NASA TECHNICAL MEMORANDUM

NASA TM X-73645

NASA TM X-73645

(NASA-TM-X-73645) A REAL TIME, LOW COST, DATA ACQUISITION TELECOMMUNICATION NETWORK (NASA) 22 p HC A02/MF A01 CSCL 17B

N77-22310

Unclas
G3/32 25105

A REAL TIME, LOW COST, DATA ACQUISITION TELECOMMUNICATION NETWORK

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1. Report No. NASA TM X-73645	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A REAL TIME, LOW COST, DATA ACQUISITION TELECOMMUNICATION NETWORK		5. Report Date
		6. Performing Organization Code
7. Author(s) R. R. Schulte		8. Performing Organization Report No. E-9151
		10. Work Unit No.
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The real-time, low-cost data acquisition communication network described features the use of asynchronous ASCII code transmissions operating at 30 characters per second on the dial-up telephone system. The network features an elaborate, but easily generated error checking system, operating in a line-by-line demand-response mode. The system is readily adaptable for any low speed computer-to-computer data transmissions requiring high reliability in data transmission. The network was developed for the acquisition of pre-launch wind data from the Eastern Test Range at Cape Kennedy to be used by NASA Lewis Research Center, General Dynamics, San Diego, and Martin-Marietta, Denver, Colorado.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Low cost telecommunication system	Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161

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Summary

The real-time low-cost, data acquisition communication network herein described was developed to replace an outdated punch card transceiver system. The network features the use of the standard ASCII code, operates at 30 characters per second asynchronously, and has elaborate error checking. The system was designed to be device independent, using demand-response protocol and low-cost dial-up data sets. The network operates synchronously in a real-time mode from the Eastern Test Range at Cape Kennedy, and is used to transmit pre-launch wind data values for the remote calculation of steering-coefficients for the on-board flight computer of a launch vehicle.

The system has proved highly successful in the areas of reliability, performance, and overall time saved in the acquisition and transmission of data by a factor of 5 to 1.

I. Introduction

On August 20, 1975, a Titan Centaur Launch Vehicle, bearing the Viking I space craft bound for the planet Mars, was successfully launched at Kennedy Space Center. With this launch and all subsequent launches managed by the NASA Lewis Research Center (LeRC) a new data communication network was introduced and used to transmit pre-launch wind data values to LeRC and the NASA contractors associated with the launch. These raw data values are received by the parties in the network and are fed into computers where calculations and wind profiles, pitch and yaw, are made. The prime contractor transmits this calculated data back to the on-board flight computer of the launch vehicle, in the form of steering coefficients. The flight computer then steers the launch vehicle during the critical lift-off phase, thru the winds measured.

The original pre-launch wind data data is obtained from two types of weather balloons, released a given time interval before and up to a launch. Wind velocities and directions are recorded at 200 foot intervals from ground level to 60,000 feet. This data is formatted and punched cards made for the two transceivers. Prior to the use of this system, the pre-launch wind data was transmitted by cards from the Eastern Test Range (ETR) thru an assortment of IBM 066 and 1050 card transceivers, with not all modes of the network being compatible with each other. (See Fig. 1a). The card data was received on like transceivers and hand carried to batch computers at the various sites. Also, in LeRC's case the data cards had to be hand carried from one building to another by courier at ETR requiring a minimum 10 minute delay. These transceivers were subject to frequent mechanical breakdowns and many card re-transmissions. Between the incompatibility of different machines at the different sites and the frequent failures, the need for a new system was clear and evident.

STAR Cat. 32

II. Description of the Network

The foremost consideration in the design of the network was commonality. Each site had different types of large scale computers (See Fig. 1a), made by different manufacturers. The machine codes were incompatible, as were the different methods, if any, of real time data input.

The first requirement then was to establish a standard code for all machines. The American Standard Code for Information Interchange (ASCII 3.4) was selected, and was easily adaptable to most sites.

The second requirement was to upgrade old computer equipment at ETR, the data source, to on-line operation. After extensive contacts with the Control Data Corporation, data controllers and line adapters were found that would fit their system. Also, a switching unit was ordered such that the same data phone input lines could be switched from prime, to back-up computers for both types of data. This proved to be a very advantageous feature, in that not only was redundancy provided, but only 3 modems and phone lines were required for the four computers. (See Figure 1b).

In the case of the receivers interfacing to the network, (NASA Lewis, General Dynamics, and Martin Marietta), each was handled independently. The most straight forward and inexpensive path for on-line interfacing where large machines are involved, is to provide a small buffer computer to handle the data in the demand-response mode, to do the error checking, and to overcome large computer systems incompatibilities without major changes of software. Following this path then, the General Dynamics Corporation elected to use an Interdata 716 which they already had on site. NASA, Lewis developed a system using an Intel 8008 micro-computer and Control Logic hardware (See Fig. 10). Martin Marietta had a Modcomp front-end computer on order, but not yet operational. In the interim, they elected to use their CDC 6671 control unit, modify their supporting software and operate on the network as a conversational terminal.

In the area of actual telecommunications, the Western Electric 103A2 type modem, or equivalent, was selected as the data set to be used. Its maximum limit of 300 baud (30 characters/sec) was well in keeping with the volume of data being transmitted. The average message block requires 2.3 minutes for transmission. The 103A2 type modem is a standard of the telecommunication industry for low speed communication and was readily accepted. It operates in the full duplex mode, thereby requiring no turn-around time or control for acknowledgements.

