclusions about the phenomena being measured (Reference 1).

A generalized information system for space experiments is illustrated in Figure 2. The sensors on the spacecraft are furnished by the individual experimenters. These sensors convert physical quantities (temperature, charged particle energy, magnetic field intensity, etc.) into electrical quantities. Signal conditioning circuits (amplifiers, feedback networks, charge integrators, etc.) located aboard the spacecraft, are frequently associated directly with the sensors for easier processing and telemetering of the electrical quantities. The signal conditioning circuits are often

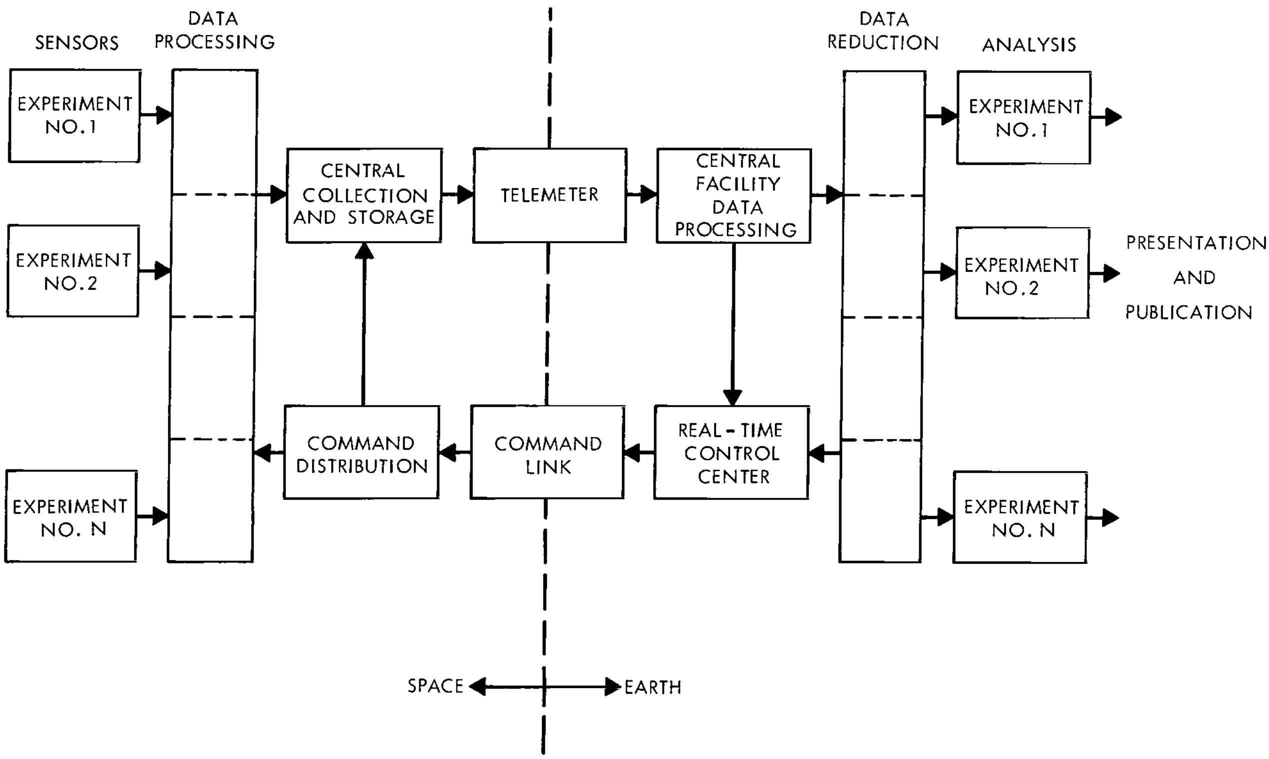

Figure 2—A typical space information system.

followed by additional processing circuits to count pulses, measure their amplitudes of pulses, measure the amplitudes of more slowly varying analog quantities, and to measure time intervals, to simplify the task of telemetering data to the ground. This processing is indicated in Figure 2 by the elongated box on the left. The box is subdivided by dashed lines indicating that some of this additional processing may be done within individual experiment assemblies, while some of it may be done within a central data processing subsystem. Two additional basic types of processing may also be done on the spacecraft within this same block. The first type of processing reduces the amount of raw data without reducing the information content. It includes the elimination of redundant information, the elimination of meaningless zero readings, and the reformatting operations which involve the rearrangement of data. The second type of additional processing reduces the information content of the raw data. This includes such processes as curve fitting, statistical analysis, spectral analysis, and mathematical manipulation.

The central collection and storage block (Figure 2) includes provisions for gathering data from the individual sources (frequently by a time division multiplexer) and bulk data storage equipment (either for time-scale compression or expansion or to permit reception of data for extended periods by a few localized receiving stations). This is followed by the telemetry link, which includes the transmitter, receiver, antennas, space path, and where needed, the encoder and decoder (Reference 2).

The data from spacecraft containing command systems which permit modification of the operation of the experiments or spacecraft are relayed in either real time or near-real time to control centers at GSFC and are displayed for operational analysis. Decisions are made which result in the initiation of commands to the spacecraft through the command link to modify the spacecraft configuration.

After the data reach the ground, additional operations are performed prior to analysis by experimenters. A number of these functions, including the establishment of data synchronization, noise removal, time decoding, and quality determination are performed within the CPF. Thereafter, the experimenters and other users receive those data tapes which contain the best estimates of the original data from each experiment output, along with the necessary status, performance, time, quality, command, and validity information. In addition, orbit and spacecraft attitude information necessary for the experimenter's analyses are also supplied for some missions.

