5.4. Data Handling Subsystem.

At the heart of the data handling subsystem is the DMU (Data Multiplex Unit), which performs the tasks of multiplexing or providing a variety of engineering and scientific values from all onboard systems. By using a time-sharing technique, this data can be made available to the ground station over a RF link and to the OBC, which needs this data to perform calculations and, based on the results, send attitude control commands to the stabilization and control system.

There are two completely redundant data multiplexer units. The DMU 1 was used for the whole spacecraft life.

The basic portion of the DMU, called the dataplexer, contains the main analog and digital multiplexers, the spacecraft clock, and timing and control signal logic all in one box. Also, the DMU uses several submultiplexer units which expand the data handling capacity of this system. There are six subcommutators (subcoms): three analog subcoms, one digital subcom and two experiment subcoms.

The analog data inputs are routed to an eight-bit analog-to-digital (A/D) converter. The A/D converter is a successive approximation type, running at the rate of 160,000 comparisons per second. The conversion time for an 8 bit word is 50 microseconds. So, the maximum conversion word rate is identical to the maximum word transmission rate through the dataplexer for telemetry and computer (80 Kbps). The range of analog signal voltage input is from 0 volts to 5.1 volts.

Formats.

The dataplexer selects digital or analog data samples from various spacecraft equipment in a time sequence controlled by a format memory. Each data sample is transformed into an eight-bit data word and transferred to a serial data bit stream. One complete sequence is called a minor frame and is 128 words in length. Each word is dedicated to a particular spacecraft parameter. Switching the telemetry format changes these parameters. However, certain words in the minor frame are dedicated to certain spacecraft parameters that must be observed regardless of the type of operation is being performed with the spacecraft. These fixed word parameters, which always appear in the same location, include frame sync words and information such as the contents of the frame counter, the spacecraft clock, variable format memory contents, and the spacecraft status bits. As there is a need to look at more than 128 telemetry channels, some words in the minor frame are set to represent a different group of fixed telemetry points or channels. This process is called subcommutating. A major frame is defined as 256 minor frames. All submultiplexer data samples are included in each major frame.

The IUE ground station has the option of specifying what type of data will be received at any time depending on what type of operations are being performed. On the one hand, there are four fixed-format and one variable-format to supply telemetry to the ground system and, on the other hand, two fixed, one variable and a computer controlled input (Direct Read Table, DRT) formats are available for the OBC. The fixed formats use ROM memories which cannot be altered after fabrication, while the variable format can be loaded with any desired sequence of dataplexer addresses to compose a format. In the DRT case, the OBC has the dataplexer addresses in its own memory.

The OBC receives not only the data specified specifically intended for the OBC but it also receives a copy of the specified data selected for transmission to the ground. The data input to the OBC's memory is done by way of the Direct Memory Access (DMA) on a prioritized time sharing basis. The DMA also provides the means by which the DRT addresses are output to the DMU.

The ROMs available for ground telemetry and their uses are as follow:

- Format 1A. It was only used during the transfer orbit.
- Format 1B or Camera format. Three-fourths of each frame is devoted to camera video data. This format was used when reading or preparing the cameras.
- Format 2A or Operational format. This format contained a balance of housekeeping and science data and was used routinely.
- Format 2B. It was only used for dumping the OBC memory.

There are also two ROMs used to format data to the OBC. The two ROMs are identical except that ROM 3A provides FES 1 data and ROM 3B provides FES 2 data. In 1985, the change to the 2 gyro/FSS control algorithm required the use of the DRT format by the OBC in order for it to receive the necessary data for this control algorithm.

The figures 5-22, 5-23 and 5-24 show the normal formats used in the last mission years.

BIT RATE = 40 KB/SEC

AVERAGE SAMPLE TIME		
MF	25.6	MSEC
ASC1	204.8	MSEC
ASC2	204.8	MSEC
ASC3	204.8	MSEC

0 1	1 ACCEL A //	2 ACCEL 0 //	3 PAS 1/2 S PULSE	4 SMSS S PULSE	5 S/C BUSS I	6 S/C BUSS V 27/29	7 GYRO 1A //	8 GYRO 1B	9 GYRO 2A //	10 GYRO 2B	11 GYRO 3A //	12 GYRO 3B	13 GYRO 4A //	14 GYRO 4B	15 GYRO 5A //
16 GYRO 5B	17 GYRO 6A //	18 GYRO 6B	19 0	20 0	21 PITCH ERROR	22 ROLL ERROR	23 //	24 FSS#1	25	26	27 //	28 FSS#2	29	30	31 0
32 1	33 //	34 FSS#1	35	36	37 //	38 FSS#2	39	40	41 GYRO 2A //	42 GYRO 2B	43 GYRO 3A //	44 GYRO 3B	45 GYRO 4A //	46 GYRO 4B	47 GYRO 5A //
48 GYRO 5B	49 GYRO 6A //	50 GYRO 6B	51 * 0	52 1	53 1	54 CMD CT1 //	55 CMD CT2 //	56 0 //	57 //	58	59	60 FES DATA	61	62	63
64 1	65 ACCEL A //	66 ACCEL B //	67 PAS 1/2 S PULSE	68 SMSS S PULSE	69 S/C BUSS I	70 S/C BUSS V 27/29	71 GYRO 1A //	72 GYRO 1B	73 GYRO 2A //	74 GYRO 2B	75 GYRO 3A //	76 GYRO 3B	77 GYRO 4A //	78 GYRO 4B	79 GYRO 5A //
80 GYRO 5B	81 GYRO 6A //	82 GYRO 6B	83 1	84 0	85 ASC3 //	86 //	87 //	88 ASC2 //	89 //	90 PITCH TACH //	91 YAW TACH //	92 ROLL TACH //	93 REDUN TACH //	94 ASC2 //	95 0
96 1	97 ACCEL A //	98 ACCEL B //	99 PAS 1/2 S PULSE	100 SMSS S PULSE	101 S/C BUSS I	102 S/C BUSS V 27/29	103 GYRO 1A //	104 GYRO 1B	105 GYRO 2A //	106 GYRO 2B	107 GYRO 3A //	108 GYRO 3B	109 GYRO 4A //	110 GYRO 4B	111 GYRO 5A //
112 GYRO 5B	113 GYRO 6A //	114 GYRO 6B	115 1	116 1	117 ASC 3 //	118 ASC 3 //	119 0	120 0 //	121 0	122 0	123 0	124 0	125 0	126 0	127 0

NOTE: '1'S ARE SIMULATED USING S/C BUSS VOLTS 0-30V. APPROX = 235 COUNTS
'0'S ARE SIMULATED USING DMC-30.
// WORD GATE REQUIRED
MF MINOR FRAME
V OBC FORMAT - DIRECT READ

* FES IS SELECTED BY :OBC CMD 6.0 - FES #1
:OBC CMD 6.1 - FES #2

NOVEMBER 12, 1985

Figure 5-22. Direct Read Table (DRT).

