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INSTRUMENTATION PROGRAMMING FOR COMPUTER CONTROLLED DIGITAL DATA PROCESSING

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TRACT

A number of considerations are necessary in instrumentation programming, many of which are either not applicable or applicable to a lesser degree in other types of programming. This paper discusses these problems in general terms and illustrates how they have been dealt with specifically. The latter is done by describing the programming and operation of a data reduction system.

INTRODUCTION

Among the prime goals of instrumentation programming are flexibility and efficiency. Flexibility as used in this paper is intended to imply simplicity as well. There are at least four types of flexibility which must be considered. These are (1) Flexibility of input, (2) Flexibility of output, (3) Dynamic flexibility of operation, (4) Flexibility of program modification.

Flexibility of input means allowing varied data acquisition requests. Flexibility of output should allow for various output formats. The operator should have many options of changing program paths during operation. This should be provided in the dynamic flexibility of operation. Possible hardware changes in the interfaced equipment should be considered in the area of flexibility of program modification.

Efficiency must be considered in the following two areas: (1) Efficient Utilization of the central computer, (2) Efficient utilization of the interfaced equipment. As an example of the latter case, there may be more than one distinct unit of equipment interfaced with the computer which, in many instances could be operated simultaneously.

Some of the problem areas encountered in instrumentation programming are interrupts, operator communication and input/output. Among the programming areas which are important in dealing with these problem areas and attaining the previously mentioned goals of instrumentation programming are the following: (1) Monitor, (2) Sub-Monitor or control program, (3) Programming language. The sub-monitor or control program is the program most directly concerned with the operation of the interfaced equipment. A control program presently in use will now be described. The importance of the monitor and programming language in the development and operation of the control program will be evident.

GENERAL DESCRIPTION OF DATA REDUCTION SYSTEM

The Data Reduction System consists of the software necessary for the operation of a Data Reduction Complex in post flight reduction of Saturn flight test data. A brief description of the Data Reduction Complex of Marshall Space Flight Center would be in order at this point. The Data Reduction Complex consists of source units, discriminator units, telemetry reduction units, a control unit, and a digital computer. The source units are two analog tape drives, telemetry receivers, microwave receivers and a telemetry calibrator. The telemetry reduction units are two microsadics (analog to digital converters), a PCM station and a Bendix Ground Station for oscillograph recordings. There are 36 discriminator units, each consisting of four channel and four filter selections. The control unit is the unit through which several switching matrices are controlled. Through these switching matrices a source unit can be selected, probably an analog tape.

A track from the tape can be selected and the output routed to a selected discriminator unit. The proper channel and filter selection can be made on the selected discriminator unit. An output line can then be selected to send the output from the discriminator unit to the desired telemetry reduction unit. Other capabilities provided through the control unit and matrices are switch settings on one microsadic and selection of specific words from a commutated package for Ground Station plotting. The control unit is interfaced to a B5500 Computer as are the microsadics and the PCM station. These are interfaced as magnetic tape units.

In order to control the interfaced equipment, several commands are available which can be written on the control unit to cause the desired matrix set up. These commands are written by the Data Reduction System and in general this system operates as follows: Circuitry is set up by means of commands to the control unit to obtain data from an analog tape and route it through the proper discriminators to the specified telemetry reduction unit. Any necessary switch settings will be made either programmatically or manually as directed through the message printers. Transmission will then begin from the analog tape unit. If transmission is to a telemetry reduction unit other than the Ground Station, a digital tape will be written on a magnetic tape connected to that unit. Since the unit is interfaced to the B5500, the tape can be read from the B5500 by the Data Reduction System. When data transmission is completed for the flight period being processed, an interrupt will be transmitted as a specific one character message through the message printer. If the completion of transmission was for a telemetry reduction unit other than the Ground Station, the digital tape will now be transmitted by the Data Reduction System to an on line B5500 tape. The program for which the data was requested will then be called by the Data Reduction System for execution. This program has been previously compiled.