III. Data Block Format and System Specifications

Data Block Format

In order to minimize the major computer programming conversion efforts, the system was specified such that the data blocks would continue to retain the older systems card images, (see Fig. 2). The 80 character column card also translated nicely into 80 character line TTY compatible computer terminals, used for debugging and actual data monitoring. The data is transmitted in a standard format with line count and type of data (i.e. windsound, jimsphere, or pitch/yaw) listed in the first line. Further identification is given in the second line such as release date, time and data description. (See Fig. 3, 4, 5 for data samples)

Data values follow in the third and subsequent lines until completed. The last line contains the characters EOT followed by spaces, a bell code in column 72, checksum values as in every line, a line feed (LF), and a carriage return (CR). This is followed by the last character transmitted which is a EOT code. The line count line includes all following lines thru the EOT line. It does not include itself (i.e. the first line) in the listed count.

System Specifications

Physical Requirements:

1. The data will be tranmitted in the standard 7 level ASCII character code, with the eighth level being designated as even parity.

2. The transmission rate will be 300 bits per second, 10 bits per character, (1 start, 7 data (Least Significant Bit First), 1 even parity, and 1 stop). (Initially the Control Data Corporation teleprocessing hardware required 2 stop bits for an 11 bit character).

3. The data sets used for transmission will be standard Western Electric 103A2's or fully equivalent, operating in a full-duplex mode.

4. The "line length" of headers, data and "EOT" lines will be exactly 80 characters. Space codes will be used to fill up any blank areas in the header or "EOT" lines. Zeros will fill up any blank positions in data lines. Data, spaces or header information will occupy line positions 1 thru 72, position 73 will be Martin Marietta's special checksum (ASCII printable characters numbered 32 thru 95) and repeated in column 74, and positions 75 thru 80 will be the exclusive OR checksum (ASCII numbers 0-7), each digit repeated once in sequence. A line feed (LF) and carriage return (CR) will always follow the 80th character position.

5. A minimum pause of 200 milli-seconds will follow each transmission of a carriage return to allow for terminal printing mechanism to return to its starting position. When the data has been received and error checked, ack owledgements will be sent by the recipient of the data. A printable exclamation point "!" will be a positive acknowledgement signifying the line is error free and the next line can be transmitted. A printable question mark "?" will be a negative acknowledgement signifying the line is in error and must be re-transmitted. In the event there are six negative acknowledgements (NAK's) for any one line, the data link will be disconnected at the data source and a new line redialed.

6. In the event <u>no</u> acknowledgements are received after a period of 6 seconds, a positive acknowledgement will be

assumed, and the next line transmitted (implicit ACK). The purpose of this specification is twofold, the first being to allow the data source computers at ETR to complete the sequence without being tied up indefinitely waiting for a response and secondly, to allow the receivers a fixed time frame for a message transmission. A side benefit also allows the data to be received at a receivers' monitor terminal for visual confirmation without a response being necessary.

Operational Characteristics:

1. The Eastern Test Range (ETR) has 3 "ports" or data paths available on different direct distance dialed phone numbers. Those ports may be group switched between the various computers, but all must be switched at the same time depending on the source of data.

2. ETR transmits the data simultaneously thru the three ports upon verbal confirmation that all parties are ready and data is available.

3. The data sequence starts when the receivers each dial-in and transmit a positive acknowledgement (!) to ETR.

4. In the event of errors being detected by one or more parties in the network, the lines in error are re-transmitted. The other parties continue to receive data without delay or interruption.

5. ETR operates only as a data source.

6. Data calls should be terminated (lines disabled) by ETR when the EOT code is transmitted or when 6 consecutive negative acknowledgements have been received for any one line.

7. The General Dynamics Corporation (GDC) operates as both receiver of data from ETR and a transmitter of P/Y values to Martin-Marietta and NASA LeRC.

8. GDC in transmit mode operates in a similar manner as ETR and has two ports available on different DDD numbers.

IV. Description of Error Checking

The error checking procedures of a given block of data are many and straight forward, which lead to a highly reliable system of raw data transmission. Current estimated values show typical error rates for the data speed and grade telephone lines used, to be in order of one bit error in 500,000 bits. With the addition of the different forms of error checking applied to the data, it is estimated the probability of an undetected bit error entering the data is as high as 1 bit error in 10^9 bits transmitted. The types of error checking done are as follows:

1. Vertical even parity checking on each ASCII character received. (Seven data bits with one parity bit).

2. An exact line length of 80 characters.

3. An exact line count as listed in the first start of message line.

4. Redundancy in line count, and all check sum values (each value given twice).

5. An exclusive OR checksum of a total line.

6. A special checksum summing data bit values and converting them to a printable ASCII character.

An error detected automatically by the receiver, with any one or more of the six error checking methods above would result in negative acknowledgement of the line of data received and cause the same line to be retransmitted. In the event of a difference of line count transmitted and lines received, the EOT line would receive 6 negative acknowledgements and the call terminated for re-dial. Generally any errors received fall into the category of "burst noise" on the telephone circuits. This "burst noise" usually lasts from one to three character times and will be detected by the vertical parity check and both checksums. If the telephone line is continually noisy, the only solution is to be disconnected and re-dial.

The Exclusive OR Checksum Characters

A checksum will be generated by the data source for each line of data using exclusive OR, binary arithmetic (7 data-bit levels only), without carries. This sum will be converted to ASCII printable characters (0-7) binary to octal conversion and transmitted at the end of the line of data (cc75-80). Each character will be printed twice with the most significant number first. (Reference Fig. 7)

Acknowledgements will be based on the receiver of the data doing similar arithmetic in the Front End computer and comparing it with the transmitted values.

