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A New Concept of Providing Telemetry Data in Real Time

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A NEW CONCEPT OF PROVIDING TELEMETRY DATA IN REAL TIME

John M. Blalock
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Introduction

The Air Force Eastern Test Range has recently installed the first elements of a new Real Time Telemetry Data System which will give the Range greatly expanded capability of providing telemetry data to the Range User in real time. This system was designed using a new concept of providing telemetry data in real time. An explanation of this new concept and of the Real Time Telemetry Data System will be presented in this paper. The impact of this system on the Range User will also be discussed.

Previous Methods

The previous method of supplying real time data to Range Users was by providing either low bit rate serial PCM data or limited bandwidth FM data. Parameters contained in a down link with a rate higher than any available retransmission rate from a down range site could not be provided to the Range User in real time. The only method of providing this data was in near real time. This entailed recording the data on magnetic tape at the down link rate and playing the tape back at some slower speed so that the new data rate was compatible with an available communications link rate.

New Method

Many Range Users require only selected parameters from the telemetry down links. If, instead of retransmitting the entire down link to the Range User, the down link is decommutated at the receiving site and only those parameters that are actually required are retransmitted, data from several down links can be sent over the same communications system previously used to retransmit one down link. More efficient usage of the available retransmission bandwidth can be made using this concept, and more Range User requirements can be supported in real time.

The new Real Time Telemetry Data System uses this concept of providing telemetry data in real time. It can select parameters from several asynchronous down links and from several AFETR stations, and provide these parameters to the Range User in real time. The number of parameters that can be provided is limited only by the available retransmission rate and the required repetition rate. The Real Time Telemetry Data System and its operation must be explained before the implementation of this new concept and its impact upon the Range User can be fully understood.

System Description

General

The Real Time Telemetry Data System (RTTDS) equipment was designed and manufactured by RCA, Moorestown, New Jersey. It uses magnetic core program- mable memories and integrated circuit logic. The equipment is divided into two major sections or groups. The first section is called the Central Site equipment and is located at Tel 4 on the

John F. Kennedy Space Center, Merritt Island, Florida. The second section is called the Signal Programmer and Conditioner (SPAC). These units are located at down range stations (either land based or shipboard). Currently, SPACs are installed at Grand Bahama Island, Antigua, and Ascension Island, which are AFETR Stations 3, 91 and 12. Additional SPACs will be installed on five range tracking ships in the near future.

The SPAC accepts digital data from time division multiplex stations (TDMs) and from analog to digital converters (A/Ds) that output a Telemetry Common Language. This Common Language (see Figure 1) consists of 48-bit parallel words. Each word contains a word clock pulse, 12 data bits, a parity bit, 11 main frame identification (MFID) bits, 11 subframe identification (SFID) bits, 4 word size bits, and other miscellaneous control bits. Data must be in this form for entry into the SPAC. The SPAC will select the desired parameters out of these different inputs and retransmit them via communications to the Central Site RTTDS equipment at Tel 4. The data from the down range SPACs is routed through the Central Site and delivered to the Range Users in several different formats. This basic data flow is shown in Figure 2. Data received and decommutated at Tel 4 can also be routed through the Central Site and delivered to the Range Users.

The Signal Programmer and Conditioner

Figure 3 is a block diagram of the SPAC equipment. Data from the TDM or A/D Common Language sources is entered into a device called a Data Selector and Storage Buffer (DSSB). This unit is contained in one rack and has a 4,096 word magnetic core memory. It can receive data from up to three different Common Language sources with the limitation that the sum of the rates of the three sources can not exceed 100,000 words per second. Programs contained in the DSSB memory control the storage of a section of the input frame that contains the parameters required by the Range User(s) in real time. At the time of data storage, current range time from the Range Time Decoder (RTD) can also be stored in the DSSB memory for later retransmission.

Parameters routed to the Data Selector and Storage Buffer will always be stored in known memory locations. Each time a parameter appears at the input, it will be stored in the same location in which the previous sample of the same parameter was stored. Therefore, the data value contained in any specific DSSB memory location is the latest value received and stored by the DSSB. There is no permanent storage of data in the DSSB. To obtain a specific data sample from the DSSB, it must be read out before another sample of the same parameter is received.