REQUESTING OF DATA

Requesting of data to be digitized for use by a B5500 program and data to be plotted on the Ground Station is done by means of several types of control cards. A digit in column one of each card will indicate its type. These types are HEADER (1), MESSAGE (2), TAPE LABEL (3) and REQUEST (4). All four types are needed in requesting data for the B5500. Only types 1 and 4 are needed in requesting data for Ground Station plotting. The fields of the HEADER card contain such information as program identification or group identification (used for Ground Station requests), equipment identification, request type, and priority. Equipment identification indicates the telemetry reduction unit to be used. Request type indicates whether the request is for digitization, previously digitized data or linearized data. Priority of course indicates the urgency of the particular data request as compared to other data requests.

The MESSAGE card contains information for any necessary messages to be printed. The TAPE LABEL card contains a label which will be written on the on line tape containing the requested digital data. The REQUEST card fields describe the data which is to be obtained. These fields are link #, channel #, sub-channel # (for FM[3] data), sub-commutator #, and commutator #. The last two fields apply only to Ground Station requests.

INTERRUPTS

Interrupts constitute an extremely important area in the operation or the Data Reduction System. All interrupts are communicated through the message printer control unit of the B5500 and all except one of these are manual interrupts. There are 18 interrupt conditions and a large number of these fall in the following groups: data transmission complete, operator action complete, and file error. In each of these cases there is a distinct one character interrupt for each telemetry reduction unit. The operator must send each of these interrupts by typing the appropriate character at the keyboard of his message printer. Other interrupts include the operator input which allows the operator to communicate additional information to the Data Reduction System, i.e., information requiring several characters to

communicate. When this interrupt is received by the Data Reduction System a message is typed requesting the operator to transmit his additional information. The only interrupt which is automated is the request for retransmission from the control unit. When commands are written on the control unit if a parity error is detected then the appropriate interrupt character (I) is transmitted automatically to the B5500 through the message printer control unit.

TABLES

Several tables are maintained by the Data Reduction System and these are a central part of the system. Among these tables are the Program Sequence Table, Ground Station Sequence Table, Interrupt Table, Data Availability Table and Hardware Availability Table.

The Program Sequence Table has an entry for each program requesting data. Other information in this table indicates whether or not the program's data has been obtained and the table's order indicates the order in which data will be sought for the requesting programs.

The Ground Station Sequence Table is similar to the Program Sequence Table but indicates the order in which groups will be plotted on the Ground Station.

The Interrupt Table will indicate which of the possible interrupts have occurred and require processing.

The Data Availability Table has an entry for each channel of each link of telemetry data to be processed. Other information in the Data Availability Table consists of the data status and the requesting program's identification. The status possibilities are initiate, in process and digitization complete.

The Hardware Availability Table will keep track of all external equipment, i.e., whether the hardware is busy, available or down. There are three sections in this table. One of these is for source units, the second is for telemetry reduction units and the third is for discriminator units. Other information in the Hardware Availability Table indicates the capabilities of the specified unit.

DATA REDUCTION SYSTEM EFFICIENCY AND FLEXIBILITY

This system is intended to provide efficient use of the interfaced equipment and contribute to efficient B5500 use by providing data to the requesting programs when it is needed. At the same time it is intended to be flexible, particularly in allowing for various changes which may not be known until the program has been placed in operation for processing data from a particular Saturn flight.

One means by whih the system provides for efficient use of the interfaced equipment is by performing a set up for more than one telemetry reduction unit at a time. Examination of the Hardware Availability Table and the Data Availability Table must be performed in determining when this simultaneous operation can take place. Another efficiency which affects both the B5500 and the interfaced equipment is the transferral of the digital data to the B5500. When this is done the telemetry reduction unit is now freed for processing other requests as the tape unit connected to it is now freed from retaining the previously digitized data. The program which requested the data can begin processing the data from the on line B5500 tape to which it was transferred. This can be done automatically without operator intervention since the tape was labelled by the Data Reduction System as requested.