Martin Marietta Special Checksum Characters

In the development of the network, it was found that the Martin-Marietta CDC 6500 computer had no way using the normal checksum method outlined above, in that the ASCII character values when taken directly in the machine were converted to internal codes and lost their identity for checksumming. This left Martin-Martin without any line checksum features. To overcome this, a special checksum method was derived and placed in Columns 73 and repeated in column 74. The basic operation of this checksum lies in the creation of an internal table within the CDC 6500 such that an integer value will be assigned to each internal code value as it is converted from its ASCII character. This integer value is pre-defined within the 64 ASCII character set. The internal codes are summed in modulo 64 arithmetic as they are received. Then the special checksum character is received it is likewise converted and compared with the sum. If they agree, a positive acknowledgement is sent back. If they disagree, a negative acknowledgement is sent back and the line is retransmitted. A sample of this special checksum is shown in Fig. 8.

V. Concluding Remarks

Since the network was designed and implemented for the August 20, 1975 Viking A Launch, it has been used successfully in 5 other launches i.e., 1) Viking B, second spacecraft to the planet Mars, 2) AC 36, an Intelsat-IVA Telecommunication satellite, 3) T-C Helios, a West German spacecraft for exploration of the Sun, 4) CTS satellite launched by McDonald-Douglas, 5) AC37 Intelsat IVA, a second telecommunication satellite.

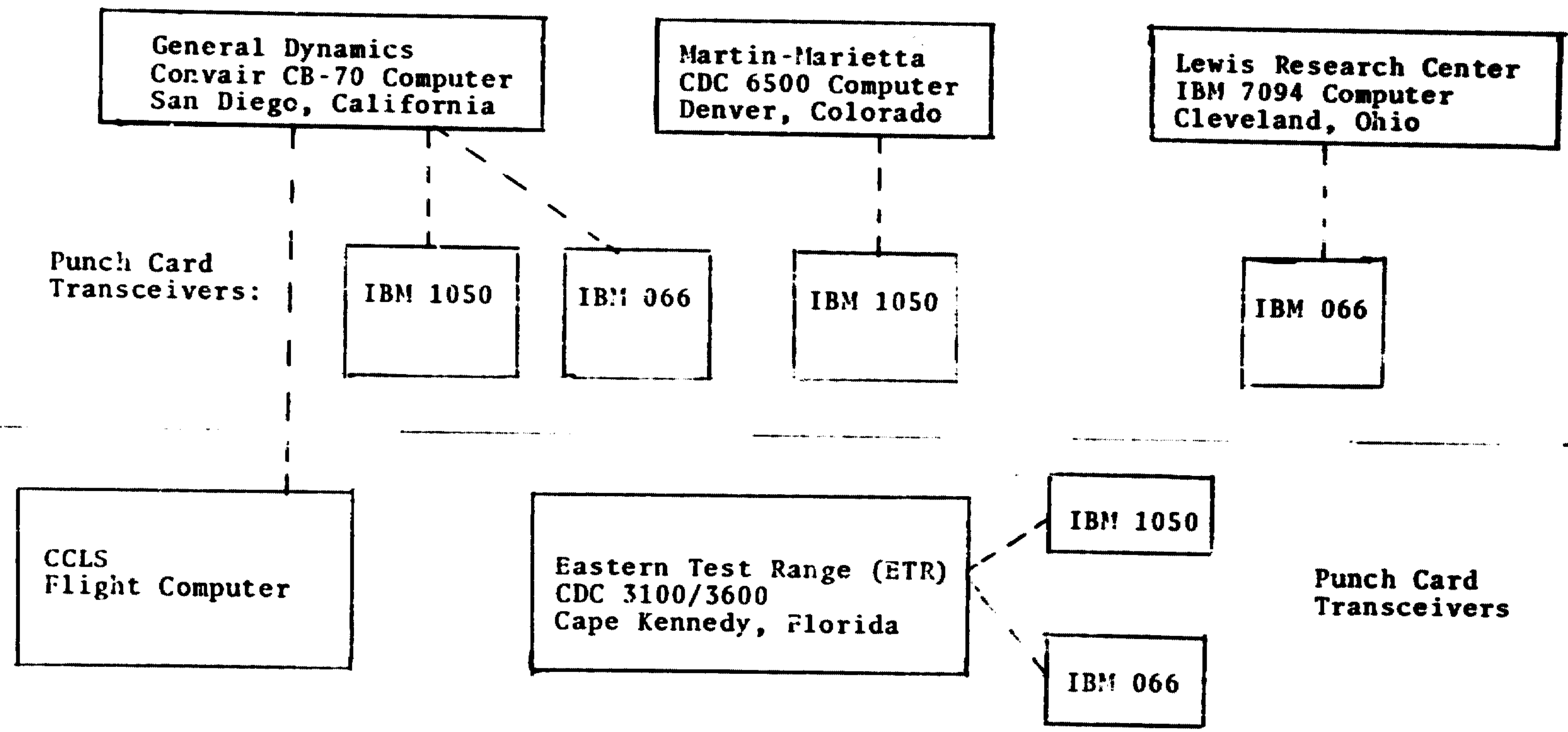
A Windsound plot of the raw data values and a superimposed smoothed curve has been included (Fig. 9) to show typical sample of the data values received.

The on-line experience of the network gained from acquisition of wind data for these launches, revealed the maximum worst case error failures to be the rejection of two consecutive lines, which occurred once during the twenty-four data runs (approximately 72,000 characters). The normal mode generally had no errors. It was found that if the data phone-lines were established for a long period of time prior to data transmission, the first data line occasionally would require re-transmission due to burst noise during the wait period. At no-time has a party in the network been disconnected because of the 6 consecutive error line specification.

An additional benefit comes from the design of the network that allows any receiver can also act as a relay point and re-transmit the data to another party. A single point failure has been eliminated once the data is obtained by one or more parties originally. This feature has instilled a level of confidence in the contractors and NASA Lewis such that all parties have since released their card transceiver equipment which had been kept as an emergency back up system.