BIT RATE=40KB/SEC

AVERAGE SAMPLE TIME		
MF	25.6	MSEC
ASC1	1.64	SEC
ASC2	1.64	SEC
ASC3	.82	SEC
DSC	1.64	SEC
ESC	1.64	SEC

0 **#	1 **#	2 **#	3 **#	4 **#	5 **#	6 **#	7 **#	8 **#	9 **#	10 **#	11 **#	12 **#	13 **#	14 **#	15 **#
						CAMERA ANALOG VIDEO DATA									
16 **#	17 **#	18 **#	19 **#	20 **#	21 **#	22 **#	23 **#	24 **#	25 **#	26 **#	27 **#	28 **#	29 **#	30 **#	31 **#
						CAMERA ANALOG VIDEO DATA									
32 **#	33 **#	34 **#	35 **#	36 **#	37 **#	38 **#	39 **#	40 **#	41 **#	42 **#	43 **#	44 **#	45 **#	46 **#	47 **#
						CAMERA ANALOG VIDEO DATA									
48 ASC1 #	49 ASC2 #	50 ASC3 #	51 *#	52 *#	53 *#	54 *#	55 *#	56 *#	57 *#	58 CMDEX COUNT # 1	59 CMDEX COUNT # 2	60 FRAME COUNT	61	62	63
						DSC DATA								STATUS GROUP	
64 **#	65 **#	66 **#	67 **#	68 **#	69 **#	70 **#	71 **#	72 **#	73 **#	74 **#	75 **#	76 **#	77 **#	78 **#	79 **#
						CAMERA ANALOG VIDEO DATA									
80 **#	81 **#	82 **#	83 **#	84 **#	85 **#	86 **#	87 **#	88 **#	89 **#	90 **#	91 **#	92 **#	93 **#	94 **#	95 **#
						CAMERA ANALOG VIDEO DATA									
96 **#	97 **#	98 **#	99 **#	100 **#	101 **#	102 **#	103 **#	104 **#	105 **#	106 **#	107 **#	108 **#	109 **#	110 **#	111 **#
						CAMERA ANALOG VIDEO DATA									
112 DSC #	113 S/C I	114 ESC1 #	115 ESC2 #	116 **#	117 **	118 **	119 **	120 **	121 **	122 **	123	124	125	126	127
							CAMERA STATUS				FRAME PARITY CODE WORD			FRAME SYNC	

* INDIRECT ADDRESS REGISTER 1
** INDIRECT ADDRESS REGISTER 2
\# WORD GATE REQUIRED
MF MINOR FRAME

V TELEMETRY FORMAT - 1B76 SCIENTIFIC INSTRUMENT VIDEO DATA JUNE 1, 1979

Figure 5-23. Format 1B (Camera format).

BIT RATE=40KB/SEC

AVERAGE SAMPLE TIME		
MF	25.6	MSEC
ASC1	.41	SEC
ASC2	.41	SEC
ASC3	.82	SEC
DSC	.41	SEC
ESC	.82	SEC

0 *#	1 *	2 *	3 *	4 *	5 *	6 *	7 DMU CAL RAMP	8 #	9	10 GYRO 1A #	11 GYRO 1B	12 GYRO 2A #	13 GYRO 2B	14 GYRO 3A #	15 GYRO 3B
			FES DATA					CAMERA1 STATUS							
16 *#	17 *	18 *	19 *	20 *	21 *	22 *	23 DMU RAD MON	24 #	25	26 GYRO 4A #	27 GYRO 4B	28 GYRO 5A #	29 GYRO 5B	30 GYRO 6A #	31 GYRO 6B
			FES DATA					CAMERA2 STATUS							
32 *#	33 *	34 *	35 *	36 *	37 *	38 *	39 PITCH ERROR CSS	40 #	41	42 BUSS I	43 BUSS V 27/29	44 #	45 #	46 #	47 #
			FES DATA					CAMERA3 STATUS					DIGITAL SUBCOM		
48 *#	49 *	50 *	51 *	52 *	53 *	54 *	55 ROLL ERROR CSS	56 #	57	58 CMDX COUNT 1 #	59 CMDX COUNT 2 #	60 FRAME COUNT	61	62	63
			FES DATA					CAMERA4 STATUS						STATUS GROUP	
64 *#	65 *	66 *	67 *	68 *	69 *	70 *	71 #	72 # 64	73 #	74 #	75 #	76 #	77 #	78 #	79 #
			FES DATA				EXPERIMENT SUBCOM-SYS1				OBC 1 DATA				
80 *#	81 *	82 *	83 *	84 *	85 *	86 *	87 #	88 # 64	89 #	90 #	91 #	92 #	93 #	94 #	95 #
			FES DATA				EXPERIMENT SUBCOM-SYS2				OBC 2 DATA				
96 *#	97 *	98 *	99 *	100 *	101 *	102 *	103 #	104 #	105 # 64	106 #	107 #	108 #	109 # 64	110 #	111 ANALOG SUBCOM3 # 32
			FES DATA					ANALOG SUBCOM 1				ANALOG SUBCOM 2			
112 **#	113 **	114 **	115 **	116 **	117 **	118 **	119 **	120 **	121 **	122 BUSS V 0,30	123	124	125	126	127
					FES/PAS DATA						FRAME PARITY CODE			FRAME SYNC	

* INDIRECT ADDRESS REGISTER 1
** INDIRECT ADDRESS REGISTER 2
\# WORD GATE REQUIRED
MF MINOR FRAME

V TELEMETRY FORMAT -2A76 OPERATIONAL FORMAT JUNE 1, 1979

Figure 5-24. Format 2A (Engineering format).