The land based SPACs were originally procured with two DSSBs per SPAC. Ascension currently has three DSSBs. The shipboard units will have only one DSSB.
The next unit in the signal flow path is the Retransmission Programmer (RP). The RP also contains a 4,096 word memory and uses integrated circuit logic. The RP's function is to request data from the DSSB(s) and format it into a serial PCM stream which is fed to a communications modem for transmission to the Central Site. To do this, the RP requests the contents of a DSSB memory location. The DSSB places the contents of this memory location on a common bus. The data is routed to the RP output buffer and clocked out in a serial format to the communications modem. The RP program is written to select the required data from memory locations of the DSSB(s) in the proper sequence. These locations contain the down link data parameters that are required by the Range User. The RP can select data from up to 16 different down links provided the SPAC has a full complement of six DSSBs with three inputs per DSSB.

To maintain the same data sampling rate as used on the down links with this number of independent asynchronous sources requires that complex data mixing problems be solved before the RP programs can be written. The output of the RP is a serial PCM NRZL format, with clock. The rate is selectable from 25 to 400,000 bits per second.

The Program Entry and Control (PEC) unit shown on the diagram in Figure 3 controls the entry of programs to the various memories of the SPAC. The PEC also controls the operation of the programs in these memories. Each memory can contain two programs at one time with one in operation and the other in standby. The PEC monitors the status of these programs as to which is operative and which is standby. It also provides for program entry via a paper tape reader, allows manual entry and modification of programs, and allows the operator to read the contents of any memory location to check the programs. These functions can be performed at the same time that a program is operating in the memory. The PEC also contains a test analyzer which, in conjunction with special test programs, allows the SPAC to be tested for equipment operability.

As shown in Figure 3, there is an optional interface with a CP 642A/USQ-20(U) computer. The computers are not now available at the down range sites. If and when they are available, they can request data from the DSSBs, perform either a data smoothing or data compaction operation on the data, and feed it back to the RP.

The Central Site

Figure 4 is a block diagram of the Central Site RTTDS equipment. The down range data from up to sixteen communications modems is fed to the Central Communications Adapter (CCA) and the Central Switch Matrix (CSM). All modems that interface with the CCA provide clock along with the data. The purpose of the CCA is to convert the data from these modems to internal RTTDS logic levels. The CSM is a diode switching matrix that switches the data from any one of the sixteen lines to the input of any one up to five Central Retransmission Decommutator and Storage Buffers (CRDSBs).

Currently, there are only two CRDSBs at the Central Site. Each CRDSB contains a 4,096 word memory. The CRDSB program must be compatible with the RP program of the SPAC that is providing data to the CRDSB. The function of the CRDSB is to decommutate and store the retransmitted data. The CRDSB will search for the sync word in the data received from the SPAC and, when sync is found, store the subsequent data words in its own memory. Each time a particular parameter appears at the input of the CRDSB, it will be stored in a particular memory location. When a new sample of a parameter is received, the old sample is destroyed and the new sample replaces the old sample in memory. In this respect, the CRDSB is just like the DSSB in that any data value contained in a CRDSB memory location will be the latest value received and stored by the CRDSB. The CRDSB can decommutate all of the different output formats from the SPAC. The maximum input rate to the CRDSB is 200,000 bits per second.

Also, at the Central Site are three Central Data Selector and Storage Buffers (CDSBS). This number is expandable up to nine. The CDSBS are identical to the DSSBs of the SPACs and operate in the same manner. The Range Time Decoder at the Central Site is identical to that in the SPAC. With a patching option, current range time from this unit can be stored in the CDSBS with the data for later retransmission.

The next unit in the signal flow path is the Distribution Programmer (DP). It functions quite similarly to the RP in that its programs request data from the different units in the required sequence by specifying the memory locations and the unit number. The unit then places the contents of that memory location onto a common bus. The data is routed through to an output buffer and delivered to the Range User(s). The main difference between the DP and the RP is the number of simultaneous output formats available from the DP. The RP has only one serial output whereas the DP has nine outputs with both serial and parallel formats. The outputs are shown in Figure 6 and will be described later.

The Program Entry and Control (PEC) unit of the Central Site functions in the same manner as that of the SPAC. It contains a memory status monitor, a paper tape reader for entering programs, a magnetic tape unit that can read programs into and out of memory, and a printer to print out the contents of a memory. It also contains a test analyzer which, in conjunction with special test programs, allows either the Central Site, or the SPAC and Central Site operating together, to be assessed for equipment operability. If mission programs are used the data will no longer be in the special format required by the test analyzer. The data can be sent to the printer and a listing of the data values can be made. Program verification is accomplished by comparing the values received and printed out versus the predicted values.

Also shown in Figure 4 is a Projection Display System (PODS). This unit provides selective presentation of system quality assessment data and associated operational status information. A typical display
format is shown in Figure 5. The information supplied to the Projection Display System is either brought up from the SPAC or entered into the system from the Range Instrumentation Control System (RICS).