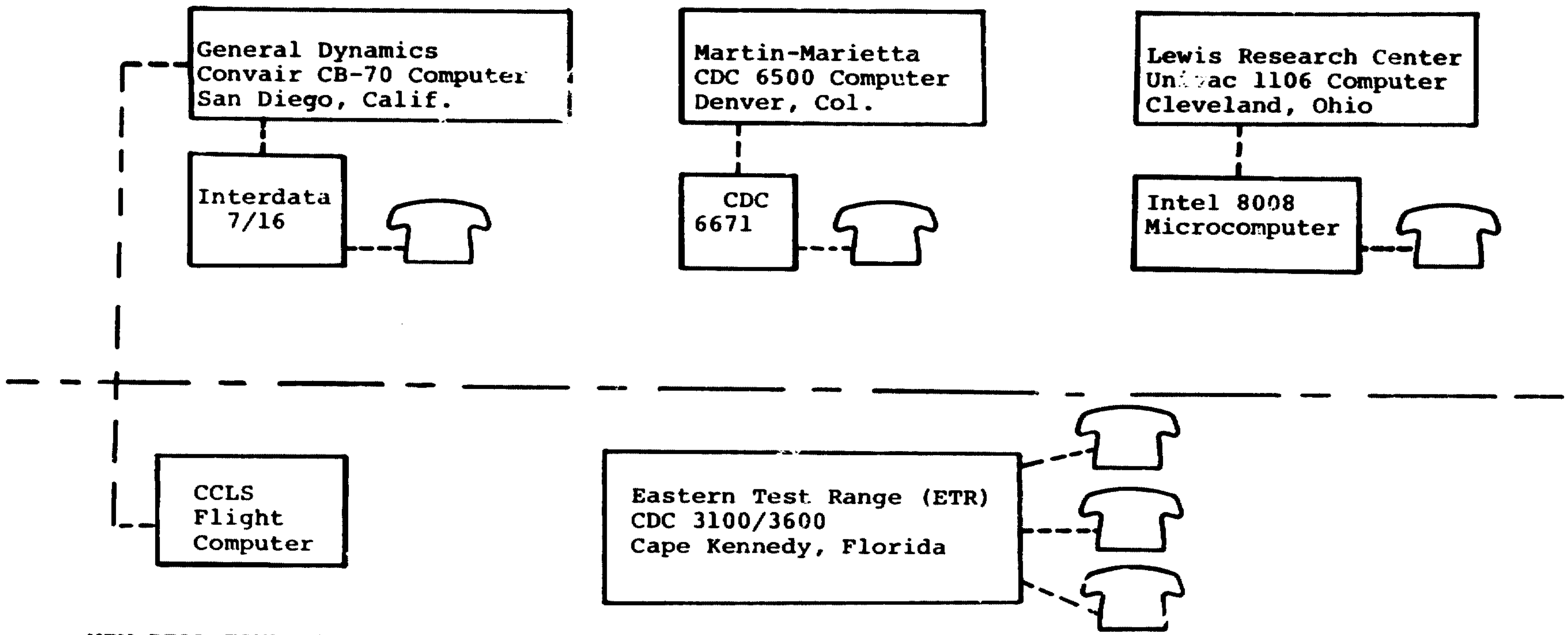
In conclusion, it has been shown that the many benefits of the system, in terms of reliability, performance, and time saved in the acquisition of the data, have far exceeded the initial design goals and has already justified the time and expense in the networks development.

The author wishes to acknowledge the contributions of Mr. Fredrick N. Goldberg and Mr. John Estes of NASA LeRC, Mr. Donald Terry of General Dynamics Corporation, San Diego, California, Mr. Robert Hanley of Martin-Marietta Corporation, Denver Colorado, and Mr. Bruce Flickenger of RCA, ETR Florida during the development, debug, and implementation phases of the network.



PRINCIPLE SITES OF THE DATA COMMUNICATION NETWORK
(OLD SYSTEM)

FIGURE 1a



NEW REAL TIME DATA COMMUNICATIONS NETWORK

FIGURE 1b

Description of Wind Data Formats

All ADDJUST wind and steering data will be communicated with two header lines.

Line No. 1 (for all types of data) will have the character "C" in column 1, the characters "SOM" (start of message) in column 2-4, and two digits in columns 5 and 6 to specify the total number of lines of data in the transmission. The digits specifying number of lines in the message will be repeated in columns 8 and 9. Columns 73 and 74 will carry the special MMC checksum for that line, Columns 75 to 80 will carry the general error checking information for that line. All other columns will be blank. Example:

```
CSOM 40   40   ID  ID                                                      MMGGGGGG
```

(ID identifies type of data i.e. P/Y, Windsound, or Jimsphere)

Line No. 2 will have the character "C" in column 1. Columns 3 and 4 will define the type of data (W=Windsonde, J=Jimsphere, R=Rawinsonde, TP=temperature and pressure, PY=steering data). Columns 2, 5, and 6 will be blank. Columns 7-22 will specify the release time of the balloon which defines the data as follows: ,HHm DD MM YY,. (HH = hours, mm = minutes, DD = date, MM = month, YY = year). Columns 23-72 will define the data as shown in the examples. Columns 73-80 will contain error checking character for line no. 2 as defined above for line no. 1. Examples:

```
C P Y   ,13 04Z  11  08  75,GDC Steering No. 03  P1A0300*TC04 Y1A0300*TCO4     MMGGGGGG
C W     ,13 04Z  11  08  75,ETR Wind data 1234, ALT 200 F, VEL FPS             MMGGGGGG
C J     ,13 14Z  11  08  75,ETR Wind data 1235, ALT 200 F, VEL FPS             MMGGGGGG
C R     ,14 49Z  11  08  75, ETR Wind data 1236, ALT 200 F, VEL FPS            MMGGGGGG
C T P   ,14 49Z  11  08  75, ETR ATMOS data, ALT 1000 F, PRESS MBAR,TEMP DEG Cx10  MMGGGGGG
EOT             (Last line termination)                          (Bell Code)  ▯MMGGGGGG
▯    (EOT Code)
```

