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SERT II CONTROL CENTER

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16. Abstract

A control center with an integrated computer for real-time processing and display of information from the SERT II spacecraft is described. Data received from the spacecraft through the NASA Goddard Space Flight Center world-wide Space Tracking and Data Acquisition Network are converted to engineering units, limit-checked, and displayed for evaluation by SERT II engineers to determine spacecraft status and command requirements. Commands sent to the spacecraft are returned by telemetry to the control center for verification before execution.

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SUMMARY

This report presents a description of a control center with an integrated computer for real-time processing and display of information from the SERT II spacecraft. Data received from the spacecraft through the NASA Goddard Space Flight Center world-wide Space Tracking and Data Acquisition Network (STADAN) are converted to engineering units, limit-checked, and displayed for evaluation by SERT II engineers to determine spacecraft status and command requirements. Commands sent to the spacecraft are returned by telemetry to the control center for verification of correctness before execution.

INTRODUCTION

The primary experiment on the SERT II (space electric rocket test) spacecraft is an ion engine and its power conditioner. The spacecraft attitude is controlled by gravity gradients, assisted by two gyroscopes. These systems require close monitoring to ensure proper operation while in orbit. This requires that a staff of qualified engineers be available to evaluate the data and to determine and schedule the necessary spacecraft commands. The control center was located at NASA Lewis, the development site of the spacecraft and experiments. Data from the spacecraft are acquired at stations of the Space Tracking and Data Acquisition Network (STADAN) system and forwarded in real time by wire and microwave links to the control center for processing and display.

This report presents a description of the SERT II control center and the processing applied to the data received. Background information on the spacecraft telemetry and command systems is given to aid in understanding the data requirements. The control center equipment is described. Details of the data selection and processing procedures are discussed, and methods of data display to aid in decision making are provided.

GENERAL DESCRIPTION

Control Center

Individual telemetered data parameters are in the form of a binary 6-bit-plus-parity word. To facilitate recognition and analysis of any problems that may arise and to aid decision making, preliminary processing is applied to the incoming data by a computer with a memory containing 8192 16-bit words. Selected parameters are checked against predetermined limits, converted to engineering units, and displayed for evaluation. Parameters are flagged if they are out of limits. The 24 parameters which are most indicative of the spacecraft systems status are displayed on a status board for quick review. In addition, all the selected parameters are typed out on three typewriters for further analysis.

The computer memory capacity of the control center was limited to 8192 words. Because of this limitation, it was not possible to order data by system or to make better than straight line approximations to the calibration curves. The number of parameters which could be processed was limited, and special calculations could be done on only one parameter. The magnitude of the constants to be used in the linear approximation was restricted, preventing conversion of several parameters to engineering units. As a result, the minimum requirements were established to be printing the data in the order they were received, labeling and limit-checking parameters, and converting to approximate engineering units where possible.

A digital printer, which prints out raw telemetry data, is used for periodic checks of all data words. Three eight-channel Brush recorders can be used to provide analog traces of 24 parameters. Three data words can be dialed into visual displays in the decommutator for quick checking during command execution.

SERT II Telemetry System

The SERT II telemetry system is a pulse-code-modulated/frequency-modulated/phase-modulated (PCM/FM/PM) multiplex system using three channels. One channel is for real-time data, one for spacecraft tape recorder data playback, and one for command verification. A block diagram of the spacecraft telemetry system is given in figure 1.

Real-time telemetry. - The telemetry multicoder has a 4-minute major frame consisting of 1200 6-bit-plus-parity words. Bit rate is 35 bits per second, non-return-to-zero (NRZ). The major frame is divided into 20 12-second minor frames of 60 words each. Words 59 and 60 of each minor frame are the frame synchronizer. Word 1 is the minor frame identification, from 0 to 19. The remaining words are assigned to four subcommutators and for special measurements. The subcommutators contain 60 data points. Two of the subcommutators each use 3 words per minor frame and cycle once every 4 minutes. The other two subcommutators each use 12 words per minor frame and cycle every minute. The remaining 27 words of the minor frame can be used for faster sampling rates, ranging from 2 to 12 seconds. The telemetry format is shown in figure 2.

Tape recorder data. - The output of the multicoder is, on command, recorded by one of the two tape recorders. The tape recorders can record up to 144 minutes of data. The data are played back at a 16:1 speed. The 144 minutes of recorded data can thus be played back in 9 minutes or less. The data are received by the ground station in reverse order. Therefore, if the ground recording of the tape is played back, reversing the reels without rewinding the tape, the tape recorder data will be in the same format as the real-time data, but at a higher speed.

Time code. - A time code generator word of five decimal characters is read out once every 4 minutes onto 4 data words. The time code will recycle to zero every 277 days, 18 hours, and 36 minutes. This time code can be used as a counter to identify major frames.