Figure 6 lists the DP outputs. Each output is under separate program control. Output 1 is the RTTD Language output. This output is available in three different formats with the same data placed on each of the three different lines. The first format is a parallel 36-bit word that is compatible with the Telemetry Common Language but does not contain all of the address bits and control bits of the Common Language. However, it can be used by the units that normally use Common Language as an input. This parallel output is used for routing data around Tel 4 to local users. The other two formats available are in a serial form with BCD identification tags or binary identification tags for KSC or CKAFS users. These outputs are fed to modems and routed to units called Receiving Control Equipments (RCEs) located near the user's equipment. The RCE is basically a serial to parallel converter. It converts the serial 36-bit fixed length words to parallel 36-bit words for entry into the Range User's equipment. The RCE output rates are from 500 to 20,000 words per second.

Output No. 2 is similar to output No. 1. It is a serial 36-bit word format designed to be used as an input to the CDC 3600 computer at the Real Time Computer Facility. The Receiving Control Equipment at the Computer Facility converts the data to a parallel format for entry into the computer.

The third output is a high rate serial PCM format without address tags. Word length is variable from 3 to 80 kilobits per second with a fixed stop at 40.8 kilobits per second for compatibility with a Bell 301 modem.

Outputs 4 and 5 are the medium rate serial outputs and are similar to output 3 except that their rates are from 50 to 3000 bits per second. They will be used to interface with modems such as the Bell 201.

Outputs 6 and 7 provide a low rate teletype format with or without start/stop characters, and with from 1 to 16 channels in parallel on each output. The maximum rate without start/stop characters at 16 channels is 1200 bits per second.

Outputs 3, 4, 5, 6, and 7 will be used to retransmit data to users remote from the KSC/CKAFS area.

The eighth output goes to the Data Correction Station at Tel 4. Its format is a parallel Common Language compatible 36-bit word. The maximum rate is 5000 words per second.

The ninth output is internal to the RTTDS and feeds the Projection Display System described earlier.

System Operation

Signal Flow

Example: data from GBI is being retransmitted to the Real Time Computer Facility. The data as received at GBI is in the serial format of the down link at the input to the TOM. The TOM identifies a data parameter by its position in the format with respect to a sync word. After the TOM decommutes the data, it is routed to the DSSB in the Telemetry Common Language format. A data parameter is now identified by a Common Language address placed on the parameter by the TOM. Data is then stored in the DSSB as described earlier. A data parameter is now identified by its location in the DSSB memory. The RP requests the data from the DSSB using the memory locations as addresses and routes the data to the communications modem in a serial PCM format. A data parameter is now identified by its format position with respect to the RP sync word. The serial stream is transmitted uprange to the CRDSB where the data is entered into the CRDSB memory. The CRDSB identifies the data by the RP format position. The data is now in a parallel format and is identified by its location in its memory. The DP requests the data from the CRDSB and outputs it in the serial format of fixed 36-bit word length where a data parameter is identified by the RTTD Language address contained in this 36-bit word. The data is routed to the Computer Facility where the RCE converts the data to a parallel format and it is entered into the computer. A data parameter is now identified by the computer memory location. A computer routine will request the data by using the memory locations as addresses. In this example there are six programmable devices in a row that must be compatible. Any change in any one of the programs will negate and make invalid the programs of the following units.

The Range has a compiler routine for the 3600 and 7049 computers that assists the programmer in solving the data mix equations for the retransmission links and in writing the RTTDS programs.

Typical Mission

Figure 8 shows the signal flow paths for several phases of a typical mission. A typical mission for the RTTDS requires that the Control Site provide data from the CDSSBs to the Range User during the launch phase. The data, received at Tel 4, is decommutated by the Tel 4 TDMs and fed to the CDSSBs. When GBI Telemetry acquires the signal and starts sending good data to Tel 4, the DP program in the RTTDS will be changed to take data from CRDSB No. 1 and send the data to the Range User. As the vehicle approaches Antigua, Antigua Telemetry will acquire the signal and the SPAC at that site will send data to CRDSB No. 2. If both sites are sending identical data, a change will not be required in the DP program other than the data source, which should be changed from the first CRDSB to the second. This can be done with a simple push of a switch on the DP control console. Once data from Antigua is received by the Range User, CRDSB No. 1 that originally was used to decommutate the GBI data will be changed to operate with a different program already contained in memory. This program will decommutate retransmitted data from a ship located somewhere between Antigua and Ascension. While data from the ship is being received, the other CRDSB will be set up to decommutate the data retransmitted from Ascension Telemetry. It now becomes obvious that the down range data will be alternated back and forth between the CRDSBs as the vehicle continues on down range.
Handover between sites is not automatic, it is manual, and the operator must perform a manual operation to make this handover from one program to another. He initiates handover using as a basis for his decision the mission profile, the voice data received from the down range site, and the quality assessment data as it is received from down range and displayed on the Projection Display System of the RTTDS.