These operations are followed by a number of additional processing steps in which the data are edited, sorted, stored, and used in mathematical analyses and other manipulations. These additional steps provide data in a form that can be readily interpreted. This function is shown as one large block with dashed subdivisions, again indicating that portions are performed by the individual experimenters, and other portions are performed within the CPF.

The final step is the analysis of the information received by the experimenters to ascertain some characteristics of the phenomena being investigated. This analysis results in the presentation and publication of these results.

REPRESENTATIVE SYSTEMS

An example of an extremely simple space information system is shown in Figure 3. This is the Explorer I system (Reference 3), which was successfully launched on January 31, 1958, and which led to discovery of the Van Allen radiation belts surrounding the earth. Pulses from a single Geiger-Müeller (GM) counter were accumulated in a five-stage binary register capable of storing 32 counts. The state of the output stage was continuously transmitted. In addition, several temperatures and the continuities of micrometeoroid detection grids were telemetered. Each signal source controlled a subcarrier oscillator so that the oscillator frequencies were proportional to the voltages from the sources. These oscillator signals were frequency multiplexed by the addition of the outputs from the oscillators. The resulting composite signal modulated the transmitters directly; and the output of the receiver on the ground was, in turn, demultiplexed by passing the signals through a number of bandpass filters and frequency discriminators. At the output of the frequency discriminators on the ground, the signals (identical in form to the signals that modulated the subcarrier oscillators in the spacecraft but with noise added) produced strip chart recordings. These strip chart recordings were manually reduced by data readers to provide tabulations of the GM counter pulse rates, temperatures, and the rates of breakage of the micrometeoroid grids. This simple system employed very little on-board data processing and very little machine processing on the ground. It was used in the first satellites to give a high probability of success at a time when instrumentation on satellites was still an undeveloped science, and when large-volume data processing techniques on the ground were relatively unknown for this application.

Since that time, increasingly complex electronics systems have been placed on spacecraft and operated reliably for several years. We now perform many more experiments that are individually

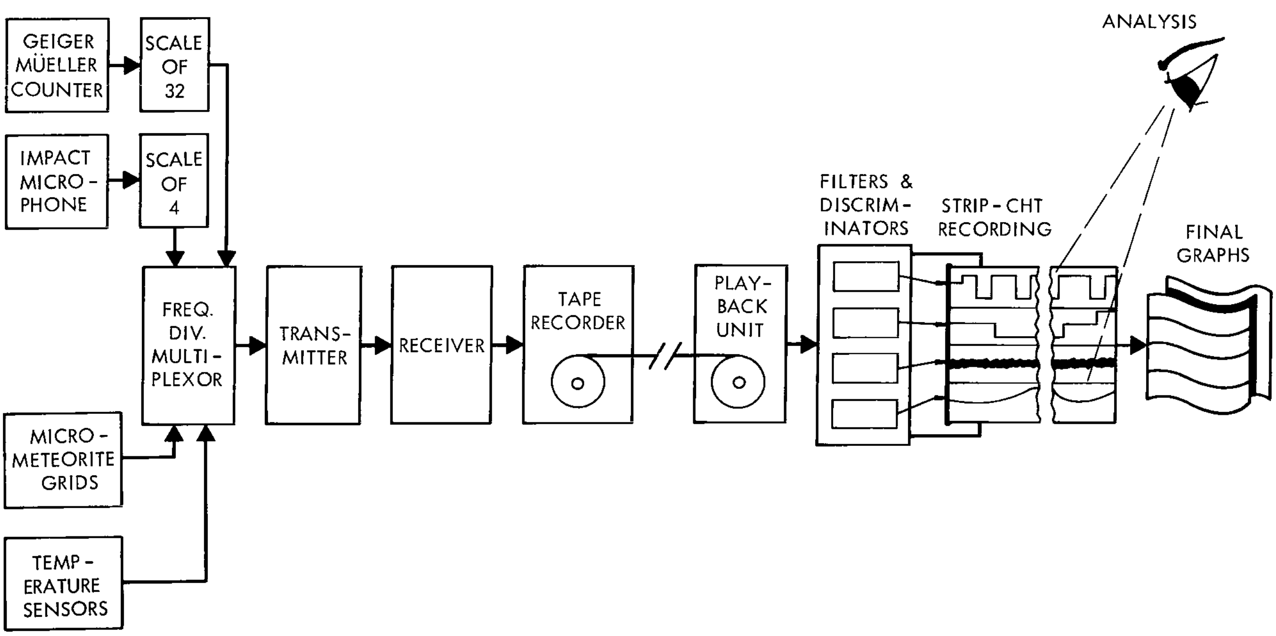

Figure 3—The Explorer I information system.

more complex than those on the early Explorers. As we investigate various phenomena in greater detail, we must make more discriminating measurements, which require a higher order of data processing. To illustrate, on Explorer I only the omnidirectional intensity of all particles above a threshold energy determined by the thickness of the GM counter wall was measured. Now, in the continued investigation of cosmic rays and energetic trapped radiation, the directional characteristics, types of particles, intensity as a function of particle energy and type, and temporal variations of these parameters must all be determined. Therefore, whereas one could once simply count the pulses, one must now perform a multiparametric pulse-height analysis of rather complex detector outputs. These additional requirements necessitate increased capability for the entire information system.

The information system for a recent large spacecraft (OGO, Reference 4) is illustrated in Figure 4. This spacecraft (in the 500-kg category) was designed for a variety of orbits ranging from low, near-circular, polar orbits (Polar Orbiting Geophysical Observatory, POGO) to very highly eccentric orbits extending to approximately 24 earth radii at apogee (Eccentric Orbiting Geophysical Observatory, EGO). The first of these observatories (OGO-I), launched on September 5, 1964, into the eccentric orbit, carried 22 experiments from 17 institutions. Subsequently, OGO-II (a POGO), OGO-III (an EGO), and OGO-IV (a POGO) were launched on October 14, 1965, June 6, 1966, and July 28, 1967, respectively.