Flexibility of input and output is provided by allowing data to be requested in any order and the output will be in the same order as the order in which it was requested.

One means of providing flexibility in the program modification area is in reading portions of tables in as data rather than having these as an actual part of the program. Therefore some modifications in hardware do not necessitate program changes but only data card changes.

Dynamic flexibility of operation is provided through the operator input interrupt. When the operator desires to make certain changes in the paths the Data Reduction System takes, he sends this interrupt.

The Data Reduction System, upon receiving this interrupt, writes a message asking for the operator's information. Among the flexibilities provided to the operator are the following:

(1) Change sequence of program requests, (2) Change sequence of Ground Station group requests (3) Delete program requests, (4) Delete Ground Station group requests, (5) Declare hardware down or available, and (6) indicate to Data Reduction System the availability of a new batch of requests to be read from the card reader.

THE ROLE OF THE MONITOR AND PROGRAMMING LANGUAGE IN EFFICIENCY AND FLEXIBILITY

The monitor in use on the Burroughs B5500 is the Master Control Program and the programming languages are ALGOL and COBOL. Both the monitor and programming language are instrumental in the implementation, efficiency, and flexibility of the Data Reduction System. The Data Reduction System is written in ALGOL and runs under the Master Control Program as do all B5500 programs. The Master Control Program controls multi-programming and multi-processing. Among its duties are handling input/output, scheduling, and calling in new program segments. The Master Control Program processes all B5500 interrupts in performing its control functions. The Master Control Program and ALGOL of course have great influence on the efficiency and flexibility of operation of all B5500 programs written in ALGOL. However, they contribute to the efficient operation of the Data Reduction System and thus efficient utilization of the B5500 in a special way. A function was provided in ALGOL whereby the Data Reduction System can indicate to the Master Control Program that execution of the Data Reduction System program should be discontinued temporarily. An indication is also given to the Master Control Program of the condition under which processing is to be resumed, namely a one character interrupt through the message printer control unit. The Data Reduction System spends much of its time awaiting interrupts. Without the function just described, the processor would be unnecessarily monopolized by the Data Reduction System.

The ability to maintain tables which are important to the Data Reduction System is greatly enhanced by the character and bit manipulation capabilities provided by the ALGOL compiler. This capability is provided in the partial word designator which allows addressing of any bit or group of bits other than the first bit of each word. The concatenate operator provides a means of forming a computer word from bits in various bit positions of several other computer words using only one ALGOL statement.

Another area in which the Master Control Program and ALGOL contribute to flexibility and efficiency is in providing a function in ALGOL which can be used to instruct the Master Control Program to call in other previously compiled programs for execution. This is made more useful by the concept of labelled tapes which allow programs to obtain their input automatically through the Master Control Program without the operator designating the tape unit.

CONCLUSIONS

Based on experience with the Data Reduction System, several conclusions have been reached concerning programming of an instrumentation - computer interfaced system. These are all concerned with the flexibility and efficiency which should be provided in a central program. Certain capabilities must be provided in the hardware (both computer and interfaced), the monitor, and the programming language in order to enable the control program to provide this flexibility and efficiency. Two items particularly needed in the hardware of the digital computer are random access storage and an interrupt system. The random access storage is needed particularly for data storage and retrieval purposes. In this way data can be maintained by the control program and made available for use by many programs. The interrupt system in addition to contributing to buffered input/output, multi-programming and multi-processing should also allow for automatic interrupts from the interfaced equipment. The interfaced equipment should provide these automatic interrupts and provide the capability of asynchronous operation of all interfaced equipment.

The monitor system should be open ended in the sense of allowing sub-monitor or control programs to be written in a standard programming language such as ALGOL. This could be done by providing in the language, facilities for adequate communication with the monitor and providing in the monitor a means of handling this communication.

The types of communication would include that used in the Data Reduction System to cause its temporary suspension by the Master Control Program. The monitor system in conjunction with the compiler should also allow for a program to call in a source language program to be compiled and executed. This would allow for last minute program modifications, and random access storage would then be rather important for program residence.