SERT II Command System

The SERT II command system is a multitone command system (fig. 3). The spacecraft command system is activated on receipt of an address tone which is unique to SERT II, to prevent it from responding to commands to other spacecraft that use the same type of system. This address tone is followed by three command tones which identify the command. Each command tone can be one of six frequencies, permitting a total of 216 commands. The spacecraft interprets these tones, stores the command as a digital serial word, and transmits a numerical code of the command. The personnel responsible for the spacecraft operation can then verify that the command received by the spacecraft is correct. The address tone is then transmitted again. On receipt of the second address tone, the spacecraft executes the command.

The address and command tones are of 1/2-second duration and are spaced 1/2 second apart. The address tone used to execute the command must be received by the spacecraft within 12.5 seconds of receipt of the command. If the address tone is not received within this time period, the command is automatically cleared and cannot be executed. The address tone of a second command will execute the first command if received within this time period.

CONTROL CENTER EQUIPMENT

A photograph of the control center and a diagram of the equipment are shown in figures 4 and 5.

Communications

Internal. - Communications within the control center are controlled by a central switchboard. Each console and the pen recorder rack have an internal phone. These phones can be tied into the Lewis internal phone network for intralaboratory communications. They can also be tied into the data tape recorder to record official communications. Two outside lines can be connected to these internal phones.

External. - The control center is connected with the STADAN network through the Goddard Space Flight Center by two data quality lines. One line is used for data transmission and one for voice. There is also a voice line, not formally used, that can be used if either of the two main lines is not working. None of these lines go through the switchboard. The lines can be switched in several minutes by changing terminal board connections. This was done to prevent inadvertent connection of the line being used for voice comminications to the control center data input.

Telemetry Equipment

Data flow through the control center equipment is detailed in figure 6.

Discriminator. - The incoming signal is fed into discriminators through a punched card selector type of patchboard which permits selection of inputs from a PCM simulator, analog tape, or data line.

The discriminators are precision instruments for separating subcarrier signals from a multiplex and demodulating the intelligence.

In addition to the primary and backup subcarrier discriminators, there is a third subcarrier discriminator, tunable through the entire telemetry band (400 Hz to 100 kHz), which is used for playback of recorded data. Initial calibration of the discriminators is provided by a five-point frequency calibrator which can be operated automatically or by manual or remote control.

Initial checkout of the system is provided by a sample tape, which generates the SERT II telemetry format and contains command verification.

Signal conditioners. - From the discriminators the data are fed to redundant signal conditioners. The primary signal conditioner is tunable from 10 to 1 000 000 bits per second, while the backup has plug-ins for bit rates of 35 and 560 bits per second. These signal conditioners accept a serial PCM input from the discriminator, condition the PCM input signal, and provide serial PCM data and bit-synchronized timing outputs for the decommutator. The PCM input signal, coded NRZC, is applied to the signal-conditioner input-conditioning circuits. These circuits filter the PCM input signal to remove the noise content, limit the peak-to-peak amplitude, and reconstruct the PCM signal to provide square-sided serial PCM wave train outputs.

Decommutators. - The conditioned signals are sent to redundant decommutators. The decommutators receive and extract data from the PCM telemetry signal and convert the decoded data into a parallel binary output.

Digital synchronization circuits are preprogrammed at an internal patchboard to recognize the frame-synchronous word pattern, 11100110100000, and synchronize the decommutator with the incoming serial pulse code modulated (PCM) data. This pattern is compatible with STADAN. The total time required for the system to lock up is approximately 1 minute.

The decommutator generates frame identification outputs, which include word-numbering outputs, word and frame rate readout commands, and frame synchronization status outputs. The word number, indicating the word position in a frame, is converted into binary-coded decimal form and is supplied as a parallel numbering output. Word-rate and frame-rate readout commands mark the end of a word and the end of a frame of PCM data.

Both decommutators feed binary data into the telemetry controller. The backup decommutator feeds binary data into a data distributor and binary coded decimal data to displays and printers. The backup decommutator is switched into the data processor automatically if major frame synchronization is lost on the primary decommutator and the backup decommutator is still in synchronization.

Tape recorders. - A seven-track magnetic analog data recording system with a voice track is used to record all incoming data. In addition to data recording and command verification, one channel is used to record internal voice communications, one for external voice communications, and one for IRIG-B timing pulses. Recorded data can be played back into the computer for processing when desired.

A nine-channel digital magnetic tape unit is used to make digital tapes for use on other Lewis computers. It can also be used to read programs into the computer and to assemble programs.

Computing Equipment

Telemetry controller. - The telemetry controller is a solid-state selector switch. It accepts data from two decommutators and from a time code translator. It switches this information into the data processor under program control by the computer. Data output is switched through the telemetry controller to three teletypewriters, the time-and-status display, analog plotters, and a data-distributor digital-to-analog (D/A) converter.

Computer. - The computer uses integrated circuitry and contains 8192 words of memory. The words have 16 data bits, a parity bit, and a memory protection bit. The memory cycle time is 0.750 microsecond. Add speed is 1.8 microseconds; multiply and divide speeds are 4.8 and 8.1 microseconds, respectively. There are three index registers. There are eight external priority interrupts. The computer accepts basic FORTRAN. It accepts data from the telemetry controller and data and instructions from a typewriter, magnetic tape, punched card, or punched paper tape.