Instrumentation for OGO experiments ranges from extremely simple generators of analog signals (e.g., currents in ion collectors), to extremely complex digital data processing subsystems involving digitization and manipulation of pulse heights from a number of detectors. Each of the two identical digital data handling subsystems on the spacecraft consists of a main time-division multiplexer with 128 data inputs and three slower sub-multiplexers with 128 inputs each. In addition, each has a flexible format time multiplexer that can be set at any one of 32 different input data formats by ground command. The latter multiplexer is intended for use with extremely high information bandwidth experiments for relatively short periods. Two large-capacity tape recorders are included on the spacecraft. They can record at 1000 bits/sec for 24 hours (EGO missions) or at 4000 bits/sec for 8 hours (POGO missions). These rates correspond to approximately one and four main multiplexer measurements per channel per second for the two cases. In addition, digital information can be telemetered directly without the tape recorder at bit rates up to 64,000 bits/sec corresponding to 55 measurements per input channel per second.

Data processing in the CPF on the ground involves four major steps. The recordings containing the raw outputs of the receiver detectors are first passed through equipment which estimates the values of original data bits; establishes bit, word, and frame synchronization; and decodes the times recorded on the tapes at the ground receiving stations. The equipment then produces a computer buffer tape. The second step involves editing this tape to ascertain that there were no errors in its production and determine data quality. The third step involves establishing the relationship between data, as recorded on the spacecraft, and Universal Time (UT). The fourth step is the decommutation (sorting) of buffer tape data and the generation of individual experimenter's data tapes which, along with orbit/attitude tapes, are forwarded to the experimenters for additional processing. Status and performance data tapes are also produced in this step for use in spacecraft analysis.

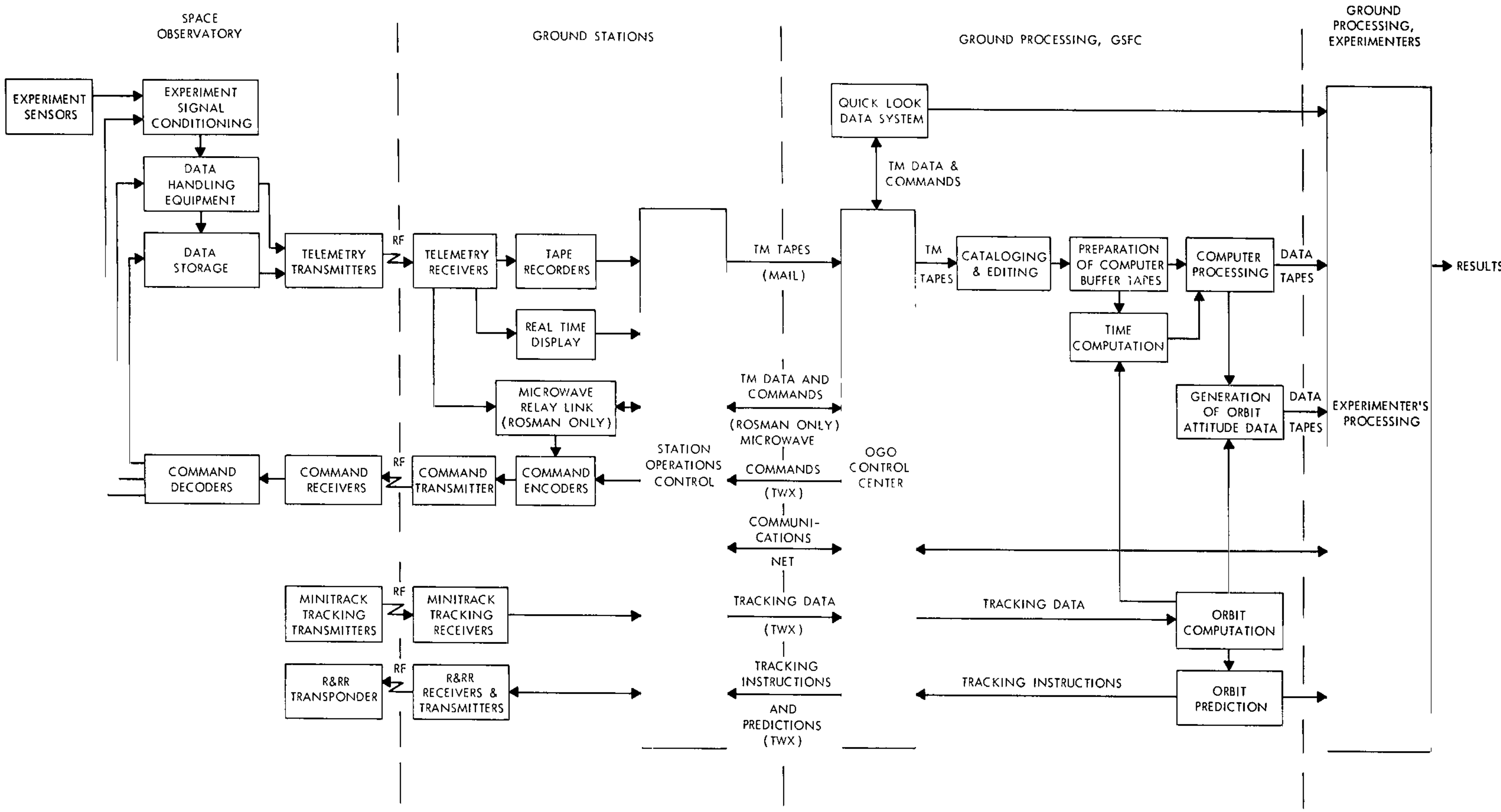

Figure 4—The information system for the Orbiting Geophysical Observatory.