Figure 3 Windsound (W) Sample

```
C   M42   42   W    W                                                               LL002222
C W     ,0529Z 15 01 76,ETR WIND DATA 2675,ALT0200 F,VEL FPS                        LL000022
 A 001  360,002,004,007,012,014,017,019,021,021,021,019,018,018,016,014,SS116655
 A 017  008,356,338,325,321,320,318,314,308,298,288,281,280,282,282,279,55117711
 A 033  275,267,266,267,265,263,259,259,262,264,264,264,266,272,276,280,II117777
 A 049  282,282,283,281,278,275,272,271,270,270,269,267,264,263,264,266,EE117733
 A 065  271,274,275,271,266,262,258,254,251,249,247,247,249,253,256,258,CC116677
 A 081  258,259,260,261,260,260,260,262,264,266,266,265,262,259,256,254,33116611
 A 097  256,259,261,261,259,258,256,254,254,253,252,251,250,250,250,249,11117777
 A 113  248,248,249,249,248,247,249,251,252,254,255,255,256,256,258,259,GG116633
 A 129  258,258,257,256,256,256,256,257,258,258,259,259,259,260,259,258,  116600
 A 145  256,254,254,254,255,254,253,252,251,252,252,253,252,253,254,255,!!116611
 A 161  256,258,259,259,260,260,261,261,261,262,262,262,263,263,264,265,--117733
 A 177  266,266,266,267,267,268,268,267,267,267,266,267,267,268,268,268,11117777
 A 193  269,269,269,269,268,267,266,264,263,263,263,262,262,262,260,257,PP116622
 A 209  257,258,259,260,261,261,261,261,261,261,260,260,260,260,260,259,__116655
 A 225  259,259,258,258,259,260,261,261,262,263,264,265,266,267,267,267,KK117777
 A 241  267,266,265,264,263,263,263,262,262,262,261,260,257,253,251,250,%%116633
 A 257  249,250,250,251,251,250,249,250,251,251,252,253,254,257,259,260,JJ117711
 A 273  260,258,254,250,249,252,256,259,260,261,262,265,267,267,266,265,<<117700
 A 289  263,263,264,266,267,267,266,265,264,265,266,267,268,268,267,267,!!116633
 A 305  267,266,264,263,262,261,261,261,262,262,262,262,000000000000000,FF115566
 S 001  008,027,028,027,028,029,029,028,026,025,024,023,022,021,019,016,DD115500
 S 017  012,008,007,008,010,013,014,015,015,015,016,017,019,021,022,023,&&115500
 S 033  022,020,020,021,022,023,022,022,023,024,024,025,026,028,031,035,[[115555
 S 049  040,045,047,046,044,043,043,042,042,043,044,043,042,042,042,043,CC115533
 S 065  043,045,046,047,048,048,049,050,051,051,053,056,059,060,059,058,++114411
 S 081  058,057,056,055,056,057,057,057,058,061,064,066,066,066,066,068,EE114411
 S 097  072,077,081,084,084,086,088,090,090,089,088,088,088,087,087,088,**115566
 S 113  089,089,089,088,086,085,088,091,093,095,095,095,095,095,095,097,00115566
 S 129  098,097,097,098,099,102,103,103,102,101,100,101,101,101,101,101,>>115500
 S 145  102,105,106,106,104,104,105,107,109,111,113,114,115,114,113,112,**115500
 S 161  111,111,111,113,115,117,120,123,124,126,127,126,126,125,124,124,44114466
 S 177  124,124,124,125,126,120,115,126,160,157,036,126,130,131,132,132,FF114400
 S 193  132,132,131,130,129,130,131,133,135,136,136,137,137,138,139,141,??114411
 S 209  143,144,146,146,146,146,146,147,150,153,153,153,15[illegible],151,150,149,&&114466
 S 225  148,146,142,139,139,139,138,136,13[illegible],130,128,126,125,123,120,117,!!114455
 S 241  114,111,109,109,[illegible],112,114,115,115,115,113,110,109,108,107,106,11114411
 S 257  [illegible],[illegible],111,113,113,113,112,110,108,103,099,094,091,086,082,079,XX115500
 S 273  077,074,068,062,058,058,059,061,063,063,063,062,062,062,061,061,..114466
 S 289  062,065,065,065,064,064,064,065,065,065,062,059,058,056,054,052,<<114466
 S 305  050,049,050,051,053,054,055,055,054,052,049,047,000000000000000,AA117777
EOT                                                                                 [##000055
```