Display Equipment

Typewriters. - Three teletypewriters are provided for engineering data displays, and one for communication with the data processor.

Time-and-status display board. - The time-and-status display board gives a quick evaluation of the status of the primary mission and backup spacecraft equipment. It consists of 25 illuminated displays for quantities in engineering units, a time-of-day display, and a countdown clock.

Digital printer and display. - The redundant decommutator has a printer that prints out each data word as it comes in. The printout is in decimal form, but not converted to engineering units. The first two digits of the printout are the frame number, from 1 to 20. The next two are the word number, from 1 to 58. There are four spaces followed by the data value, from 0 to 61 counts, then the parity and synchronization status (0 if all right, 1 if out (fig. 7)). This decommutator has a visual binary-analog light display and four two-digit-with-parity decimal displays that will read out any word selected.

Pen recorders. - Two strip-chart plotters, with incremental chart drive, display selected measurements as a function of time. Three pen recorders, each with eight-channel capability, are available for data display. These are fed through D/A converters, which accept the six-bit parallel binary multiplexed data words. Inputs to the D/A converters can be from the telemetry controller or from the redundant decommutator through a data distributor, which provides channel transfer pulses by patchboard selection.

Command System

Commands can be given to the STADAN station before the station pass or during the pass. If the command is given before the pass, the punched paper tape of the command can be played back to the control center by the STADAN station for review. If it is correct, the same tape is used in the command encoder.

A command encoder receives the command from the punched paper tape, times it, and relays it to the transmitter for transmission to the spacecraft. Commands can be set into the command encoder manually, but for quick reaction and to avoid errors, it is preferred to use a library of tapes. On issuance of a command by the STADAN station and retransmission by the spacecraft, the command, as interpreted by the spacecraft decoder, is processed through the command encoder and displayed on each console. On verification of the correct command, the STADAN station is verbally instructed to execute the command by personnel on duty at the control center.

DATA PROCESSING AND DISPLAY

Processing

Computer input. - The data are serially input to the computer and stored in two 58-word buffers. After acquisition of the spacecraft telemetry, the computer begins accepting data from the first decommutator which achieves major frame lockup. The data are loaded into one of the two 58-word buffers. When it is full, the data are loaded into the second buffer. The first word into a buffer should be the minor frame identification. To verify that it is, the first word in the first buffer is checked against the first word in the second buffer to determine whether they are in numerical sequence. At initial lockup, the data from the full buffer are transmitted to the calculation routine for processing and display. The data are flagged on both the teletypewriter and the time status displays to indicate that it is questionable until the successive minor frame identification (ID) words are in numerical sequence.

After initial lockup and two successive ID words in numerical sequence have been received, if an out-of-sequence ID word is received, 1 is added to the previous in-sequence ID word and used for processing. This procedure is continued until the decommutator receives a zero ID word. If the ID word following the zero ID word is 1, a new sequence is started based on this. During this process, a flag is shown on the displays to indicate questionable data until the new sequence based on the zero ID word is started. If major frame synchronization is lost on the decommutator being used, the computer switches to the other decommutator.

One display of the time status board is used to show the status of the input to the computer. It is identified by the initials FR ID. This is followed by the number of the minor frame ID word which has just been transmitted to the computer calculation routine. The minor frame ID number is incremented by 1 to read from 1 to 20, as in the published instrumentation lists. If lockup has not yet been achieved, the number 99 appears in this place to indicate that no data are coming in. At the other side of the display is the number 1 or 2 to show the decommutator which is feeding data to the computer, followed by the initials SYS. If the minor frame ID words are in numerical sequence, these ID numbers are green. If not in sequence, the numbers are red.

Calculations. - When an input buffer is full and its ID word has been checked, the processing routine accepts data from it for calculation. The data are sorted into 1-minute data, 4-minute data, and special data according to their position in the minor frame. One-minute data are processed through subroutines which repeat every five minor frames. Four-minute data are processed through subroutines which repeat every 20 minor frames. The program is capable of processing 100 1-minute words and 60 4-minute words.

The first step in calculation is to check the parity of the data word. The number of counts in the data word is then checked against the limits assigned. The standard calculation is to apply the equation $y = m(x + b)$ to the data. In the equation, x is the telemetry counts, y is the value in engineering units, and m and b must be $\leqq \pm 127$. Decimal point location is omitted, being designated as part of the typewriter format. There is remaining capability for several special routines to be applied to supercommutated parameters.

Outputs to displays. - After calculation, the computed values of selected parameters are sent directly to the time status board. Those to be displayed on the typewriters are sent to one of three separate buffers, one for each typewriter. Because of the slow output speed of the typewriters, they are stored in these buffers until called for. These buffers contain four alphameric characters, to identify each parameter, and a decimal point. The decimal point will always appear in a fixed location on the typewriter for a given parameter. Each typewriter can display up to 40 parameters per minute. No more than 15 of these can occur in any 12-second interval. Because of memory limitations on the buffer capacity, a parameter can be displayed on only one of the three typewriters.