Indirect addressing (IA) is used as a method to conserve hardware and software space. As it was noted earlier, more than one unit device has been designed to perform the same function, for example there are two FES units, two PAS units, two OBC units, four camera units, etc. The data words allocated to record one of these units may also be used with the redundant unit. The method by which this is possible utilizes the indirect address method which specifies indirectly the address of the unit to be sampled. In other words, this approach minimizes the need for changing an entire format for an experiment having several channels of outputs.

Telemetry and computer sample rates.

The maximum data sample rate (SRATE) through the multiplexer is 80 Kbps with 40 Kbps maximum telemetry data rate and 40 Kbps maximum data rate to the OBC. The DMU is used for both telemetry and computer data-collecting functions, so the input data are split into 2 serial data bit channels, one for each use. The computer and telemetry channels would receive alternate words from the multiplexer if the telemetry bit rate were maximum. In this case, the ratio of computer-to-telemetry words, called the multiplex ratio (MXR) is 1:1, for low telemetry bit rates, the MXR is greater than this and can be selected by ground command as the rest of the DMU parameters (bit rate, indirect addressing, encoding, ground telemetry format, computer format, etc).

The figure 5-25 shows the possible combinations of MXR and SRATE.

TLM TBITRATE(KBPS)	OBC BITRATE(KBPS)	MXR	SRATE
80	0	0=ALL TLM	0
40	0		1
20	0		2
10	0		3
5	0		4
2.5	0		5
40	40	1	0
20	20		1
10	10		2
5	5		3
2.5	2.5		4
1.25	1.25		5
20	40	2	0
10	20		1
5	10		2
2.5	5		3
1.25	2.5		4
----	----		5
10	40	3	0
5	20		1
2.5	10		2
1.25	5		3
----	----		4
----	----		5
5	40	4	0
2.5	20		1
1.25	10		2
----	--		3
----	--		4
----	--		5
2.5	40	5	0
1.25	20		1
----	--		2
----	--		3
----	--		4
----	--		5
1.25	40	6	0
----	--		1
----	--		2
----	--		3
----	--		4
----	--		5

Figure 5-25. Telemetry bitrate possibilities.

Although there were many possible combinations of MXR and SRATE, some of them proved to be the source of many problems during operations, so some restrictions were implemented.

- The 40 Kbps telemetry data rate resulted in faulty data decommutation and was suspected of causing OBC crashes; for this reason, operations were limited to 20 Kbps on November 15, 1978.

- The OBC data rates of less than 20 Kbps were not normally allowed because they resulted in less accurate attitude control.

- The MXR parameter was not permitted to be equal 4 because this caused problems with the DMU.

Operations were usually conducted using 20 Kbps for computer telemetry and 20 Kbps or 5 Kbps (when the signal strength was very low) for ground telemetry.

In addition to the normal mode of transmitting data, another method, known as convolutional encoding exists on the IUE. It is commonly referred to as the convolved data mode. Using a complex algorithm where two bits are telemetered for each data bit, this mode can produce an effective 3 dB gain in signal strength. Since convolved data effectively reduces the amount of data dropouts, it was the nominal mode used during the IUE mission.

5.4.1. The DMU anomaly.

The DMU anomaly was a problem related with erroneous fluctuations in telemetry data. Some telemetry words with values between 160 and 191 were reported as 159. Also, some values around 127 were changed to 63. The 159 wrong values affected both engineering and science data, while the second one only occurred in a few channels and was never observed in science images. As all corrupted values were always analog ones, it was assumed to be a malfunction of the A/D converter of the DMU.

The corruption of specific data points, in particular the reaction wheel tach values, in telemetry was first noted on October 24, 1994 and continued to be observed on a frequent but sporadic basis. At this time, the values of the tachs as received by the OBC DRT format were placed in telemetry, which showed that the OBC was also receiving corrupt values (159s). The corruption only appeared sporadically when the telemetry format was 1B.

On January 1, 1995 the SWP y-alignment value was observed to be corrupted. This parameter had a normal value of 127, its value when corrupted was 63.

On January 6, 1995 the corruption of data was observed with the DMU set to format 2A. When it happened, the DMU and OBC had reached very high temperatures, around 25.6° C and 55.8°C, respectively, for several hours.

A few days later, the 159 corrupted value also appeared in science images. New operation restrictions were applied to avoid high OBC and DMU temperatures. As the OBC was also receiving bad data, a main concern was that the spacecraft attitude control could be affected (some analog values were used by the OBC to determine if its direct read was in synchronization. If the data was determined to not be in synchronization, no attitude programs would be permitted to run).

During the rest of the IUE life, the corrupted data continued appearing in some spectral images, but this problem never affected the spacecraft attitude control. The conclusions reached about this problem are as follow,

- The corruption is directly associated with the DMU and OBC temperatures, as is shown in the figures 5-26 and 5-27.

- The corruption seemed not to be dependent of the radiation environment, as could be seen in the figure 5-28.

- The frequency of corrupted data increased with the time spent in format 1B. The format 1B exercises the A/D converter more frequently than the format 2A. The table below shows the results of a test conducted to check this dependency on November 22, 1995.

- The images did not seem to begin to be corrupted until the level of corruption in the engineering parameters reached values up to 60 %. The engineering data corruption is computed as the number of points corrupted over the total during the time considered. The image corruption is measured as,

  (n° (159s) - n° (168:170))/standard deviation

  The figure 5-29 shows this effect.