Figure 3 Windsound (W) Sample

Figure 4 Jimsphere (J) Sample

```
!CSOM38   38  J   J                                                     <<002222
 C J    ,0547Z 15 01 76,ETR WIND DATA 2675,ALT 200 F,VEL FPS            //000077
  A 001  330,349,353,355,357,000,003,013,015,029,025,036,036,038,052,030,55117777
  A 017  334,357,300,308,260,255,241,253,259,278,235,241,260,257,265,270,##117777
  A 033  268,276,279,283,279,273,272,271,260,265,267,270,276,279,282,284,PP117700
  A 049  280,274,270,265,268,268,269,268,270,274,272,272,273,271,271,271,BB116644
  A 065  272,273,273,270,268,265,260,255,255,252,253,256,255,255,255,257,77117733
  A 081  261,262,264,263,260,263,262,263,265,269,267,267,263,264,265,265,99116655
  A 097  265,266,264,262,261,259,258,258,258,257,255,253,253,253,255,255,HH117700
  A 113  256,258,257,257,258,260,261,258,261,262,260,260,257,258,258,255,88117744
  A 129  255,255,259,259,257,260,259,260,260,260,258,257,256,256,254,254,@@117722
  A 145  254,255,257,258,259,259,259,260,261,261,262,261,262,263,264,267,<<116644
  A 161  267,268,266,266,265,268,266,266,268,267,266,267,268,265,266,266,""116666
  A 177  265,265,264,264,266,266,268,268,268,271,270,269,269,265,266,264,ZZ117766
  A 193  262,260,259,258,257,258,259,259,261,261,261,259,259,260,265,260,DD116622
  A 209  257,260,262,261,261,261,259,257,258,259,262,265,266,264,262,264,;;116611
  A 225  263,263,268,267,269,267,266,264,260,258,256,257,258,259,261,259,SS116677
  A 241  258,260,264,263,260,256,254,251,251,252,251,252,254,252,253,252,WW117755
  A 257  253,256,255,257,257,260,263,267,265,268,268,265,261,259,256,252,II117711
  A 273  249,251,254,258,259,260,263,266,269,273,274,271,267,264,263,260,AA116633
  S 001  006,016,027,038,037,040,034,035,031,031,028,029,023,025,018,012,77114411
  S 017  007,005,006,007,004,007,008,012,009,011,014,014,017,015,018,017,..115522
  S 033  018,022,022,020,019,023,020,020,022,025,025,029,034,039,041,041,))114477
  S 049  042,043,042,043,046,045,044,047,047,045,045,046,046,049,050,050,XX114400
  S 065  050,044,044,047,050,049,048,052,053,053,056,052,053,051,048,052,VV115500
  S 081  052,055,056,055,056,055,057,061,066,068,071,071,075,079,081,083,44115500
  S 097  085,087,087,087,088,088,088,088,087,086,086,085,087,088,090,089,>>115522
  S 113  087,086,085,086,086,087,090,092,093,093,092,092,094,094,092,093,PP114400
  S 129  096,097,098,102,099,099,105,105,107,115,111,112,112,112,112,113,YY115533
  S 145  113,115,116,115,115,115,114,112,113,116,116,117,117,119,119,122,BB114422
  S 161  123,123,120,119,118,117,118,124,130,135,134,134,134,134,132,132,BB115522
  S 177  131,130,127,127,127,126,125,127,132,134,137,138,138,135,137,139,&&115522
  S 193  138,138,137,139,140,145,148,149,152,155,150,148,148,143,140,142,11114455
  S 209  140,142,143,147,148,151,154,157,155,151,147,143,139,140,140,140,[[115533
  S 225  139,137,136,135,134,131,128,126,115,110,111,117,122,124,119,110,FF115544
  S 241  110,111,103,098,098,099,097,100,102,104,105,107,111,115,114,112,BB115566
  S 257  105,099,093,087,085,087,087,082,074,068,070,072,073,073,072,072,HH115522
  S 273  070,066,065,065,066,066,066,068,068,070,068,065,065,065,066,067,GG115511
!EOT                                                                    [##000055
```

Figure 4 Jimsphere (J) Sample

```
ᴗᴐum14  14  PY  PY                                                     ..002222
C PY  ,0529Z 15 01 76,GDC STEERING NO. 05      P1A0500*AC38 Y1A0500*AC38**115544
 P2=   608789-14, 357632-16, 755672-16, 694324-16, 670009-16,-375552-16,77117777
      -303199-15, 101966-15, 207843-15, 592514-16, 134336-16,           @@000044
 P1=  -788499-10,-190465-10,-136517-10,-118425-10,-945250-11,-879390-11,YY117777
      -710853-11,-107889-10,-104503-10,-685972-11,-359565-11,           22000066
 P0=   157080-05, 131628-05, 116619-05, 106182-05, 993261-06, 947674-06,JJ116644
       902766-06, 859643-06, 808248-06, 724529-06, 611035-06,           GG001177
 Y2=   147650-14, 423503-15,-827787-16, 211275-15,-450200-15, 531094-15,^^117700
      -625774-15, 384839-15,-496969-16,-152572-17, 145919-18,           HH000066
 Y1=  -126442-10,-226265-11, 363086-11,-626241-12, 113502-11,-206174-11,VV117700
       418728-11,-240033-11,-730755-12,-301636-12,-280238-13,           NN000044
 Y0=   0.        ,-176778-07,-867474-08, 150743-07, 189228-07, 133429-07,;;115533
       163115-07, 216036-07, 192229-07, 694566-08, 302655-09,           88001144
EOT                                                                    113311
```

Figure 5 Pitch/Yaw (P/Y) Sample

Figure 6a - Data Transmission Sequence

Data Call Originator (Data Receiver) (LeRC, GDC, MM)	Data Source (ETR, GDC)
1.	The 103AZ Data Sets are enabled (terminal ready high) by the CPU and are placed in the auto-answer mode.
2. The System Operator initiates data call to source.	
	2a. Data set answers automatically and places 2020 hz tone on the line.
3. The System Operator places own dataset in data mode by pushing "data button".	
	3a. Data set receives carrier tone 1020 hz and provides connect status to CPU.
4. The System Operator initiates the data transfer sequence by sending a "!" code (41/octal) (A positive acknowledgement).	
	4a. The CPU accepts the acknowledgement code and transmits the first line of data.
5. The system receives the line of data and analyzes the error codes transmitted at the end of the line. If there are no errors the system automatically transmits a positive acknowledgement "!". If there is an error, a negative acknowledgement "?" is automatically transmitted.	
	5a. The CPU analyzes the acknowledgement code received and does the following: A. If it is a positive acknowledgement, the CPU will transmit the next line of data. B. If it is a negative acknowledgement, the CPU will transmit the same line of data over again.