It is evident that there are several areas which contribute to the success or failure of instrumentation programming. Each of these previously mentioned areas is important. However, one final factor should be mentioned. This is the area of communication between the system programmer and the engineer or technician. It is in this area where a large part of the responsibility lies in achieving the maximum contribution from each of the other areas to overall system efficiency and flexibility.

NOMENCLATURE

CH	=	Discriminator Channel
DAT	=	Data Availability Table
DRS	=	Data Reduction System
HAT	=	Hardware Availability Table
MCP	=	Master Control Program
OF	=	Discriminator Output Filter
PST	=	Program Sequence Table

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GENERAL FLOW
DRS CONTROL SECTION

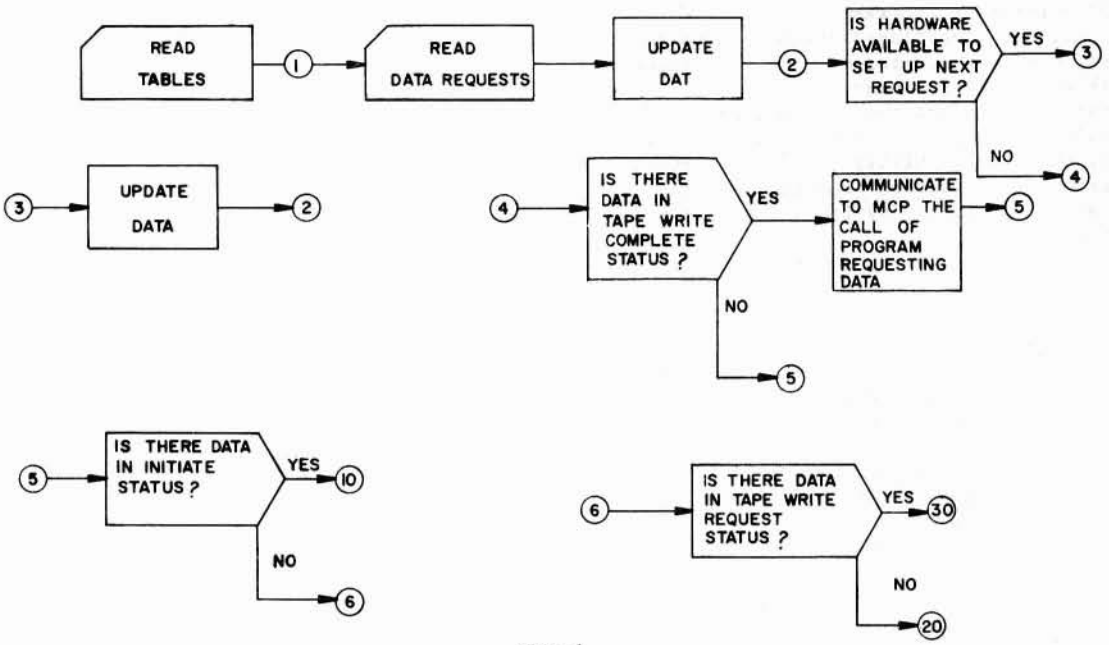

Fig. 1

GENERAL FLOW
DRS-SET UP SECTION

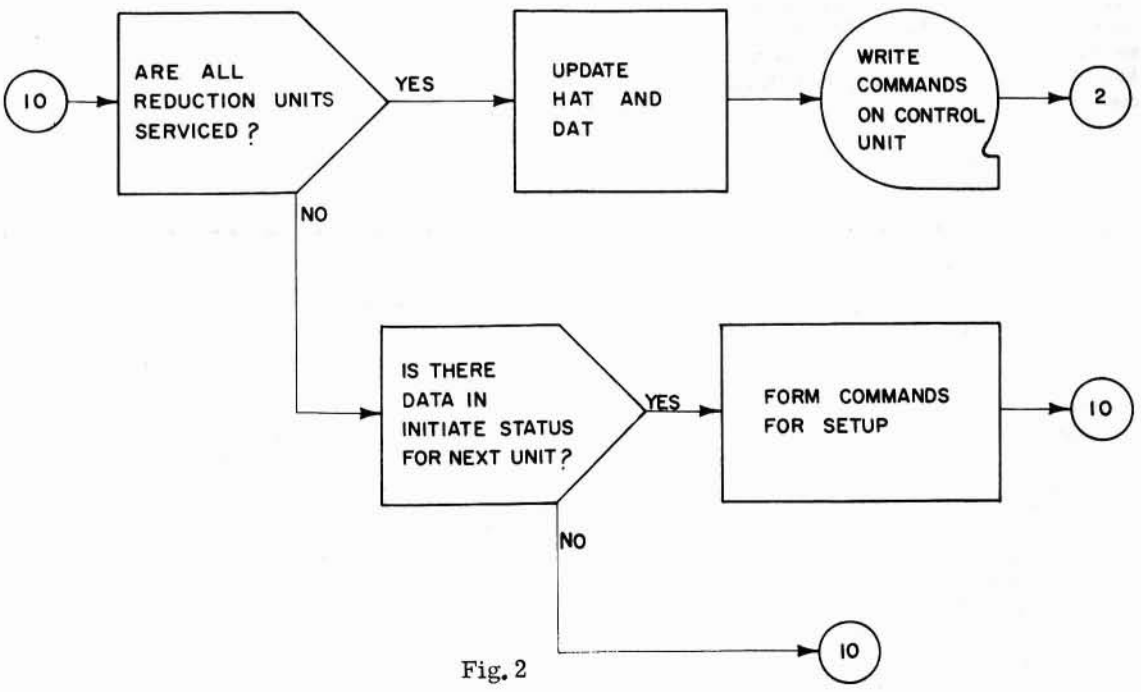

Fig. 2

GENERAL FLOW
DRS-INTERRUPT SECTION

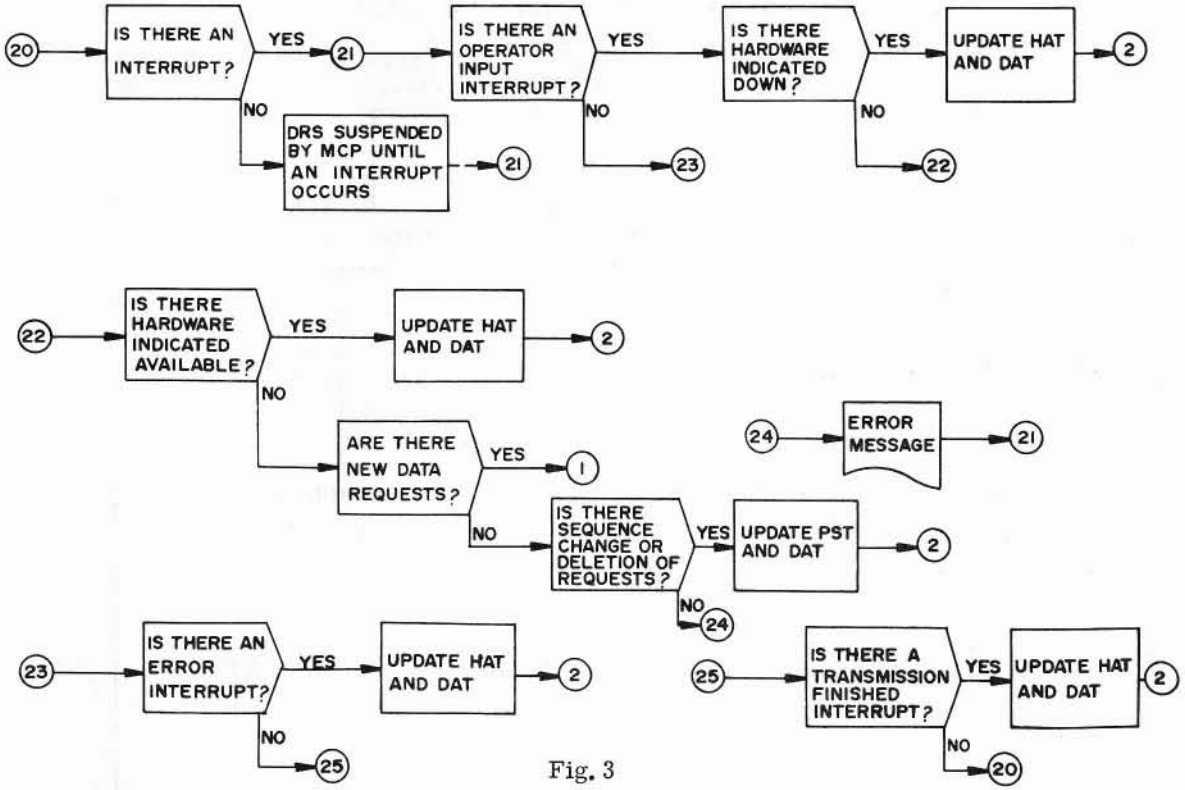

Fig. 3

GENERAL FLOW
DRS-TAPEWRITE SECTION

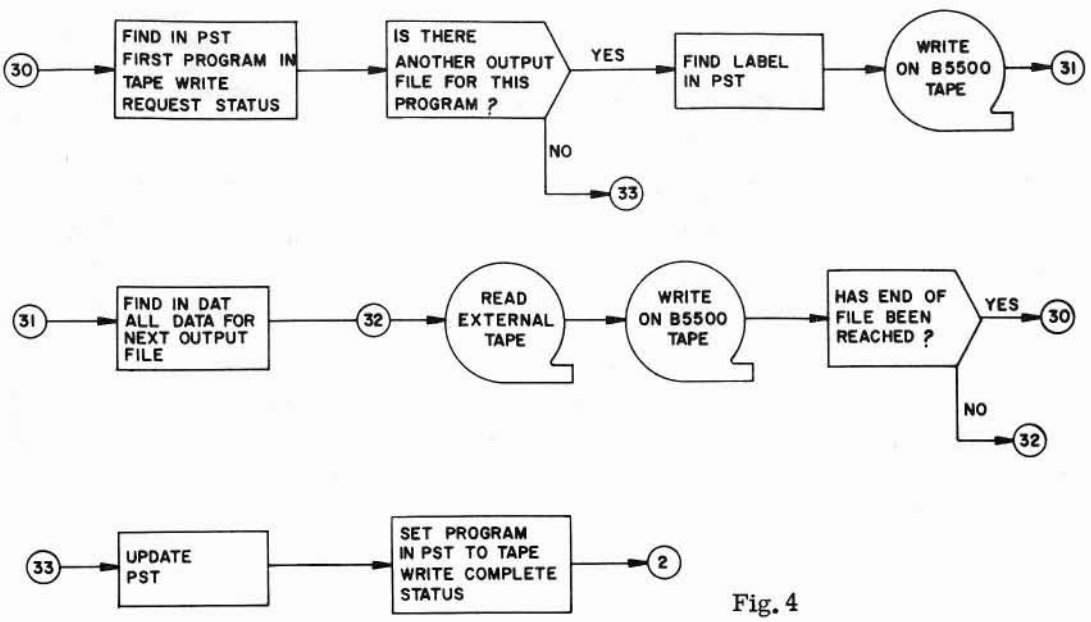

Fig. 4