EXPERIMENTER'S TIMETABLE

Each experimenter invests a considerable effort in conducting a specific space experiment. The timetable shown in Figure 5 is representative of the Explorer, IMP, and Observatory missions. It indicates that a specific experiment may require from 7 to 9 years for completion. This time requirement includes the time from the beginning of the actual building of the experiment hardware to completion of data analysis. Even before experiment selection, the experimenter may have invested a considerable effort in the development of new detector techniques; therefore, the time scale may, in fact, be 1 to 2 years longer than indicated.

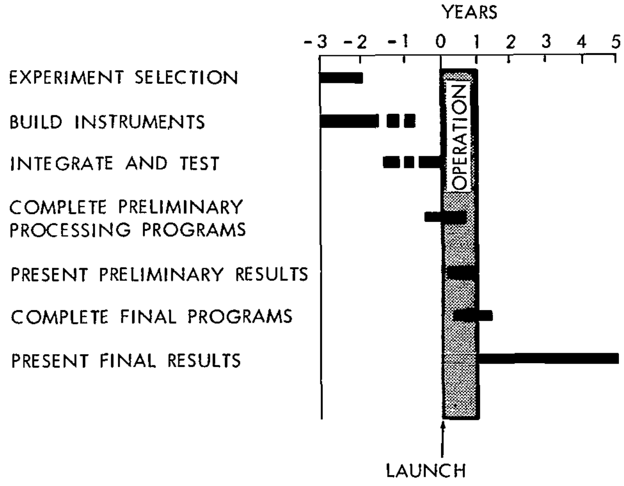

Figure 5—A space sciences experimenter's timetable.

Preparations for data processing activities sometimes begin as early as 2 to 3 years before launch. However, the experimenters are often unable to predict the detailed characteristics of their expected data accurately enough to permit writing the final processing programs before launch. It is often necessary to study the actual flight data before deciding precisely how to process the data and display them for analysis. Thus, experimenters can sometimes present preliminary results within a few months after launch using interim processing systems; however, it usually requires 6 months to a year after launch to prepare the final processing programs. Detailed reduction and analysis then occurs over a period of 2 to 5 years.

This long time scale produces problems for the experimenters especially for those at universities since graduate students are unable to complete any single experiment from instrument design through data reduction. For many reasons, including this one, GSFC is attempting to reduce the processing backlog in the CPF and to maintain the processing in a current status. Some progress in shortening the experimenter's time scale can be made by additional work on on-board processing equipment and techniques and by the development of improved programming and display techniques for experimenter's ground data reduction. The remainder of this paper will discuss these three activities in more detail.

ON-BOARD DATA PROCESSING

In the earlier programs data processing on the spacecraft was kept relatively simple to obtain high equipment reliability and high confidence in our ability to interpret the results after flight. However, steps have already been taken to increase the amount of data processing on the spacecraft. A simple example is the inclusion of floating point counters on several spacecraft which count pulses in a non-linear manner to provide a large dynamic range and a fixed accuracy. Processing in many current experiments is considerably more complex, involving, for example, the accurate digitization of a number of photomultiplier and solid-state detector pulse heights resulting from cosmic rays when a given logic condition is met. Specialized computers for computing an autocorrelation function and for performing statistical analyses are being built for some of the IMP-F experiments.

There are several arguments for developing more extensive on-board processing techniques. The volume of data returned from satellites is extremely large, and processing the data on the ground, both in the CPF and by individual experimenters, is expensive and time-consuming. On-board processing may check the present high growth-rate of data volume by reducing the volume of unused data. Furthermore, on-board computers may permit obtaining information otherwise unavailable due to telemetry link bandwidth limitations.

A system designed for significant on-board data processing should be able to perform any degree of processing, from essentially zero to a larger amount, by reprogramming from the ground after launching. Thus, the spacecraft can be launched with a very simple data processing program. Then, as characteristics of phenomena and instrument behavior are ascertained in orbit, additional degrees of data processing can be added. The system should also be designed for immediate reprogramming for very simple processing to verify proper operation of experiments and data handling equipment and to provide a high level of confidence in the data, particularly if anomalous effects are seen.

On-board computers with stored, but replaceable, programs are now being developed by several groups. Some of these computers may be able to control calibration of experiments, and computation of spacecraft attitude relative to the sun or magnetic field (with resulting control of experiment sampling times and programs). The computer may also interface with the spacecraft attitude control, power, and thermal control subsystems.

A good example is the on-board computer currently being developed in the Information Processing Division at GSFC (Figure 6). It employs a data bus with a variable number of memory modules (1 through 8) and central processing units (CPU) (1 through 3) to provide a multi-mission capability. The input/output (I/O) provisions are also modular to adapt the basic computer to a large variety of experiments and spacecraft. The memory modules are woven plated wires, randomly accessed, with true non-destructive readout. Each module will provide 8192 eighteen-bit words of storage with a 2-microsecond cycle time. The CPU employs a full parallel adder and parallel transfer at register and I/O interfaces and uses automatic scaling for binary point bookkeeping and hardware multiply/divide. Add and multiply times are about 6 and 45 microseconds, respectively,