Figure 6a - Concluded

6. This process (step 5 and 5a) is repeated until the whle data block is transmitted. If there are six negative acknowledgements for any one line, the sequence is stopped and the line disconnected.

7. Following the last line of data, the characters EOT and a EOT code is transmitted. (04 octal)

8. The EOT code is received and detected, indicating the transmission is complete. The data set is disconnected (terminal ready dropped) automatically.

8a. The CPU senses the loss of carrier and drops terminal ready disconnecting the data set and phone line.

Figure 7 - Sample Calculation of Checksum

First Line	ASCII Character/CODE/8		Binary Value
1st character	C	1 0 3	1 0 0 0 0 1 1
2	S	1 2 3	1 0 1 0 0 1 1
3	O	1 1 7	1 0 0 1 1 1 1
4	M	1 1 5	1 0 0 1 1 0 1
5	4	0 6 4	0 1 1 0 1 0 0
6	2	0 6 2	0 1 1 0 0 1 0
7	Space	0 4 0	0 1 0 0 0 0 0
8	Space	0 4 0	0 1 0 0 0 0 0
9	4	0 6 4	0 1 1 0 1 0 0
10	2	0 6 2	0 1 1 0 0 1 0
11	Space	0 4 0	0 1 0 0 0 0 0
12	Space	0 4 0	0 1 0 0 0 0 0
13	W	1 2 7	1 0 1 0 1 1 1
14	Space	0 4 0	0 1 0 0 0 0 0
15	Space	0 4 0	0 1 0 0 0 0 0
16	Space	0 4 0	0 1 0 0 0 0 0
17	W	1 2 7	1 0 1 0 1 1 1
18-72[2]	Space	0 4 0	0 1 0 0 0 0 0
73	L	1 1 4	1 0 0 1 1 0 0
74	L	1 1 4	1 0 0 1 1 0 0
75	X_1 = 0		
76	X_2 = 0		0 0 1 0 0 1 0
77	Y_1 = 2		
78	Y_2 = 2		0 2 2
79	Z_1 = 2		
80	Z_2 = 2		

1 - where X_n, Y_n, and Z_n are generated checksum values and converted to ASCII printable characters (i.e. X + 60/8 = 6X/8)

2 - Note: In exclusive OR summing without carries, even repeated characters are self canceling.

Figure 8 - Sample Calculation of Martin-Marietta's Special Checksum

I. Sample Integer Assignments

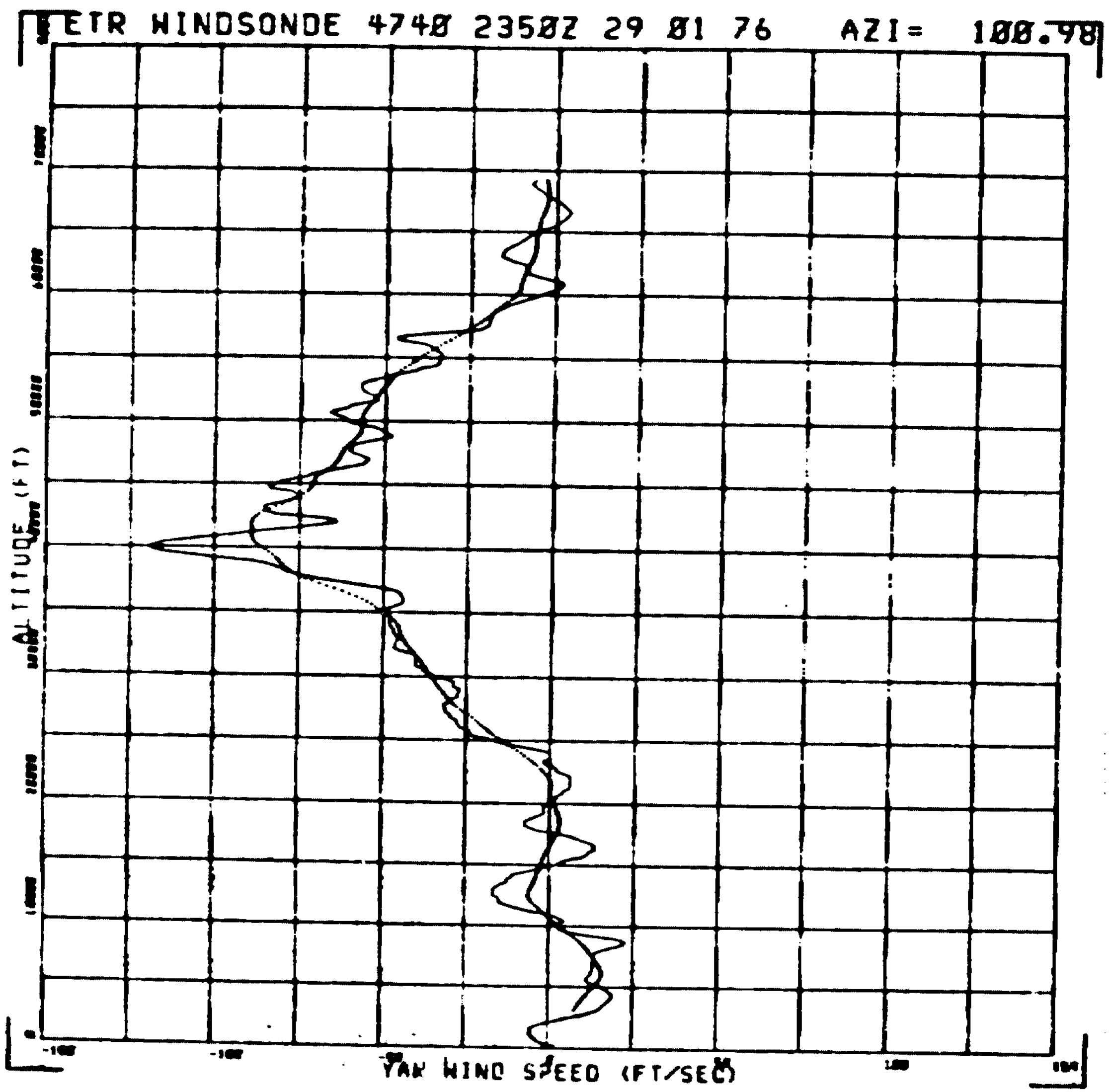
ASCII Character	Octal Value	Sequenced Integer Code
Space Code	0 1 0 0 0 0 0	0
0 (Zero)	0 1 1 0 0 0 0	16
C	1 0 0 0 0 1 1	35
P	1 0 1 0 0 0 0	48