Image n°	**Time spent in 1B**	**Time spent in 2A since the last time the s/c was in 1B**	**Average around 159 (148-158 and 160-170)**	**159s**
LWP 31732	26 m	-	79	85
LWP 31733	26 m	7 m	82	119
LWP 31734	26 m	14 m	78	121
LWP 31735	26 m	22 m	77	212
LWP 31736	30 m	5 m	71	522
LWP 31737	29 m	2 m	69	633
LWP 31738	29 m	130 m	77	254

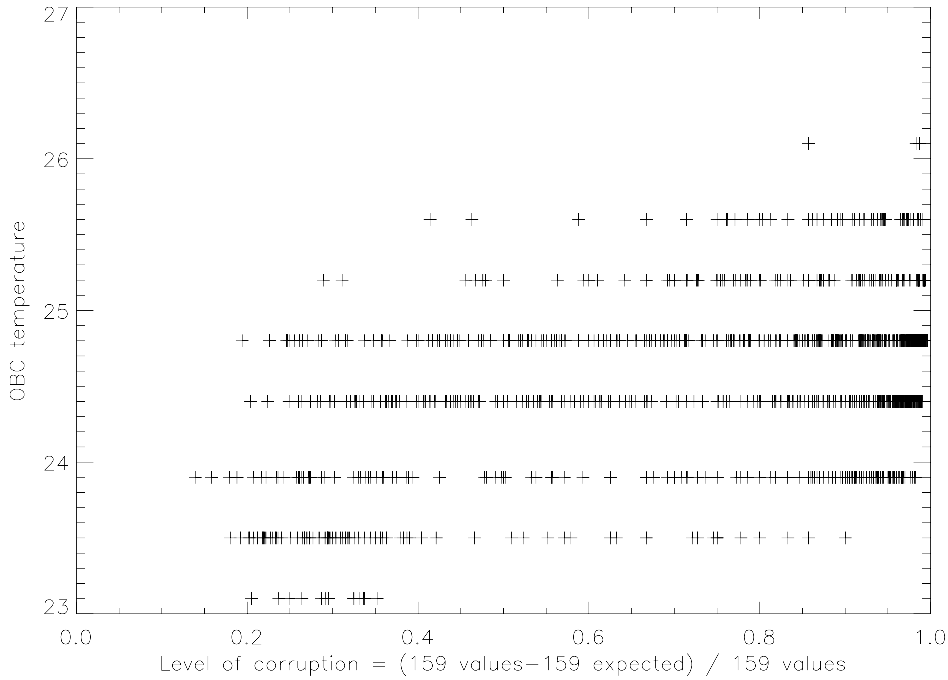

Figure 5-26. Corruption vs DMU temperature.

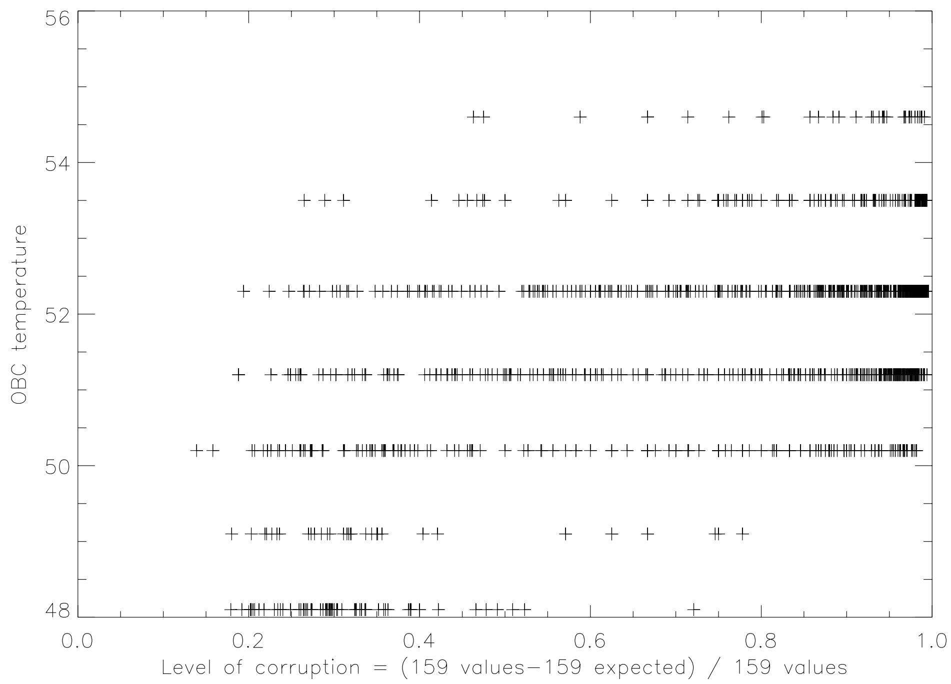

Figure 5-27. Corruption vs OBC temperature.

