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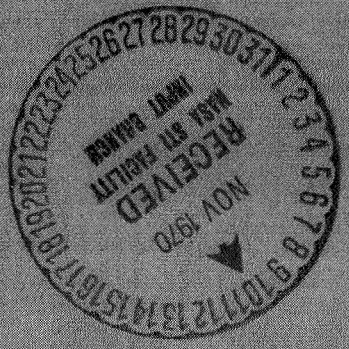

COMPUTER PROGRAMMING SUPPORT OF SERT II CONTROL CENTER

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Computer support of the SERT II (Space Electric Rocket Test) control center provides visual display of spacecraft data. The real-time data are limit checked and converted to engineering units so they can be easily read by project engineers.

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SUMMARY

Computer support of the SERT II (Space Electric Rocket Test) control center provides visual display of spacecraft data. The real-time data are limit checked and converted to engineering units so they can be easily read by project engineers.

Incoming data are digitized and recorded so that the project engineer can perform detailed analyses at his convenience. The digitized data are made readily accessible to other computers in a standard magnetic tape format which is in general use at Lewis.

INTRODUCTION

Lewis Research Center personnel designed and launched the SERT II spacecraft. A computer center was installed at Lewis to assist in monitoring data from the experiments on the spacecraft. The computer center is operated in either of two modes: The first mode operates in real time and processes and displays the data in engineering units on a digital display board or on any one of three teletypewriters as the spacecraft passes over a ground station. Experimenters use these outputs of spacecraft data to make decisions in controlling the spacecraft. The second mode reads data from analog magnetic tapes that were recorded at a ground station or the control center and then writes digital magnetic tapes for later processing on another computer.

The computer used in the SERT II control center is an Electro-Mechanical Research EMR 6130 with 8192, 16-bit words of core memory. Peripheral equipment includes three 10-character-per-second teletypes for output only, a 10-character-per-second console teletype (for input and output), a 200-card-per-minute card reader, a 300-character-per-second high-speed paper tape reader, a 63.3-character-per-second paper tape punch, and one nine-track digital magnetic tape deck.

The computer is also connected to an EMR 2761 data distributor. The data distributor can be connected to various devices by the operators. Input to the computer from the EMR 2761 uses two pulse code modulation (PCM) data channels which accept telemetry from the spacecraft or from an analog tape unit. A time code translator is also available for input to the data distributor. Output from the computer may be sent, by means of the data distributor, to three teletypewriters, two plotters, and a display board with 32 digital displays.

The computer system was purchased with general purpose software support supplied by the manufacturer. The EMR Computer Division supplied two monitor systems, a FORTRAN compiler, an assembler, a loader, and basic library subroutines. The EMR Telemetry Division wrote input and output subroutines for the 2761 data distributor and for the three teletypes connected to the 2761.

Lewis personnel wrote programs to support the two functions of the EMR 6130 computer. The first program, called TEL, accepts telemetry input data, selects desired data for conversion to engineering units, and outputs the value to a teletype or a digital display. SERT II project engineers are able to observe these data values and monitor conditions as the data are acquired from the spacecraft when the TEL program is operating. The second program, called MAGGIE accepts input data from an analog tape and records all the digitized data on magnetic tape. The digital magnetic tapes are kept for future detailed processing on a large-scale computer.

Both MAGGIE and TEL run under control of a monitor system supplied by EMR and make use of subroutines supplied by EMR. This monitor provides necessary bookkeeping of program status and handles external priority interrupts. Because of the limited core size of the computer, MAGGIE and TEL must be separate functions.

Lewis personnel wrote an assembler which runs on the IBM 7094/704X Direct Couple Systems. This assembler was used to simplify and speed up the tasks of writing and debugging programs for the EMR 6130. A table generator was also written to accept a simple punched card format on the Direct Couple Systems and produce a parameter table to be read by the TEL program. The input to the parameter table is easily changed by SERT II personnel and controls the choice of data to be output by the TEL program.

TELEMETRY INPUT

Telemetry data are sent to the Lewis control center from tracking stations in the Satellite Tracking and Data Analysis Network (STADAN). Data transmitted to Lewis are also recorded on analog tapes at the STADAN tracking station. The spacecraft contains two onboard tape recorders. When the spacecraft passes over a station, a command is sent to begin recording data on one tape recorder. A command is then sent to read the data that have been recorded on the other onboard tape recorder and write them on analog tape at the tracking station. The tracking stations send SERT II analog tapes to Lewis so that they may be digitized and analyzed.

The computer can receive telemetry data on two PCM channels through the 2761 data distributor. Operating personnel configure the system so the PCM channels receive data either from the spacecraft or from an analog tape.