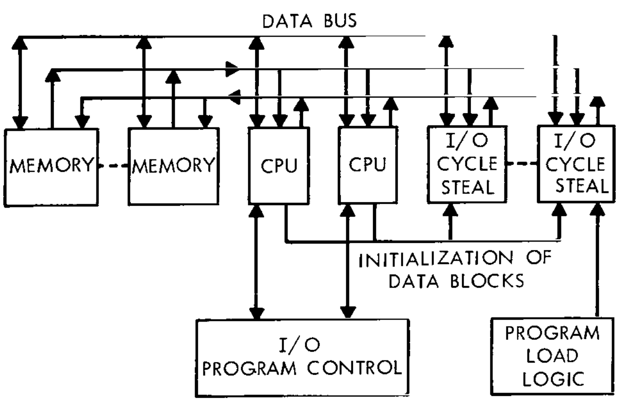

Figure 6—The organization of the on-board computer being developed by the Information Processing Division, GSFC.

including operand fetch. An alternate CPU employing serial arithmetic is also planned for missions not requiring the speed of the parallel system. The I/O equipment will be customized for each mission but will have an overall capability exceeding the requirements of any single application. It has a cycle steal capability for rapid and direct exchange of data with the memory, priority interrupt for entry of data by external control, and external request scanning for entry of data by programmed control. The computer can be used as a multi-processor. Digital tape storage units may be added when they become available. The single memory module, single parallel CPU, average I/O version of this computer is expected to weigh approximately 12 pounds and have a volume of about 0.25 cubic foot. It will consume from 3 watts (idling) to 13 watts (400,000-word/sec memory exchange rate). It will be ready for missions in the 1969 to 1970 era.

The use of general purpose on-board computers will greatly affect ground data processing. The early spacecraft, which had no command capability, depended on the ground network and the CPF to gather transmitted data and to make them available at some later time for analysis. There were very few requirements for real-time and near-real-time processing since there was no possibility of modifying the operation of the spacecraft or experiments. Since spacecraft systems have become more complex and extensive command capabilities have been added, it is now necessary to perform a large amount of processing within the various Mission Control Centers (MCC) to ascertain spacecraft performance and to control spacecraft operation. When general purpose on-board computers are used, even greater reliance on real-time and near-real-time ground processing will be necessary for on-board processing to be most effective. Thus, we can expect a shift toward more real-time and near-real-time processing in the MCCs and CPF. Although its extent is unpredictable, it is entirely possible that spacecraft employing such on-board computers will have most data processing performed immediately, using data transmission links from the data acquisition stations to GSFC and additional data transmission links directly to the experimenter's laboratories. The Data Reduction Laboratory (DRL), described in a later section of this paper, will eventually ascertain the desirability and practicability of this type of operation.

GROUND DATA PROCESSING IN THE CENTRAL FACILITY

After the satellite telemetry data are tape-recorded at the 12 data acquisition stations, the tapes are forwarded to GSFC for processing. Initial processing is performed in the CPF which includes the necessary production control, tape inventory, quality control, and library provisions, in addition to the processing lines and computer equipment. This facility produces a set of tapes for each experimenter which contains the data from his experiment, plus the necessary auxiliary information and the spacecraft orbit and attitude.

The functions performed by the CPF are illustrated in Figure 7. One tape from every shipment of each data acquisition station is evaluated soon after receipt to determine whether its equipment was operating properly, thus enabling correction of abnormalities as soon as possible. After evaluation, the tapes are mounted on one of the Satellite Telemetry Automatic Reduction Systems (STARS) for initial processing. In this processing, the signals are conditioned; and bit,

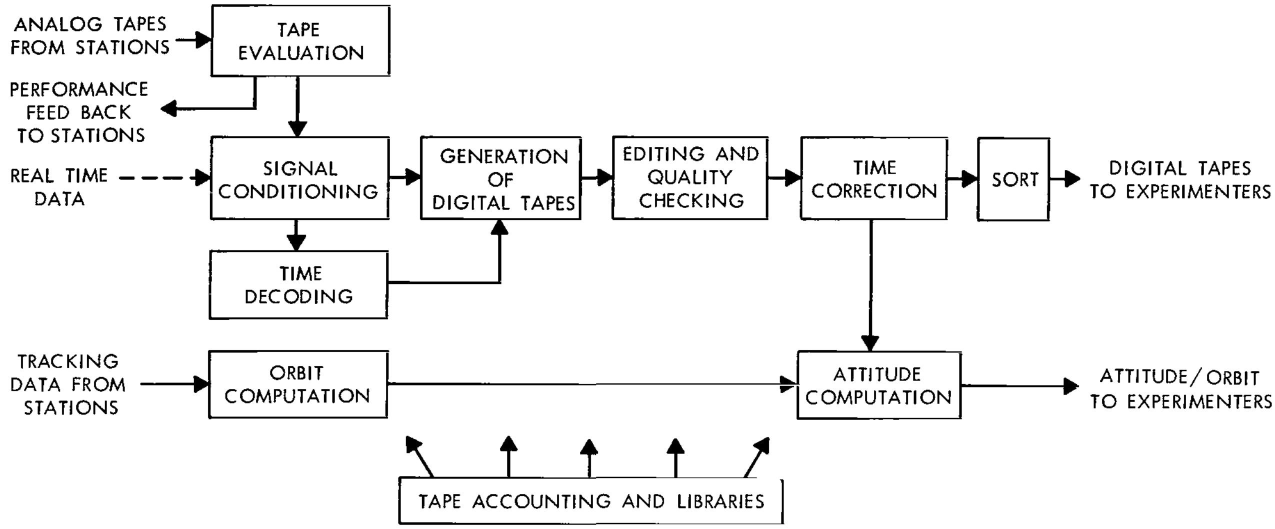

Figure 7—The functions performed within GSFC Central Processing Facility.

word, and frame synchronization are established. In the signal conditioning operation, a best guess is made as to the original content of the signal on a bit-by-bit or tone burst-by-tone burst basis. This operation usually includes the integration of the signal for the duration of the bit or tone burst period before a decision is made. Concurrently with these operations, the times recorded on the tapes at the data acquisition stations are decoded and continuously compared with a local clock. Both the reconstructed telemetry data and the times are buffered in a core memory and then recorded on a computer-compatible buffer tape.