Engineering inputs. - Tables of alphameric identifiers, telemetry location, calibration constants, and other processing information are generated for those parameters that are to be processed by the standard routine. These tables are initially put on computer cards, one card per parameter. These cards are then processed on the Lewis IBM 7094 computer and put into a binary format. The resulting binary table deck contains 18 cards. For facility in loading the program into the control center computer, the information on the binary cards and the calculation routine are combined onto one punched paper tape. When ready for operation, the tables and routine can be input to the computer from this paper tape in about 30 seconds. To make new tables from the original source cards takes from 2 hours to a day, depending on the computer work load. Thus, changes in the tables can be incorporated into the program readily. When a request is received to add or delete a parameter, or change the limits or calibration constants, a card is made up and inserted in the decimal card deck. The cards in this deck are separated into two parts, the first consisting of parameters sampled every minute and the second of parameters sampled every 4 minutes. In each part, the cards must be in order of occurrence in the telemetry format, that is, sorted by ID and word number. The source deck format is given in the appendix.

Data Display

Typewriters. - A typical typewriter printout is shown in figure 8. Each minute of data, beginning with minor frame 0, and every five minor frames thereafter, is headed by the time in days from January 1, hours, minutes, and seconds. Time is local time. The four-character alphameric identifier for each parameter is followed by a space in which an asterisk appears if the telemetry word fails parity check. The next space is reserved for an arrow pointing up or down if the data are out of limits. Direction of the arrow indicates whether the value is high or low. The polarity and calculated value of the parameter follows.

For SERT II, approximately 104 parameters are typed out. They are arranged on the typewriters by systems. Typewriter 1 contains telemetry and attitude control parameters. Typewriter 2 shows thruster and related experiment parameters. Typewriter 3 displays power systems, general housekeeping, and other experiment parameters.

Time status board. - The time/status board is illustrated in figure 9. It has provisions for display of 25 parameters. Two permanent slides are used to show the parameter. These are followed by two displays that are each capable of displaying numbers from zero through 9, controlled by the computer. The next two rear projected displays are not computer controlled, but can be set to read zero, or can be blank.

The next to the last rear projected display can be set by the computer to one of four readings. For parameters which do not change polarity, this slide is solid green when the telemetry data are good, is solid red when the data fail parity check, and shows a red HI or LO if the data are out of limits. Since only four readings are possible, for parameters which change polarity, this slide shows a green + or - when the data are good and a red + or - when the data fail the parity check or when the parameter falls outside of its limits.

The last slide is a permanent slide which is used to show the engineering units of the parameter.

Auxiliary displays. - The strip-chart recorders, incremental plotters, and digital printer are driven directly from the telemetry gear through the data distributer and digital-to-analog converters, without using the computer. The strip-chart recorders (fig. 10) and incremental plotters (fig. 11) are used for graphic display of selected parameters. The digital printer is used for recording selected parameters or every parameter in decimal counts as received by the telemetry (not converted to engineering units). The printer is used to obtain a permanent record of every parameter on telemetry once per STADAN station pass. This equipment also serves as a backup, in case of a computer failure.

Further Processing

General information tapes. - The telemetry data gathered during the course of the SERT II mission are considerable, and much of it must be correlated with the spacecraft ground trace. Since this necessitates more data reduction than can be accomplished on the control center computer and still support the STADAN station passes, the telemetry data must be put in a format acceptable to other computers. The analog tape of the real-time telemetry data and spacecraft tape recorder data is played back through the computer between passes using a tape formatting program. The data are put into format and recorded on the digital tape recorder for use on other computers. A 144-minute tape recorder playback takes 9 feet of digital tape. Each reel of digital tape thus contains about 125 spacecraft tape recorder playbacks. Setup time for making these general information (GIF) tapes is about 5 minutes, and a tape recorder playback can be digitized in 12 to 15 minutes. Separate tapes are made of the real-time and spacecraft tape recorder data for facility in later processing. The data are put on the tapes in chronological sequence.

Spacecraft tape recorder data. - The spacecraft tape recorders record the telemetry data in the same format and at the same rate as the real-time telemetry data are transmitted. Since they record for a maximum of 144 minutes, they are played back at 16 times their recording speed in order to be assured of completing playback while the spacecraft is over a STADAN station. The maximum playback time is thus 9 minutes, and the average STADAN station pass 15 to 17 minutes, which allows ample time for command transmission. At a 16:1 speed, the bit rate is 560 bits per second. The data are transmitted on IRIG channel 10 (5400 Hz).

Routine tape recorder playbacks are recorded at the STADAN station and later mailed to Lewis. When the recorded data are desired immediately, the tape recorder data can be played back from the station recording over the communications link. Because the lines in this link are only adequate for transmissions between 300 and 3000 hertz, the data must be played at 8:1, or one-half of the station recording speed. All spacecraft tape recorder data are put onto general information (GIF) tapes for use on other computers.