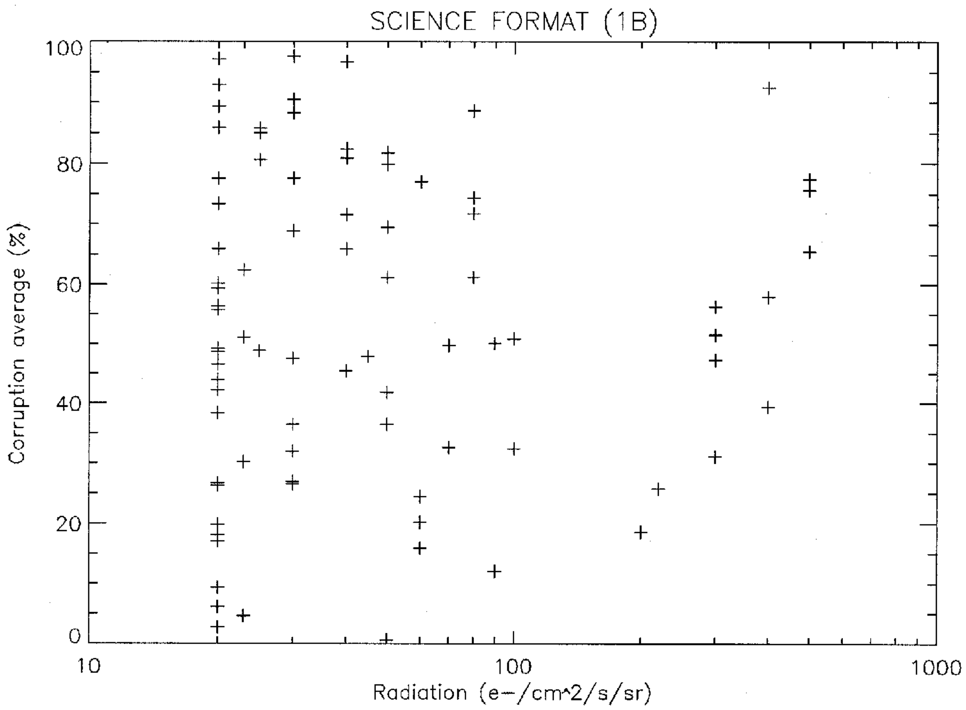

Figure 5-28. Corruption vs radiation.

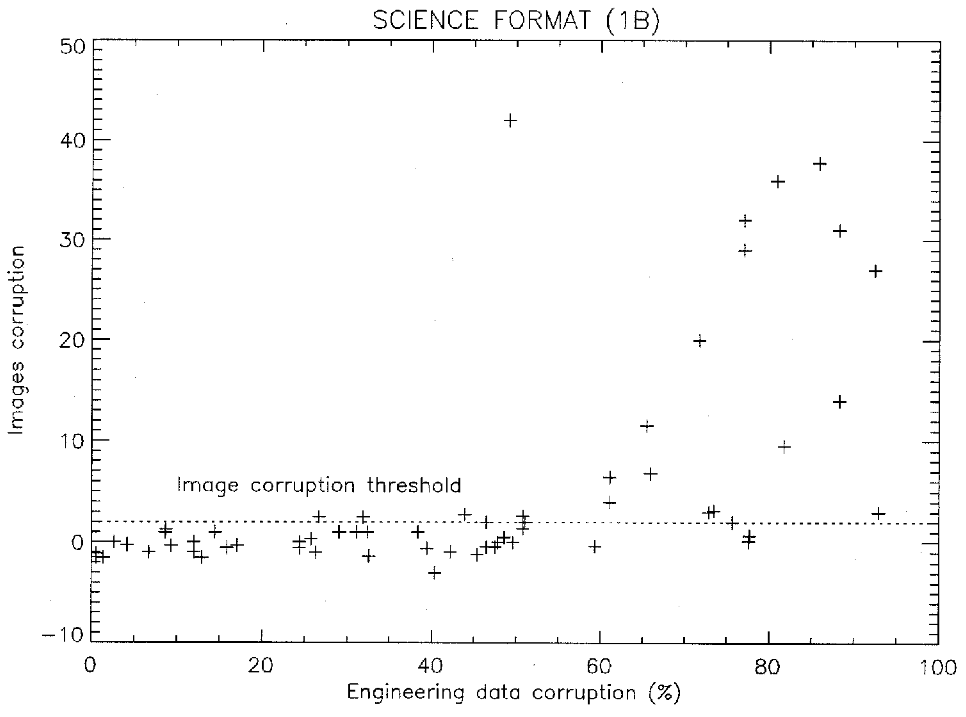

Figure 5-29. Image corruption vs engineering data corruption.

Operational restrictions.

The appearance of corrupted telemetry values had made it necessary to restrict the operating temperatures of the OBC and DMU. A Flight Operations Directive (FOD) limited the OBC and DMU temperatures to 54.6° and 26.1° respectively since January 17, 1995.

The limits imposed on the OBC were intended to prevent the DMU from reaching the temperature where the rate of data corruption becomes excessive. The DMU temperature follows the OBC temperature trend closely but with a lag time; therefore restricting the OBC temperature should prevent the DMU temperature from reaching its critical point.

5.4.2. DMU radiation monitor.

The DMU Radiation Monitor is a type of "free running"experiment on board the spacecraft. The purpose of the package is to examine the damaging effect of radiation in space on certain COS/MOS types of chips. These chips are similar to those used in the data and command systems on board the satellite.

Each of the eight chips was monitored for about five minutes, during a monitor sequence, with data collected every 0.512 sec on all chips. A complete period of all eight cycles appears on the figure 5-30.

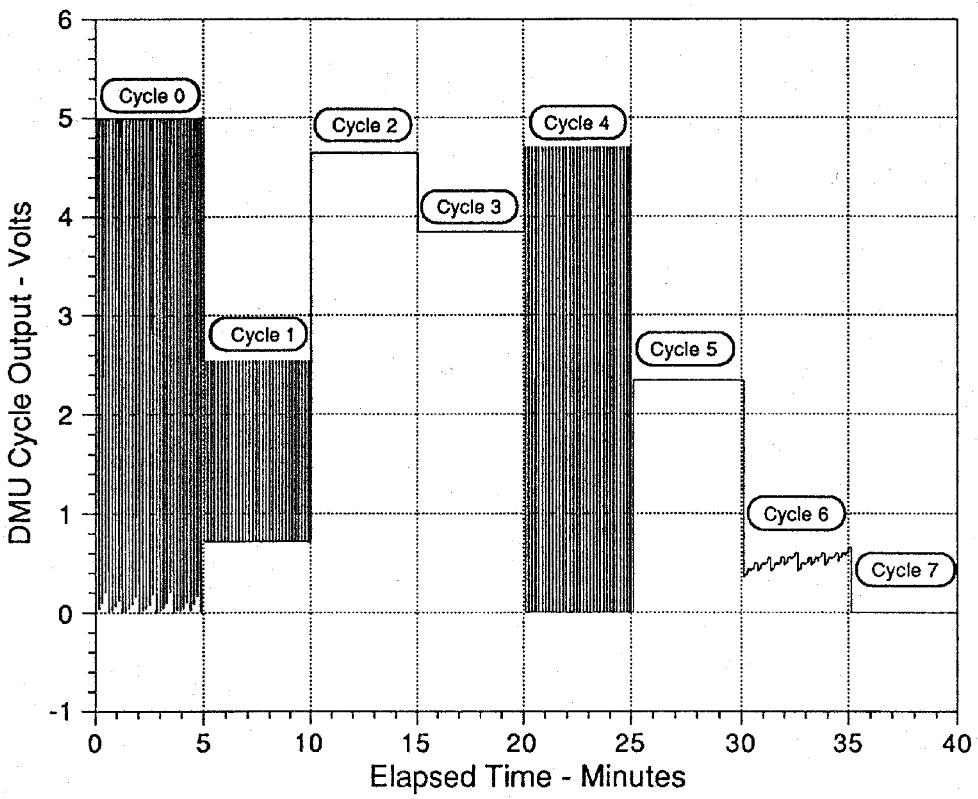

Figure 5-30. DMU Radiation monitor sequence output.