In the latest model of the processing lines (STARS Phase II), a CDC 3200 computer is included to perform two major functions (Reference 5). The set-up of the processing line is under computer control to reduce both the time required to prepare for each run and the number of operator errors. Initial computer pre-editing is performed during this first pass to determine data quality as early as possible. In addition, a simulator is included for system checkout. A photograph of a STARS II PCM processing line is shown in Figure 8. A drawing of the STARS area of the CPF (Figure 9) indicates the arrangement of the approximately 15 major processing lines. The organization of the computer area of the CPF is shown in Figure 10.

After initial processing on STARS, all additional processing is performed on general purpose computers. Further editing of the buffer tapes checks the internal consistency and the quality of the data. The times, either telemetered with the data from the spacecraft clock, or recorded with the data from a ground clock, or both, are converted to UT. Corrections are made for clock errors and propagation times. This step is especially crucial, since it is common practice to use time to correlate the flight data with orbital position and with other housekeeping and experimental data during the analysis phase.

The data, now including UT, are arranged into a convenient format and sorted (decommutated) onto separate data tapes for each experimenter. Thus, each output tape contains the data from a

Figure 8—A view of a portion of one of the Phase II Satellite Telemetry Automatic Reduction Systems.

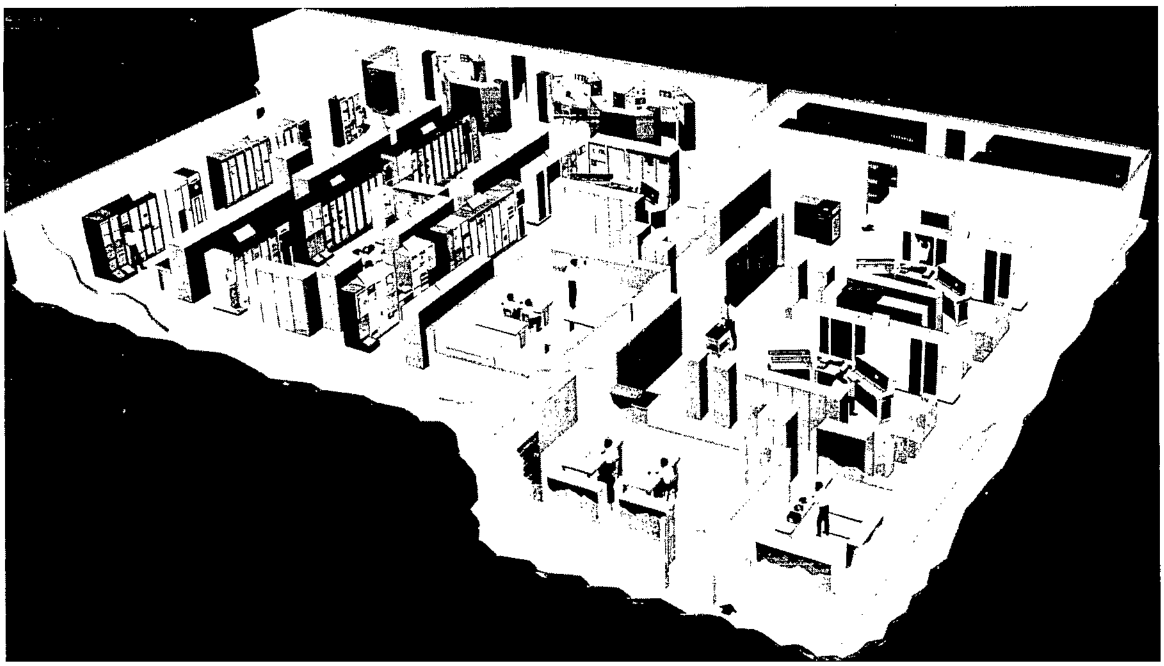

Figure 9—Artist's sketch of the telemetry processing portion of the Central Processing Facility, showing the tape evaluation lines (upper left), the analog library (upper right), production control and dispatching (lower right), and the digitizing lines (center). The processing line in the lower right corner is the one shown in Figure 8.