If the spacecraft tape recorder data are being played back from the STADAN station, they are being received at too high a rate to be displayed on the typewriters. Therefore, the program for generating GIF tapes is put in the computer and a GIF tape is made as the data are received. The Brush recorders can be used to display parameters as the data are received, and, if the parameters desired are properly spaced in the telemetry format, some can be printed out by the digital printer. The GIF tape program does not include provisions for display on the time status board, although the board is capable of following at this speed.

Setup and playback time of the spacecraft tape recorder data directly from the STADAN station takes 15 to 20 minutes. As soon as this is completed, the GIF tape can be put on another computer, located in the same general area as the control center. The data are processed in the same way as real-time data and printed out on a 180-line-per-minute printer. The data are the same as on the control center typewriters, but all three typewriter outputs are arranged in columns on one page. Setup and printout time is approximately 20 to 30 minutes. Thus, a complete spacecraft tape recorder record can be reviewed within an hour of playback if required. The program also decodes the spacecraft time code generator time into days, hours, and minutes since the last reset of the time code generator. The decoded time can then be converted to local time.

Time correlation. - Spacecraft tape recorder data must be time correlated to be useful. To accomplish this correlation, the time code generator telemetry words are used as major frame identifiers. The multicoder timing rate is by means of crystal controlled oscillator accurate to ±0.05 percent. Thus, if the time of sampling any major frame is known, any other frame can be related to it by use of the time code identifier. Incoming data to the control center are stored for 12 seconds for minor frame ID check and then sent to the calculating routine. The time of receipt of the real-time data by the calculating routine is typed out every minute or every 5 minor frames. The time delay for transmission to the control center is negligible for the accuracy desired (±1 sec). Therefore, subtracting 12 seconds from the time typed out gives the sampling time of the first word in the minor frame.

For convenience, during printout of the data on other computers, the time code generator word is converted to its equivalent in days, hours, and minutes. By adding the proper amount to this, the time can be converted to Greenwich mean time. Furthermore, since the time of receipt of the first word of the major frame for real-time data is known in seconds, the timing can be obtained to this accuracy for all the data. Checks to data indicate that the variance between real-time and multicoder time is 4 seconds per day. This is a constant bias which can be removed.

CONCLUDING REMARKS

The SERT II control center has so far met all mission requirements in a satisfactory manner. No problems have arisen because of center operations. The displays are sufficient to permit operation of the center by the technicians, with a SERT II engineer on call. Several spacecraft operational problems have occurred during off-duty hours. These have been immediately recognized by the technicians and the engineer on call has been notified. On the basis of the displays, they have been able to provide him with sufficient information to identify the problem and contact the cognizant system engineers in ample time to take the desired corrective action.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, November 24, 1970,
704-13.

APPENDIX - SOURCE DECK INFORMATION

The 6130 source deck contains the following information, right-justified except for the alphameric characters, which are left-justified:

Card column	Description
1-4	Up to four alphameric characters by which the parameter being processed can be identified. These characters are typed out on the typewriters to identify parameters.
7, 8	The parameter telemetry minor frame identification number (1 to 20).
11, 22	The parameter word location number in the telemetry minor frame (1 to 58).
16	If the parameter calibration curve has a negative slope, the upper and lower limits must be reversed by the computer. In this case, a 1 should appear in this column; otherwise, a zero will appear here.
19, 20	The upper flagging limit, in counts, for the parameter being processed. This number must be greater than the lower flagging limit. If the telemetry counts exceed this number, the parameter will be flagged as high if column 16 is zero, low if column 16 is 1.
23, 24	The lower flagging limit, in counts, for the parameter being processed. Must be less than the number in column 20.
25-28	The constant, m, to be used in the equation $y = m(x + b)$ to convert the parameter being processed into engineering units (m must be less than ± 128).
29-32	The constant b to be used in the equation $y = m(x + b)$(b must be less than ± 128).
36	If the parameter is to appear on the time/status board, a 1 must appear in column 36.
43, 44	If the parameter is to appear on the time status board, the number of its location on the board is given here (1 to 25).
48	If the parameter is to be typed out on a typewriter, the number of the typewriter it is to be typed on is given here (1 to 3). Only one typewriter at a time can present a given parameter.

52 The decimal point location on the typewriter, for the parameter: 0 = X.XXX, 1 = XX.XX, 2 = XXX.X, and 3 = XXXX.. No other choice is available.

56 If the typewriter or time status board is to display + and - for the parameter being processed, a 1 must be in this column.

60 The parameter is calculated as a four-digit number. Only two digits on the time status board can display a number other than zero. If the left two digits of the calculated number are to be displayed, this column is zero. If the middle two are to be displayed, this column is 1. If the x or y intercept of the linear fit of the parameter is not zero, but the parameter is never negative, a 2 in this column will display zero when the calculation gives a negative value.

Parameters requiring special processing necessitate a program change, which must be done by the programmer.