Cycles 0, 1, 4 and 6 produce fluctuating voltages which are graphed along with historical data. Cycles 2, 3, 5 and 7 are constant values and are displayed in historical graph form. A brief explanation of the cycles accompanies each graph.

- **Cycle 0.** (Figures 5-31 and 5-32)
  32 cycles of an exponential rise and fall between an approximate 5.20 v and ground.

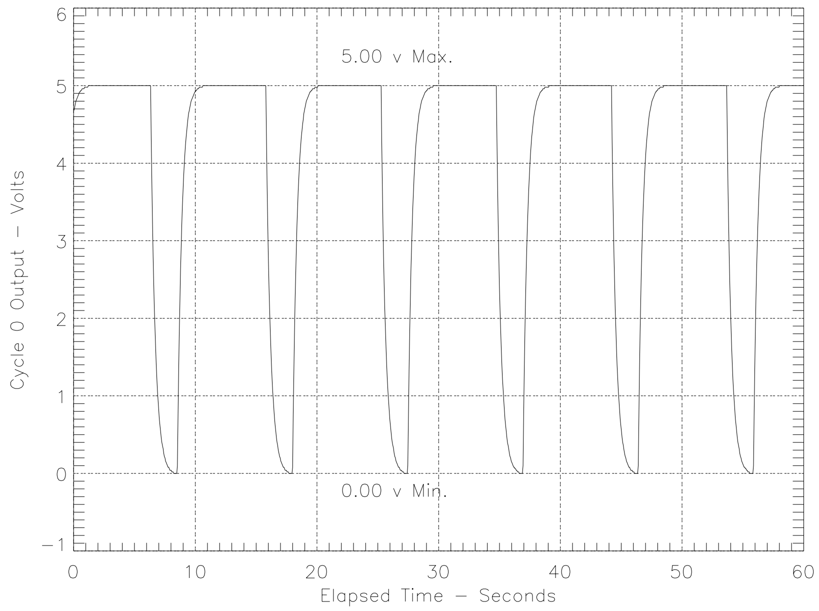

Figure 5-31. Cycle 0 output.

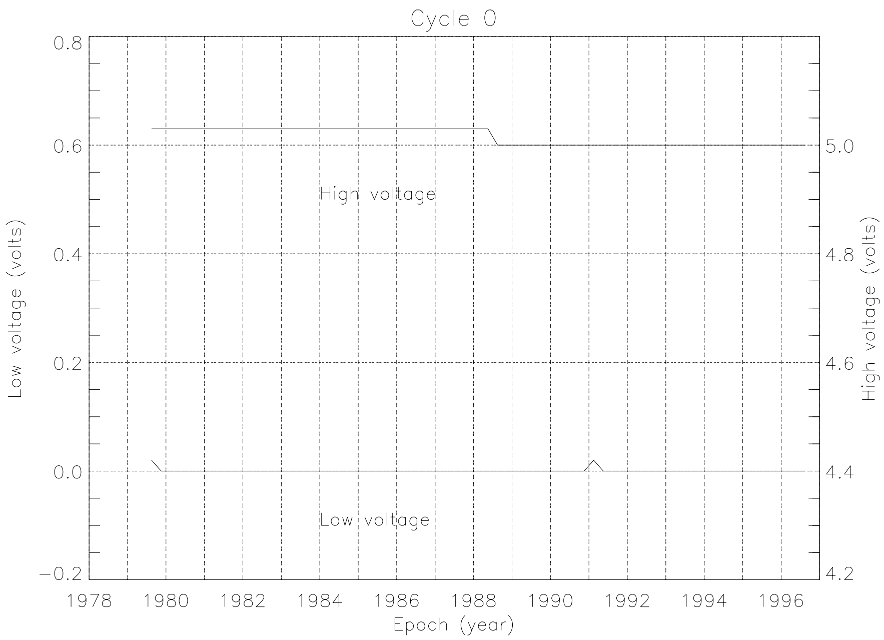

Figure 5-32. History of the Cycle 0 output.

- **Cycle 1.** (Figures 5-33 and 5-34)
  32 switchings between off and device threshold of a PMOS unit.

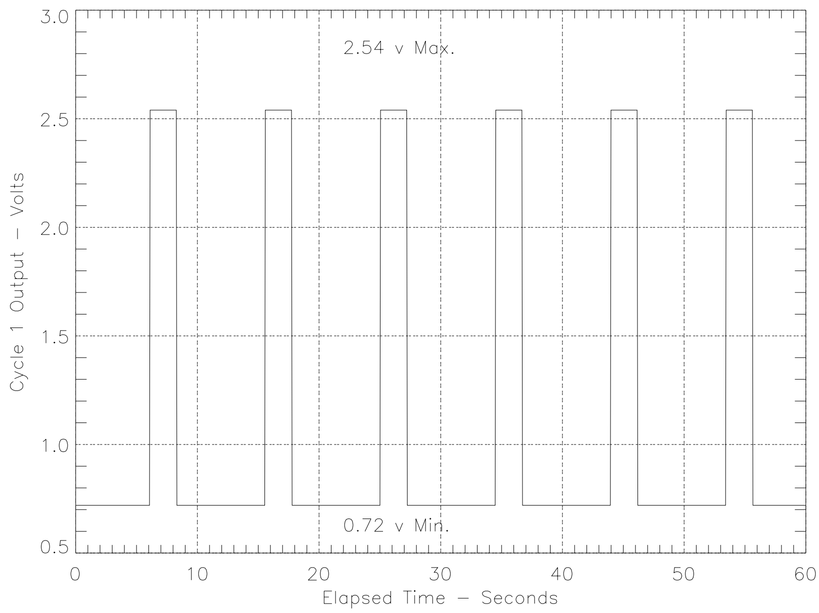

Figure 5-33. Cycle 1 output.