Several sets of programs will be required for the RTTDS for any mission. Each data mix requires a different set of compatible programs. In this example, the first set of programs was used to send the Tel 4 data to the Range User. The second set of programs was used to send both GBI and Antigua data to the Range Users. The same programs were used for both sites since they were required to send identical data. The third set of programs was used to send the ship data and the Ascension data to the Range Users.

Format Considerations

Normal Mode

The data as supplied to the Range User by the Real Time Telemetry Data System will be different from that previously provided by the Range when the entire serial stream was supplied. This is true since the system can select data from several different asynchronous sources, mix this data maintaining the same sampling rates if possible, operate at a fixed rate compatible with the available communications modems, etc. It is possible for the system to select and retransmit all of the data from one or more low rate down links. However, since the data must be retransmitted from the SPAC to the Central Site at a rate fixed by the available communications modems, it probably will require bit stuffing to a higher rate. If a retransmission rate equal to or higher than the down link rate is not available, only part of the data may be retransmitted in real time.

As mentioned in the description of the operation of the USSBs and the CRDDSs, when a data parameter is requested from these units, the latest value received and stored in their memories is the value that is transmitted. The RP in the SPAC can read from the DSSB faster than the DSSB is loaded by the TDM. It is possible for the RP to request a parameter from the DSSB immediately after it is received and stored. The RP might then request the next parameter before it is received and stored by the DSSB. The value that was received and stored by the DSSB during the previous down link frame would be the value retransmitted under these conditions. In this particular example an updated value from one frame was retransmitted and the next word retransmitted was a value that had been in storage since the previous frame. Frame correlation of the data is not maintained. Since the RP rate and the down link rates are asynchronous, it is possible that the RP would miss a sample of a particular word or send a sample twice. For the other condition where the DSSB input is much faster than the RP output, the RP could not take all the input words, but the correlation problem still exists. Down link frame correlation can also be lost when the DP takes data from the CRDDSs or the DDSSBs.

Data Freeze Sub Mode

To be able to provide data words correlated within a down link frame to the Range User, a special sub mode called Data Freeze can be implemented in the RTTDS. In this sub mode the DSSBs operate in four mutually exclusive states. The states cycle, 1, 2, 3, and 4 and then back to 1, and in that order only. The first state is "read in", the second is "wait to be read out," the third is "read out," and the fourth is "wait to be read in." In this sub mode a frame of data is stored in the DSSB and the input is then inhibited until the stored data has been read out by the RP. A frame is read in, the RP reads it out, and another frame is read in. It can be seen that for an ideal timing situation wherein it takes one frame period to read in a frame and the RP immediately requests it, the waiting time is reduced to zero and the RP will read out the data within one frame period. The DSSB will then read in another frame but an entire frame of input data has been missed. For a more realistic timing situation the RP would not request the data immediately after it is loaded. This is quite likely, since the rates of the RP and the down link are completely asynchronous. The data lost in the worst timing situation can be two frames out of three. To avoid this situation, three DSSBs must be used in the Data Freeze sub mode. The DSSBs load alternate frames and the RP reads alternate frames from the DSSBs. Control of this loading and unloading is through special logic designed for this specific purpose. Only one input of the DSSBs can be used for Data Freeze.

At the Central Site the data is loaded into the CRDDS where the program is written as if the data were supercommutated at a three to one ratio. This means that the first frame received from the SPAC is loaded into one set of memory locations, the next frame into a second set, the third frame into a third set, the fourth frame back into the first set of memory locations, etc. The DP must read out one set of the data within the time it takes to load in a set. When the DP requests data from the CRDDS, special data freeze control logic directs the DP to the set of memory locations that contains the last updated group of correlated data. If the DP does read slower than the input rate to the CRDDS, it will get behind and can miss an entire frame of data. If it reads faster, it might send a group of correlated data more than once. The DP and CRDDSs operate in Data Freeze in the same manner as the RP and DSSBs.

The RTTDS can provide frame correlated words from a down link, but because of the various considerations described above, it is impossible from a practical standpoint for the DP to exactly duplicate the serial PCM down link as an output from the Central Site RTTDS at Tel 4.