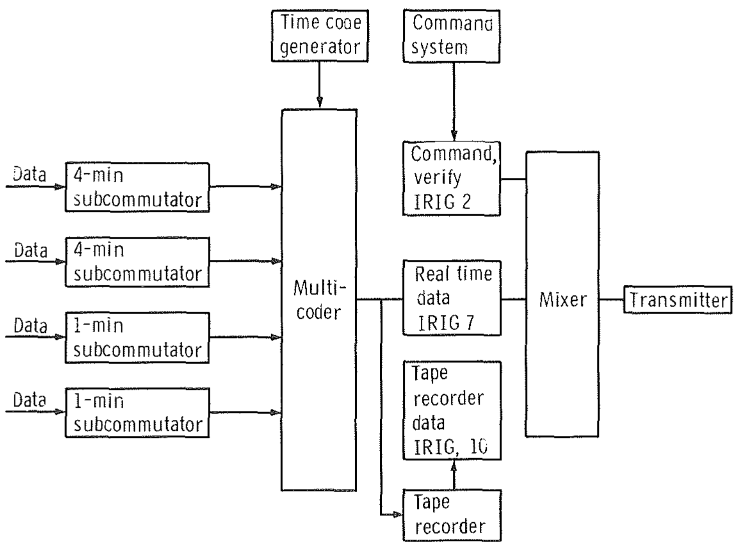

Figure 1. - SERT II telemetry system.

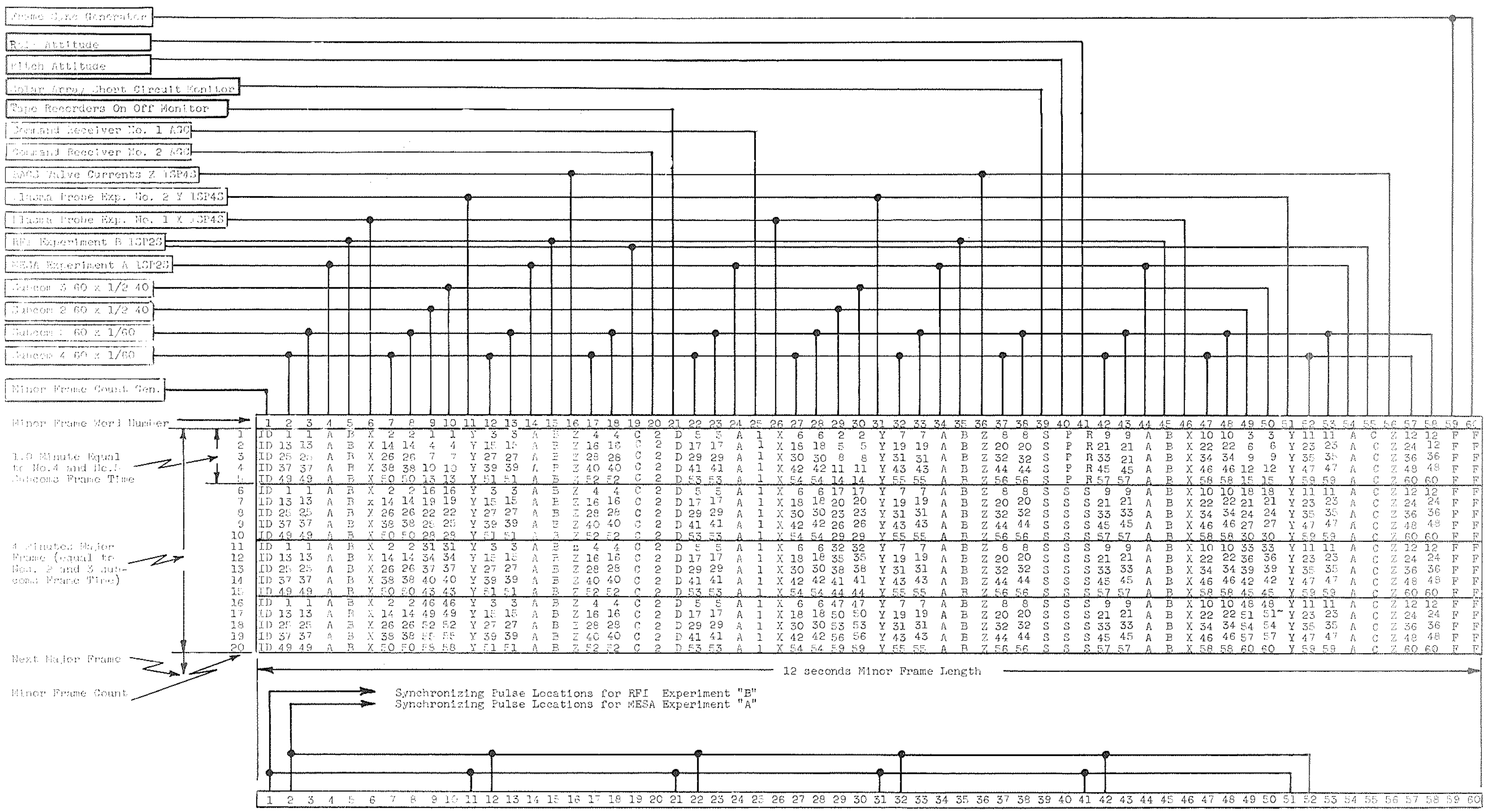

Figure 2. - SERT II telemetry frame format.