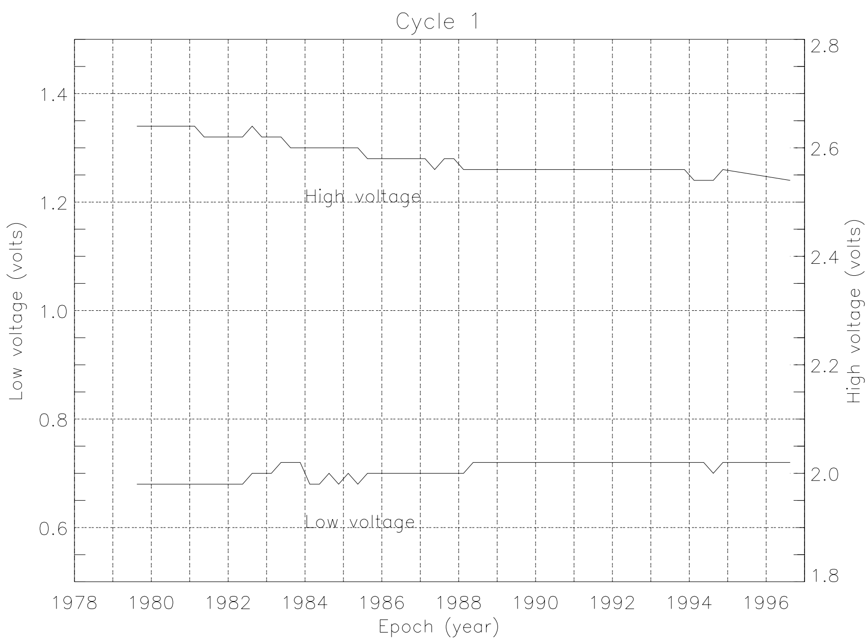

Figure 5-34. History of the Cycle 1 output.

- **Cycle 2.** (Figures 5-35)
The reading of a low threshold device at a continuous threshold.

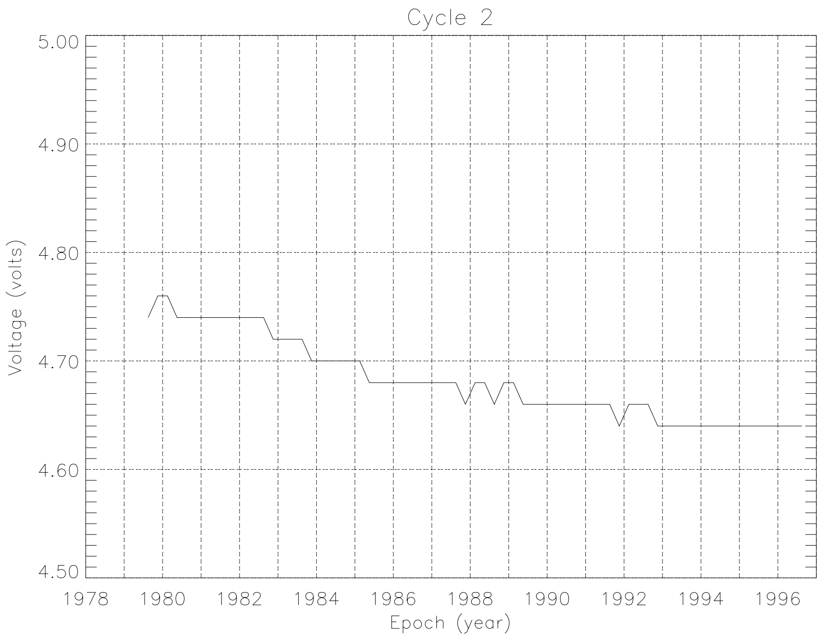

Figure 5-35. History of Cycle 2 output.

- **Cycle 3.** (Figures 5-36)
The operating threshold of a COS/MOS device.

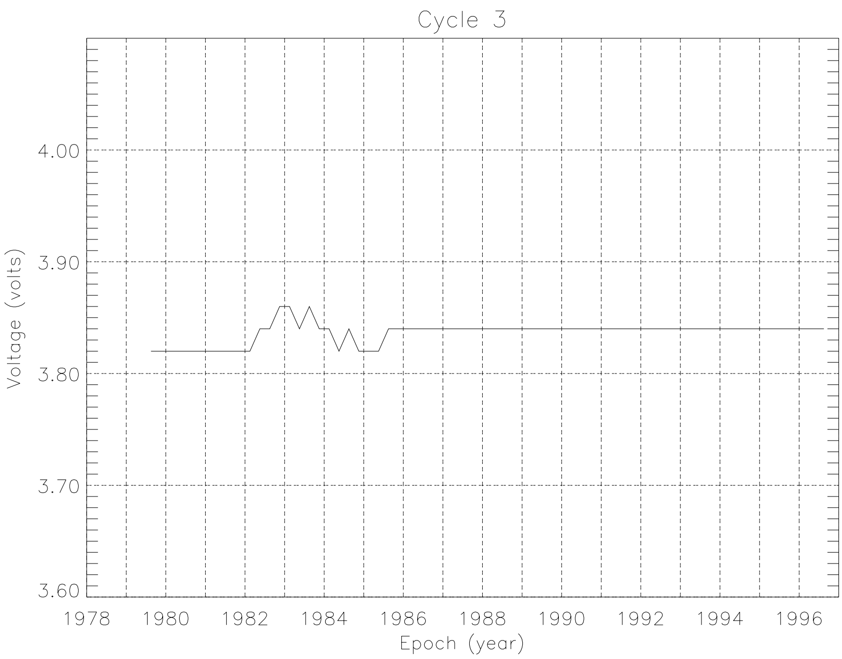

Figure 5-36. History of Cycle 3 output.