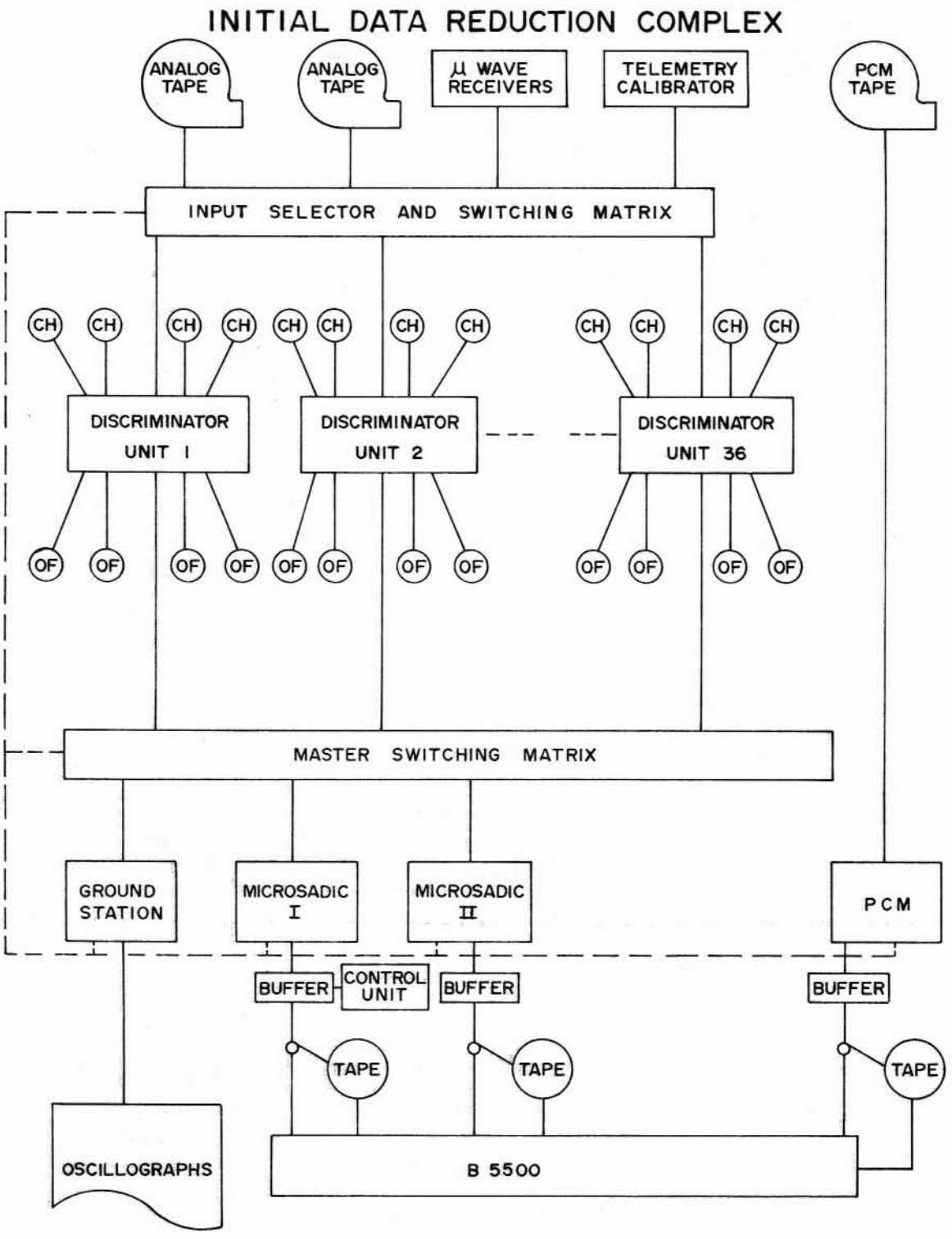
INITIAL DATA REDUCTION COMPLEX
ANALOG TAPE
ANALOG TAPE
μ WAVE RECEIVERS
TELEMETRY CALIBRATOR
PCM TAPE
INPUT SELECTOR AND SWITCHING MATRIX
CH
DISCRIMINATOR UNIT 1
DISCRIMINATOR UNIT 2
DISCRIMINATOR UNIT 36
OF
MASTER SWITCHING MATRIX
GROUND STATION
MICROSADIC I
MICROSADIC II
PCM
BUFFER
CONTROL UNIT
TAPE
OSCILLOGRAPHS
B 5500

Fig. 5