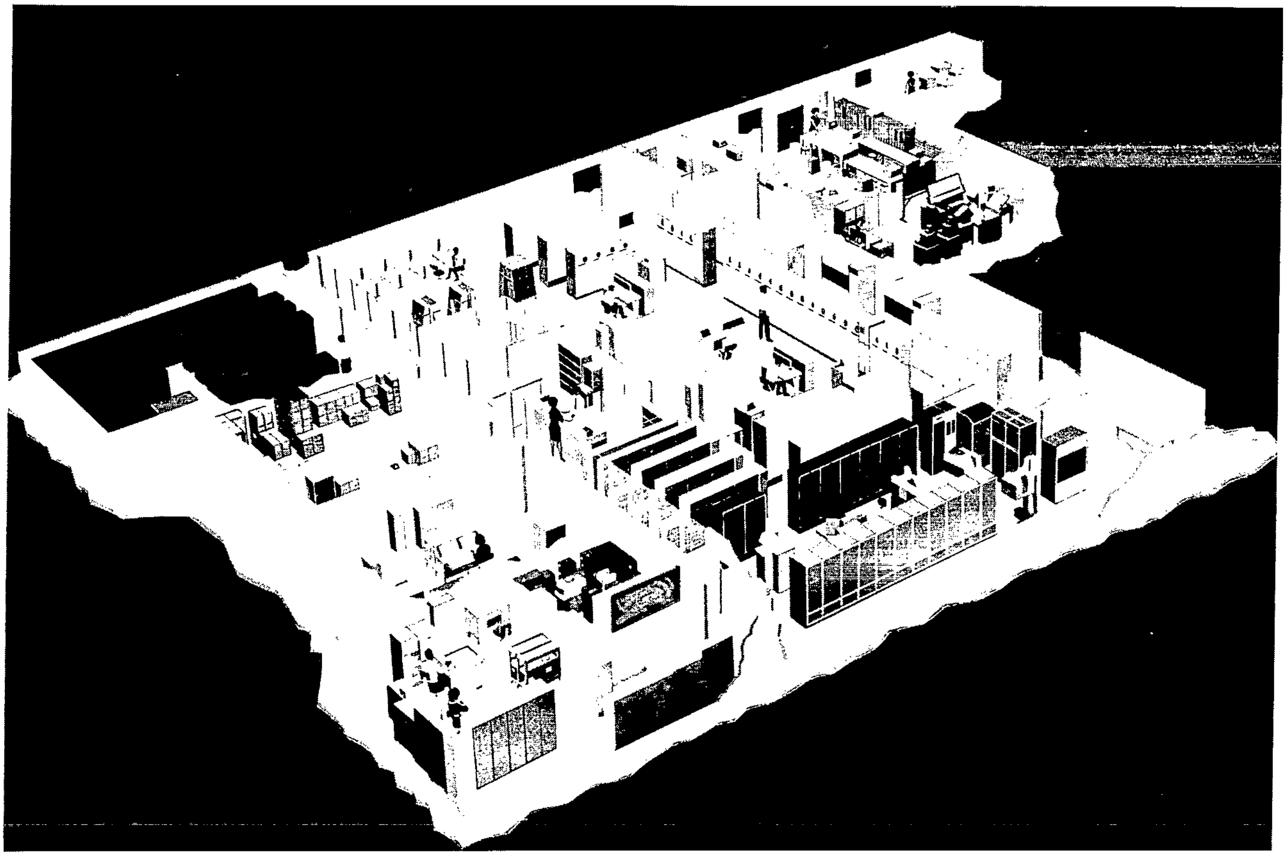

Figure 10—Artist's sketch of the computer portion of the Central Processing Facility, showing the 2 Univac 1108, IBM 1401, and IBM 7010 computers in the center, surrounded by the dispatching office, various tape libraries, and the printing/plotting area.

specific experiment, UT, and various pertinent spacecraft data (e.g., temperature of the experiment mounting plate, voltage of the power bus, etc.).

In parallel with the telemetry data processing, the spacecraft orbit is computed for each minute using inputs from the radio interferometer and range and range rate tracking stations. This computed orbit, along with attitude control system error signals and attitude sensor output signals obtained from the telemetered spacecraft data, is used to compute the instantaneous look directions for the detectors. Both orbit and attitude information are shipped to experimenters with their telemetered data tapes.

Since the identification of each command received by the spacecraft is not contained in the telemetered data, it is also necessary to decode the commands from the original acquisition station tapes where they are recorded at the time of command transmission. The complete command list is then furnished to the experimenters in the form of a magnetic tape, punched cards, or a listing. This task may be quite large since tens of thousands of commands are transmitted to some spacecraft.

The data processing operations outlined above also involve a number of bookkeeping and library functions. The original data acquisition station tapes are cataloged upon arrival and are eventually placed in permanent storage in the analog tape archive, which at present numbers approximately 150,000 reels of tape. An intermediate digital "edit tape" is also placed in permanent storage for use if computer reprocessing is necessary. A number of documents are generated during the processing operations which are used by the processing facility staff to evaluate system performance. These documents are supplied to the experimenters as an accurate record of the content of all the tapes and the quality of the data.

Several significant changes from the data flow indicated in Figure 7 are being made. These include the movement of some of the pre-editing and quality checking functions to the STARS Phase II data processing lines. This change permits the determination of the quality of the data and success of the processing operation during the first pass through the equipment in the CPF. Thus, earlier and more accurate system analyses are provided for the further perfection of the information system.

A second change is leading to the generation of a set of Master Digital Data Tapes near the end of processing in the CPF. These tapes will contain all raw telemetered data, commands, corrected time, orbit, spacecraft attitude, and quality information in chronological sequence. These tapes will be the source of all further sorting and processing and will become the prime archival medium, replacing the earlier analog station tapes and edit tapes. A large step towards implementing this new philosophy was taken on IMP-F (launched on May 24, 1967). A further step is being taken in preparation for the Small Scientific Satellite (SSS or S^3).

ADDITIONAL GROUND DATA REDUCTION

After the data are available in raw form, the experimenters must still reduce them to forms suitable for reaching meaningful conclusions about the phenomena being investigated. This reduction commonly includes reformatting, sorting, merging, accumulation, statistical analysis, and mathematical manipulation of the raw data. It also provides for outputting summarized data in a readable form such as line printer tabulations, X-Y plots, and motion pictures. It is useful to remember that most experimenters perform four different operations on their data.

1. Scan All Data

A detailed analysis of every piece of data received from a particular experiment may not be necessary. In these cases all of the data are scanned to select the interesting portions, since it is not possible to predict the time periods or regions in space which will produce those interesting data. For example, bursts of particles are occasionally emitted by the sun and an objective of many experiments is to detect and analyze these unpredictable bursts.