The actual data rate from the spacecraft is five words per second. The data are arranged in blocks so that the first word of each block is a sequence number, which advances consecutively from 0 to 19. Each block contains 60 words, but the last two words are synchronization and status signals which are not transmitted to the computer memory. The computer receives 58 data values for each block. A complete pattern of data sampling repeats only once every 20 blocks or 4 minutes. A large subset of

this pattern repeats once every five blocks or 1 minute.

The computer program only uses the data from one PCM channel.

Both PCM channels are expected to input data continuously and simultaneously. If the input status of a channel is not valid, that channel is turned off and restarted so that it may be resynchronized. If the channel being used by the computer program loses its valid status, the program will use the other channel if its status is valid. Both channels are kept running so that any data loss is minimized.

TEL - Program to Display Telemetry Input Data

The TEL program accepts input from the two PCM channels, converts specified data words to engineering units, and types out or displays the resulting values.

The TEL program is normally loaded into memory with parameter tables available. This is done by reading the parameter tables on an initial load and dumping the computer memory onto paper tape for subsequent reloading and execution.

The parameter tables are supplied by SERT II personnel. Parameters include a four-character name, block sequence identification, word number, high and low limits, two coefficients, display number if any, teletype number if any, and any variations on mode of output. These parameters are first keypunched on cards in a readable format. These cards are then processed on the IBM 7094/704X Direct Couple System to produce a compact table on binary cards. These cards are later read into the TEL program. The tables have been organized with the assumption that one block of data contains 58 words. Each incoming data block is identified by the first word, which is a block sequence number between 0 and 19. Five blocks of data span 1 minute, and most data words repeat in a 1-minute pattern. Those words which are only sampled once every 4 minutes always occur in word number 9, 10, 29, 30, 49, or 50. Therefore, one table is constructed with one bit position for each word in five blocks of data. A second table is constructed with one bit for each of the 4-minute data words in each of 20 entries for the 20 blocks necessary for 4 minutes. These two tables contain a 1 bit for each data word which is to be output, and a 0 bit for the words which will be ignored.

A third table of parameters is constructed with five computer words for each data word which is to be output:

(1) Words 1 and 2 - A four-character identification of the data

(2) Word 3 - A high and low limit for the area in which the data is to be considered good

(3) Word 4 - Two constants m and b for the calculation $y = m(x + b)$, where x is the data value input and y is the value which will be output

To conserve table space the two limits are packed into word 3 and the m and b constants are packed into word 4.

(4) Word 5 - Indication of each device to be used for output and the desired formats (This arrangement allows a data value to be output on a display and/or a teletype.)

When parameters indicate output to the data display, they also indicate the display number, which two of three possible digits to display, and whether that display indicates

polarity or HI, LO. When a parameter indicates output to the teletype, it also indicates which one of the three teletypes is to receive the data, and the position of the decimal point. The parameter may also specify that a zero should be output in lieu of a negative value.

On initial entry into TEL, the time code translator is started. This causes the computer to receive an interrupt every second. When the interrupt is received, the time code translator is interrogated and the current day of year, hour, minute, and second will be entered for display on the status display board. When the time is read, the status of each PCM channel is also read.

Normal entry into TEL starts the output of a 32-word buffer to the display units. Each word contains the number of the display, two decimal digits, and control for a four-way indicator. The four-way indicators may offer a choice of red light for bad data, green light for good data, characters HI or LO for out-of-range data values. Several displays have been physically modified so that the four-way indicator offers the choice of a red +, green +, green -, or red -, where red is used for out-of-range data and the + and - signs show the polarity.

The telemetry input portion of the TEL program checks the status of the two PCM input channels and starts the input from the data channel to computer memory as soon as this status is good. Channel 2 is initially chosen as the prime data channel. When the status on a data channel is bad, that channel is sent a stop command and the other channel is restarted. If the status of both channels is bad, a block sequence of 99 is displayed until they have been restarted.

While a channel is running, it will input a 58-word data block to memory and then issue an interrupt. The first word of the data block is a block sequence counter and is sent to the display board. If the block sequence counters are not sequential, the block of data will be flagged and the expected counter assumed. Each block sequence counter is compared to the previous block sequence counter as it was actually read in.

After TEL has initialized starting conditions and started the PCM input, time code translator, and data display output, the program waits until a block of data has been input. When the identification of the block indicates that it is block 0, 5, 10, or 15, the current time is output to all teletypes. The time will appear on the teletypes every minute and will be the time the block of data finished entering the computer (which is 12 seconds after the block began entering the computer). The tables are then checked to see if any 4-minute data is to be processed. If so, the desired data words are processed and output according to the five-word table entry. Next, the table for 1-minute data words is scanned and each desired word is processed according to the proper five-word table entry. Each data word to be displayed is parity checked and limit checked, then converted to engineering units with its particular $m(x + b)$ equation. This calculated value and its indicators and flag are sent to the appropriate subroutines to format them for output.