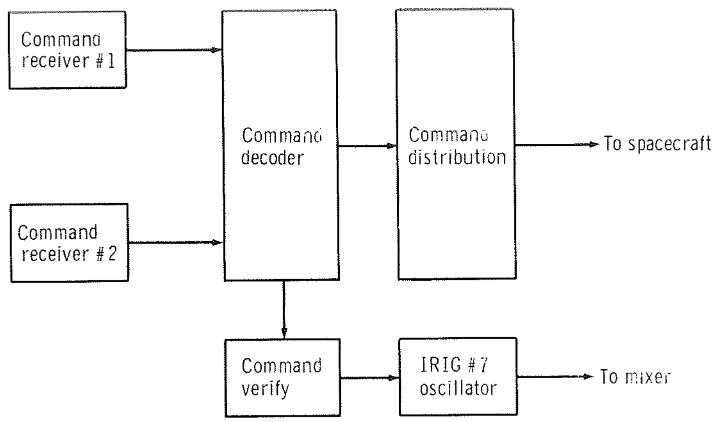

Figure 3. - SERT II command system.

C-69-2753

Figure 4. - SERT II control center.

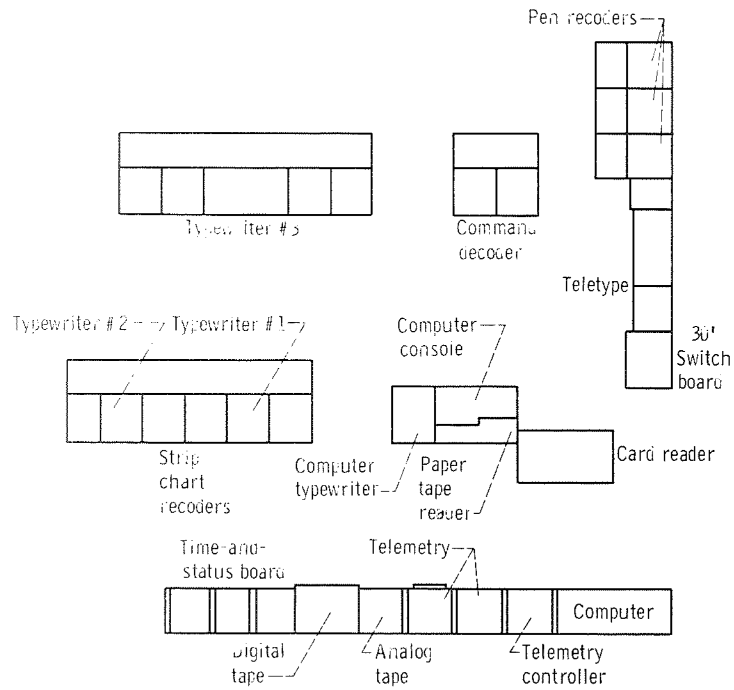

Figure 5. - SERT II control center.

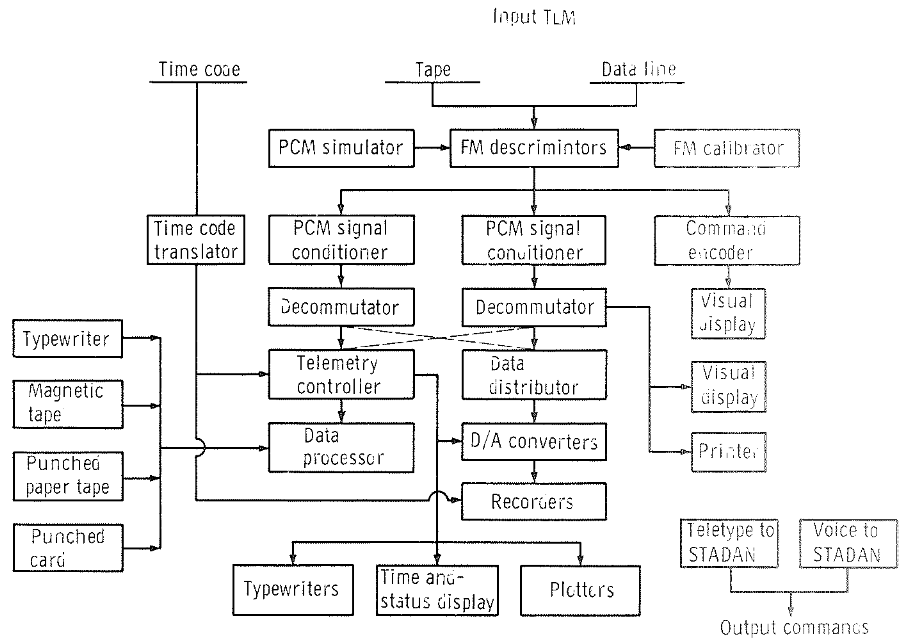

Figure 6. - SERT II control center data flow.

```
0405                 3900  RFI Output
0404                 3100  MESA Digital Output
0403                 2200  Pitch Attitude
0402                 2300  Pitch Attitude
0401                 0300  ID
0358                 1500  Thrustor Vapor. Voltage Sys 1
0357                 3000  Thrustor Vapor. Current Sys 1
0356                 3000  BACS Gas Valve Currents

  Word number          Synchronization decom
 Minor frame number    Parity
                       Data
```