Conclusion

Previous methods used on the AFETR for supplying real time telemetry data to Range Users were limited almost entirely to supplying low bit rate serial PCM data or narrow bandwidth FM data.

The Real Time Telemetry Data System can select parameters from any down link that can be demodulated by existing AFETR TDM demodulators. The number of down links that can be accepted depends on the number of Data Selector and Storage Buffers available and
the actual down link rates. The amount of data 
that can be retransmitted from the down range sites 
is limited by the retransmission bandwidths now 
available.

This selected data from several sites is available 
to the Range Users in parallel, serial PCM, and 
teletype formats. Thus, most of the data that is 
required by the Range Users will be available in 
a standard format in real time.

By implementing this new concept of providing telem­
etry data in real time, the AFETR has greatly ex­
panded its real time telemetry retransmission cap­
abilities and will be able to support Range User 
requirements to a much higher degree than pre­
viously attained.
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**DATA**

(12 BINARY LINES)

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**SUB FRAME IDENTIFICATION**

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**MAIN FRAME IDENTIFICATION**

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**PROGRAM SWITCHOVER**

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**AFETR TELEMETRY COMMON LANGUAGE FORMAT**

*FIG. 1*
BLOCK DIAGRAM
REAL TIME TELEMETRY DATA SYSTEM
FIG. 2
TELEMETRY COMMON LANGUAGE INPUTS FROM TDMs OR A/DS

OPTIONAL CP 642A/USQ-20 COMPUTER

TO DSSBs

DATA SELECTOR & STORAGE BUFFER

RANGE TIME DECODER

RETRANSMISSION PROGRAMMER

SERIAL PCM OUTPUT TO COMMUNICATIONS MODEM

ALL UNITS

DATA SELECTOR & STORAGE BUFFER

DATA SELECTOR & STORAGE BUFFER (UP TO 6)

PROGRAM ENTRY & CONTROL

BLOCK DIAGRAM
SIGNAL PROGRAMMER & CONDITIONER

FIG. 3
DOWNRANGE DATA FROM COMM MODEMS

16 LINES

CENTRAL COMM ADAPTER & CENTRAL SWITCH MATRIX

CENTRAL RETRANSMISSION DECOMMUTATOR & STORAGE BUFFER

CENTRAL RETRANSMISSION DECOMMUTATOR & STORAGE BUFFER

CENTRAL RETRANSMISSION DECOMMUTATOR & STORAGE BUFFER

(UP TO 5)

CENTRAL DATA SELECTOR & STORAGE BUFFER

CENTRAL DATA SELECTOR & STORAGE BUFFER

CENTRAL DATA SELECTOR & STORAGE BUFFER

(UP TO 9)

CENTRAL DATA SELECTOR & STORAGE BUFFER

RANGE TIME

TO CDSSBs

RANGE TIME

DISTRIBUTION PROGRAMMER

TO USERS

RANGE TIME

TO USERS

RECEIVING CONTROL EQUIPMENT

PROJECTION DISPLAY SYSTEM

MAG TAPE PRINTER

ALL UNITS

PROGRAM ENTRY & CONTROL

TELEMETRY COMMON LANGUAGE INPUTS FROM TDM'S OR A/D'S

CENTRAL SITE BLOCK DIAGRAM

FIG. 4
THESE CIRCLES REPRESENT RED, GREEN, WHITE OR DARK SPOTS FROM FIBER OPTICS SPOT PROJECTOR.

THIS IS ONLY ONE PORTION OF A MUCH LARGER SLIDE.

FORMAT
PROJECTION DISPLAY SYSTEM
FIG. 5
DISTRIBUTION PROGRAMMER OUTPUTS
REAL TIME TELEMETRY DATA SYSTEM

FIG. 6
GBI

RECEIVER

TDM

DATA SELECTOR & STORAGE BUFFER

RETRANSMISSION PROGRAMMER

REAL TIME COMPUTER FACILITY

RECEIVING CONTROL EQUIPMENT

REAL TIME COMPUTER

COMM

DISTRIBUTION PROGRAMMER

COMM

CENTRAL RETRANS DECOM & STORAGE BUFFER

SIGNAL FLOW

REAL TIME TELEMETRY DATA SYSTEM

FIG. 7
PHASE 1 ....... TEL 4

PHASE 2 ....... GBI

PHASE 3 ....... ANTIGUA

PHASE 4 ....... SHIP 1

PHASE 5 ....... ASCENSION

TYPICAL MISSION PHASES FOR RTTDS

FIG. 8

13-13