II. Checksum Calculation for First Lines

	ASCII Character	Integer Value
1st Character	C	35
2	S	51
3	O	47
4	M	45
5	4	20
6	2	18
7	Space	0
8	Space	0
9	4	20
10	2	18
11	Space	0
12	Space	0
13	W	55
14	Space	0
15	Space	0
16	Space	0
17	W	55
18-72	Spaces	0
		364/10 = 554/8

5 54/8 = 44/10 decimal integer value

The ASCII character for integer value 44 is "L", which is then transmitted in columns 73 and 74.



Solid line = raw data

Dashed line = smooth data

Sample Plot of Wind Data

Figure 9

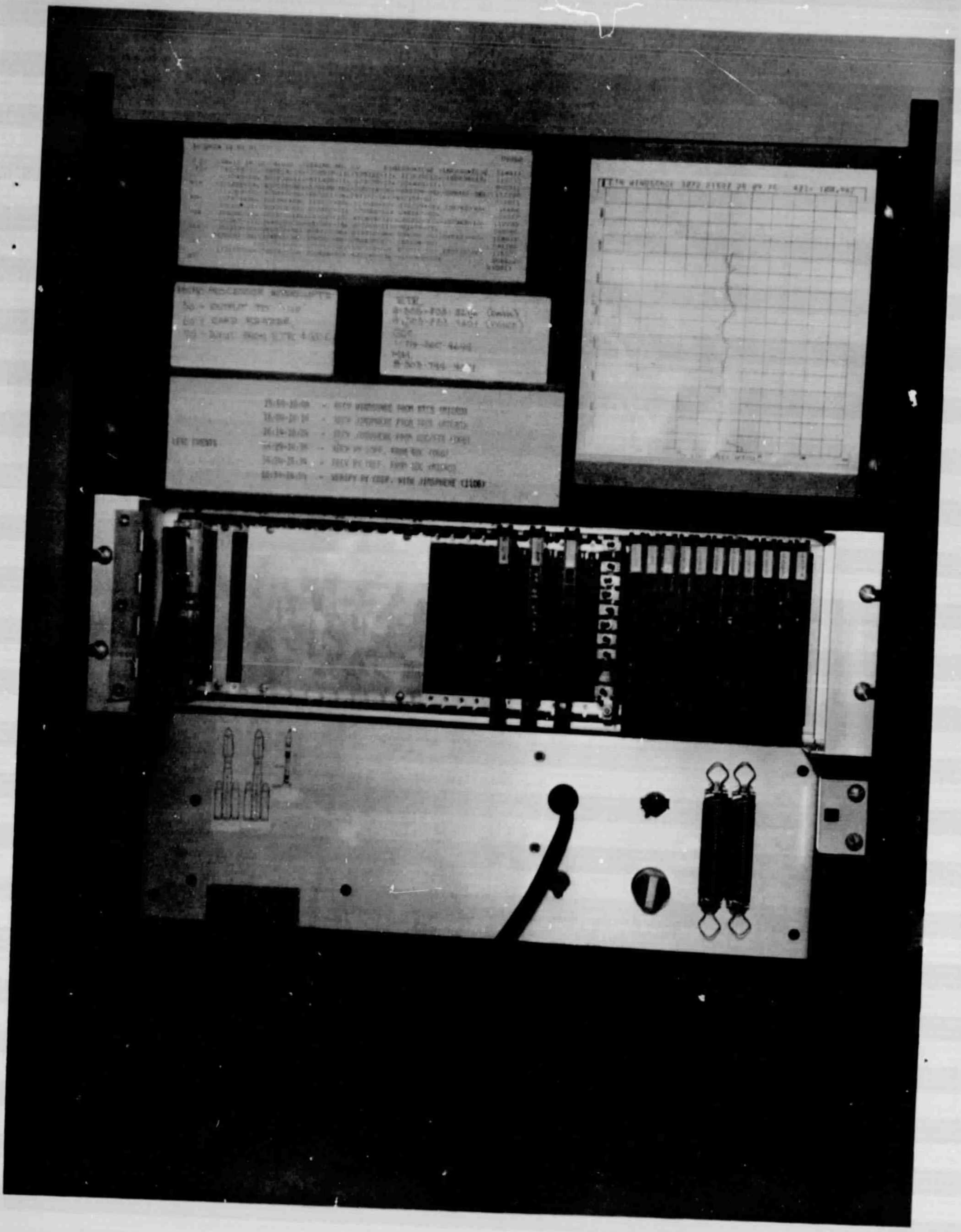


Figure 10 - Micro-Computer