Figure 7. - Data printer output.

```
DAY HR  MN
283 16 45 05
ST8F ↓  66.0
ST9F    89.1
ST10    75.9
BCHO   26.24
BATF    82.5
BCHH   33.92
BATV   33.28
BATA    .082
28A     3.04
28V    36.00
BUSV   26.68
ST11    79.2
SUNF    66.7
56A    16.40
TY2F    89.7
CAL2   61.00
CAL3   61.00
56A    16.40
56V  ↑  61.2

DAY HR  MN
283 16 46 05
BCHO   26.24
BATF    82.5
BCHH   33.92
BATV   33.28
BATA    .082
28A     2.72
28V    36.90
BUSV   26.68
RX1F   165.6
RX2F   161.0
SUNF    66.7
56A    16.40
RXPF   115.2
56A    16.40
56V *↓    .0
```

Figure 8. - Typical typewriter output.

BUS	VOLT	XX HI LO	V	Day: hr: min: sec					I2	AMPS	X, X	HI LO	A
BATT	VOLT	XX HI LO	V	Hr: min: sec					I5	MA	.XXX	HI LO	MA
BATT	TEMP	XX ±	°F	FR	ID	XX	1	SYS	I6	MA	X.X	HI LO	MA
56A	AMPS	XX HI LO	A	CMG	3	XX	±	DEG	V5	VOLT	XX00	HI LO	V
56V	VOLT	XX HI LO	V	CMG	4	XX	±	DEG	V6	NEG VOLT	XX00	HI LO	-V
28A	AMPS	XX HI LO	A	MESA	DGTL	X.X	HI LO	μG	I4	AMPS	X.X	HI LO	A
28A	VOLT	XX HI LO	V	PCF2	TEMP	XX0	HI LO	°F	V4	VOLT	XX	HI LO	V
COMD	SYS	XX HI LO	V	ARC	CNTR	XX		ARCS	V8	VOLT	XX	HI LO	V
CAL4	5V	XX HI LO	CNTS	CAL5	5V	XX	HI LO	CNTS	I9	MA	.XX	HI LO	MA

Figure 9. - Time-and-status board display.

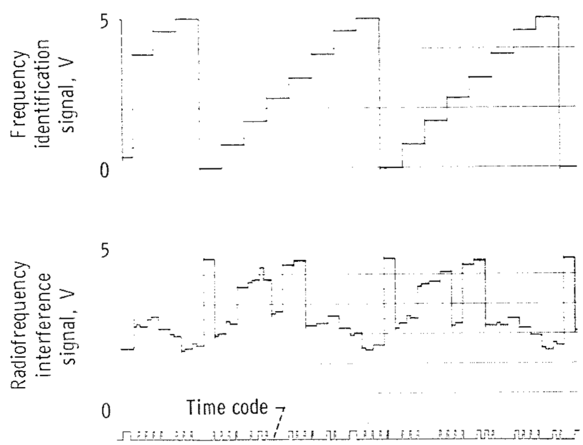

Figure 10. - Typical Brush recorder output.

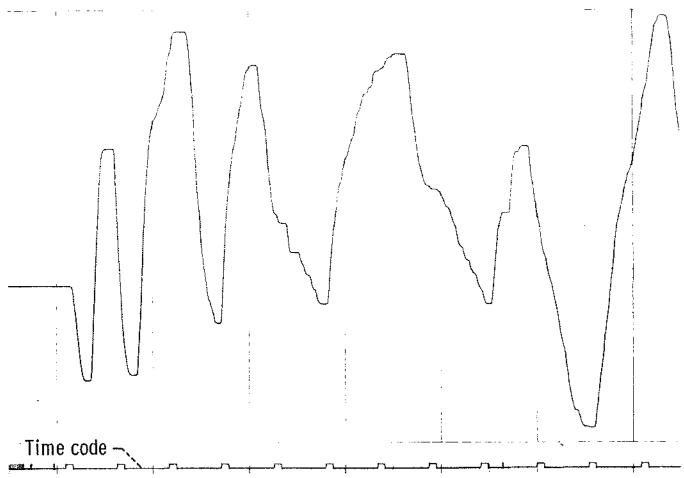

Figure 11. - Typical strip-chart record.

NASA-Langley, 1971 —— 11 E-5966

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