A value to be output to a teletype is converted to four EBCDIC numeric characters, plus sign, decimal point, and error indicators. An $\uparrow$ indicates the value is too high, a $\downarrow$ indicates the value is too low. An asterisk may denote incorrect parity, incorrect block sequencing, or more than four digits.

Since the speed of the teletypes is a limiting factor in execution of this program, it is necessary to buffer the output for the teletypes. There is a buffer of 20 lines for each teletype.

When a value is to be output to the display, two of four possible numeric digits are chosen and converted to a four-bit BCD code. The proper value for the four-way indicator is chosen. HI or red + indicates the value is too high, LO or red - indicates the value is too low. A red light indicates parity error or block sequencing error. If the value chosen to be displayed is greater than two digits, the value 99 will be displayed.

The computer operator has several control functions at his disposal. He may exercise these functions by using a computer sense switch. The TEL program will stop all other executions except interrupt controlled functions and then accept a request from the operator through the console teletype. For example, the operator may request the computer to load a new set of parameters from the card reader, or he may wish to change control of the teletype output (i. e., the output to any teletype may be stopped or restarted or transferred to any other teletype).

MAGGIE - Program to Write Digital Magnetic Tape

Data which are to be retained at Lewis are read from an analog telemetry tape, digitized, and recorded on a nine-track digital magnetic tape. This digital tape is written in a Generalized Input Format (GIF). The GIF format is already in use at Lewis and programs are available to help programmers process GIF tapes on the IBM 7094/704X Direct Couple Computer.

MAGGIE allows the operator a choice of three different options. He may start recording at the beginning of a reel of tape, add on to an existing reel or request a GIF tape dump. This last request will write on the console teletype the most important contents of every control record read from the beginning of the tape to a record which indicates the end of the tape.

A block of data which constitutes a logical record contains 58 data words and an appropriate time designation. These 58 data words are a minor frame of data and are accumulated every 12 seconds. The first data word is the minor frame identification. Minor frames are numbered consecutively from 0 to 19 so that a complete pattern of data occurs every 4 minutes. Several logical records may be written on the tape as a single physical record so long as the physical record length does not exceed 1000 16-bit words. Continuous blocks of data are grouped together in readings and labeled with a four-digit reading number. A reading will generally cover the time period of one pass over a ground station or the data read during one pass from the onboard tape recorder. More than 100 readings may be recorded on a single 1200-foot reel of tape.

Each reading will begin with an identification control record. This control will specify SERT II, reading number, and recording parameters such as word length, tape source, and initial time. The tape source will be REAL for real time or TAPE for tape dump and a four-letter designation of the ground station which recorded it. (This source designation must be made by the computer operator.) The initial time for a real-time reading will be 12 seconds (one block) after the first word of the first block of data was

acquired. The initial time for a tape dump reading will be 12 seconds before the last block was acquired by the ground station from the onboard tape recorder.

Each data block will have a time designation. For a real-time reading this will be a Zulu representation of the time being read from the time code translator at the end of acquisition of a block of data. This time will be 12 seconds later than the time the first word of the block was acquired. For a tape dump reading the appropriate Zulu time must be calculated from data words. Every 4 minutes these data words are incremented such that the time for data block 0 is represented and each successive data block is 12 seconds later. A continual count of data blocks is kept and a check made to ensure that 20 blocks of data are acquired between successive data block 0's. If there have not been 20 blocks, a GAP control record is entered.

Data are read from the two PCM input channels by the same subroutine which controls PCM input for the TEL program.

Data blocks will be continually acquired and placed in a 1000-word buffer for output to the tape. Whenever the buffer is full, the data will be written on the tape. Every data word acquired is buffered for tape output but no calculations are performed.

A reading is usually ended by the operator. The reading is also ended when tape writing errors occur. The reading will end with a control record, called EOF, designating a logical end of file. The tape will then be ended with a control record indicating the logical end of tape record, LEOT.

CONCLUDING REMARKS

The EMR 6130 computer is a useful tool for the SERT II project. The display of real-time data expressed in engineering units enables project engineers to monitor the operations of the spacecraft in real time.

Many reels of analog data may be condensed to only a few reels of digital magnetic tape. The data on these digital tapes may then be sorted and processed chronologically on large-scale computers. The data processing is facilitated by existing programs which handle the Generalized Input Format.

Lewis Research Center,
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