To simplify the scanning of all the data, it is common to reduce them to strip chart or other visually meaningful form for rapid viewing. One recent technique which shows great promise is the generation of motion pictures, from sequences of photographs of a suitable display of the data. In one case the amplitude of the output of a swept, very low frequency (VLF) receiver was plotted as a function of its frequency to provide a frequency spectrum. A picture of this spectrum was taken each time the receiver sweep was completed (once every 256 telemetry frames) and the developed film was run through a motion picture projector. It was possible to quickly identify interesting fluctuations from the steady state conditions.

2. Analyze Selected Portions of Data

Limited portions of the data may require detailed analysis. These may include data obtained during transversal of the magnetospheric boundary surface, the transition region, and the shock front, for studying the interaction of the solar plasma with the earth's magnetic field. Another example is the detailed study of the ionized layers surrounding the earth at heights from one hundred to several hundred kilometers. Additional examples of interesting subjects for detailed study include solar storms, day-night effects, the auroral zones, and the astronomical investigation of certain portions of the celestial sphere.

3. Map in Either Space or Time

A frequent scientific objective is to determine the spatial extent of specified phenomena. Data are selected as the spacecraft moves from position to position in its orbit and the location of the orbit shifts in a sun-earth coordinate system. Thus, a complete mapping in space may require a year or more. Often these data must be reduced to one or a few plots to provide a map of the phenomena.

In addition to a map in space, a map in time may be needed, with scales ranging from minutes or hours to many years. For example, in studying numerous solar-related phenomena, some changes occur in a few minutes during the buildup of a solar flare. On the other hand, other changes involve a time scale equal to the length of the sun spot cycle of 11 years. For complete understanding of the phenomena, it may be necessary to investigate the data from a particular type of sensor for at least that period of time.

4. Analyze All Data

Some experiments, generally those with very low event accumulation rates, may require full analysis of all data for extended periods to obtain statistical significance. In one type of cosmic ray experiment only a few heavy particles of some types may be seen each week; hence data must be accumulated many months to be significant.

Note that the processing techniques for meeting each of the four data analysis requirements listed above may be considerably different. Any one experiment may require processing programs for several of these four analysis functions. At the present time these reduction programs are usually prepared by individual experimenters, with frequent parallel development of similar subroutines by different groups. To assist the experimenters in their tasks, several new development activities are needed.

1. Basic Computer Programming Techniques for Telemetry Data Manipulation

Present programming techniques such as FORTRAN, COBOL, etc., are poorly suited to the rapid development of new programs for data manipulation. New modular programming systems for data manipulation are needed.

2. Subroutine Organization

Subroutines (computer programming modules) for performing specific functions (e.g., scale factor correction) need to be assembled into a library system and made available to the community of users. This subroutine structure should be built into the program structure discussed in Item 1 above.

3. Better Display Techniques, Devices, and Programs

Many experimenters still obtain data outputs as printed tabulations and use considerable manual effort to reduce them to charts and graphs. Dynamic cathode ray tube (CRT) displays, motion pictures, color, three-dimensional displays, and other forms of display should provide a more rapid means for arriving at the desired processing programs and a more rapid and comprehensive understanding of the phenomena being investigated.

Several efforts are underway to develop some of these techniques. The DRL (Figure 11), being developed by GSFC Information Processing Division, will provide several operator stations with two displays each. One alphanumeric CRT and keyboard at each station will provide dialog communication with one of the central Univac 1108 computers for rapid program development. The second CRT will display alphanumeric and graphic data in either static or dynamic form. Remote communications consoles can be added later for experimenters to develop programs from their own laboratories. It will be possible to enter data either in real time, via the data link from several of the STADAN stations, or off-line, from either analog or digital tapes. In addition to the rapid program development capability, the dynamic display capability of the DRL will provide operational real-time and near-real-time data presentation for the support of experiment/spacecraft operations, especially during critical operating periods. This basic DRL is scheduled for completion in mid-1968.

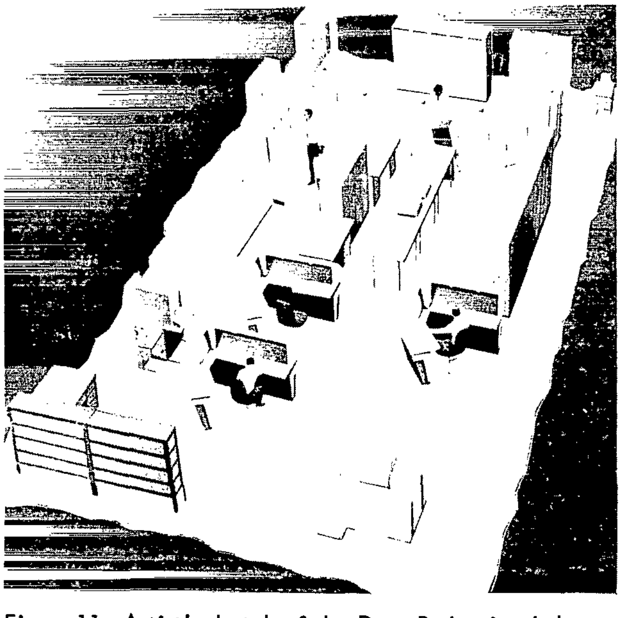

Figure 11—Artist's sketch of the Data Reduction Laboratory showing the real time control center in the rear and the operators consoles in the front.

SUMMARY

Information systems for space sciences experiments continue to undergo an evolutionary process. Improvements are continuing in the performance of individual components of the information system (e.g., in the speed, efficiency, and frequency ratings of transistors employed in the telemetry transmitters). However, the most significant changes foreseen during the next 3- to 5-year period involve the use of additional on-board data processing, improvement in the operation of the CPF, and the development of new computer programming and display techniques. These activities are needed if we are to avoid falling further behind in processing the large volumes of data being returned from our orbiting spacecraft.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, August 7, 1967
311-07-11-01-51

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