- **Cycle 4.** (Figures 5-37 and 5-38)
  32 switchings between off and device threshold of a low threshold device.

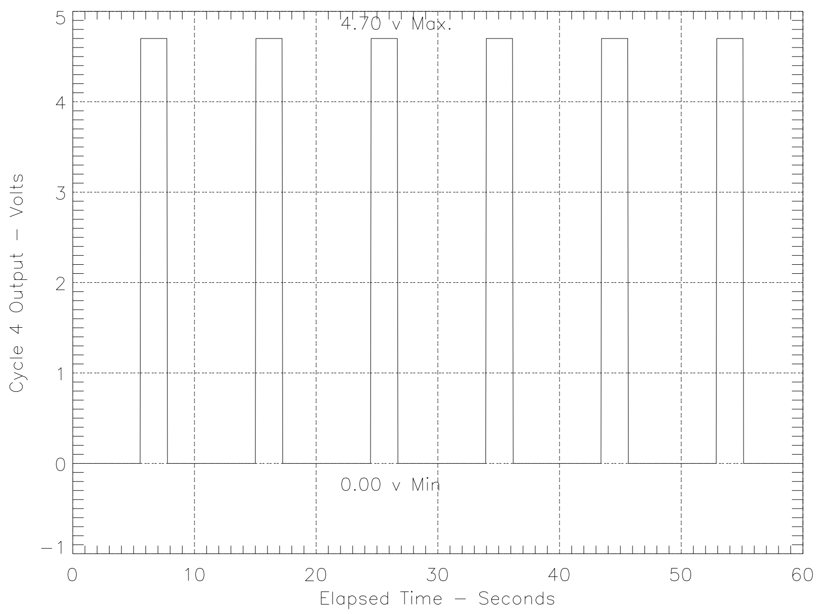

Figure 5-37. Cycle 4 output.

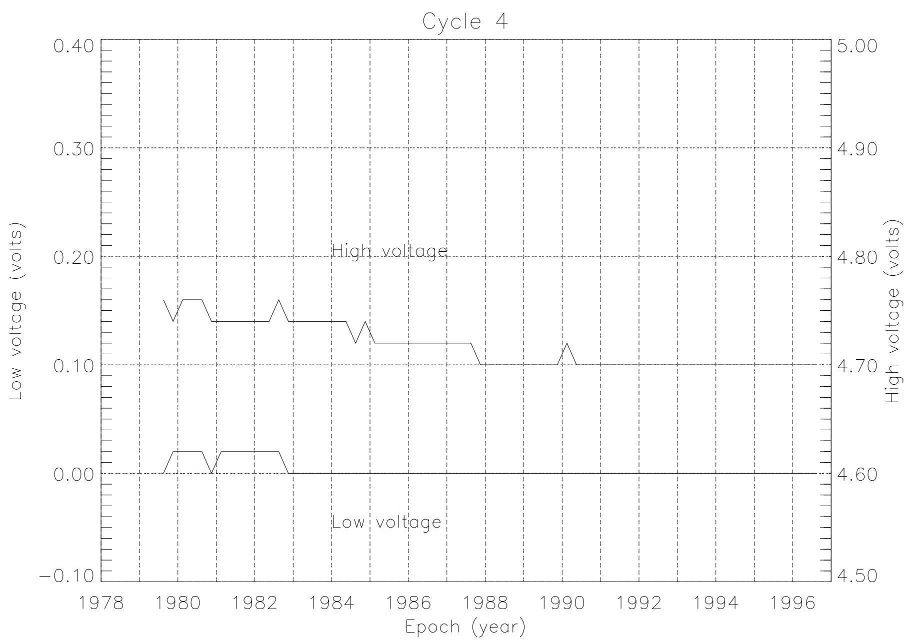

Figure 5-38. History of the Cycle 4 output.

- **Cycle 5.** (Figure 5-39)
  The reading of a high threshold device at a continuous threshold.

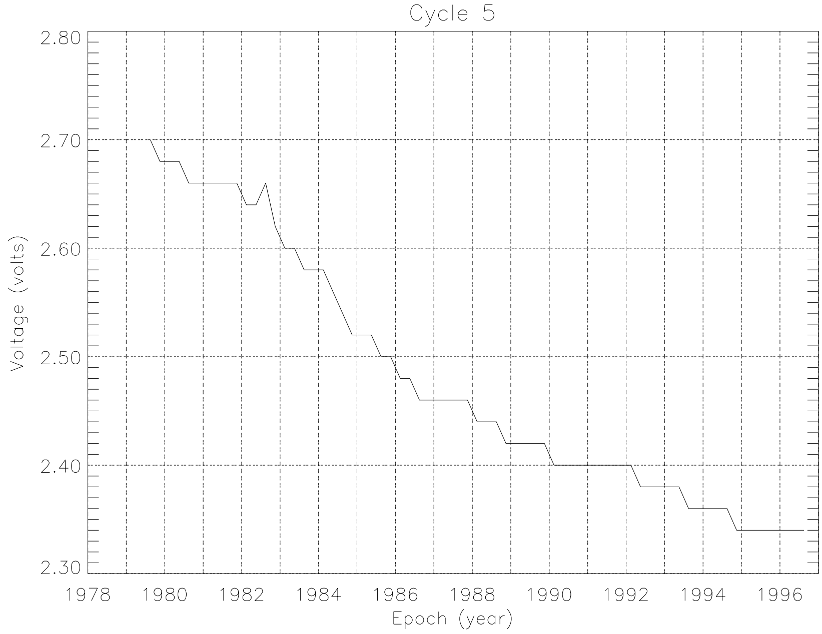

Figure 5-39. History of Cycle 5 output.

- **Cycle 6.** (Figure 5-40)
  The voltage of a PMOS chip going through small changes, as it advances through 32 states.

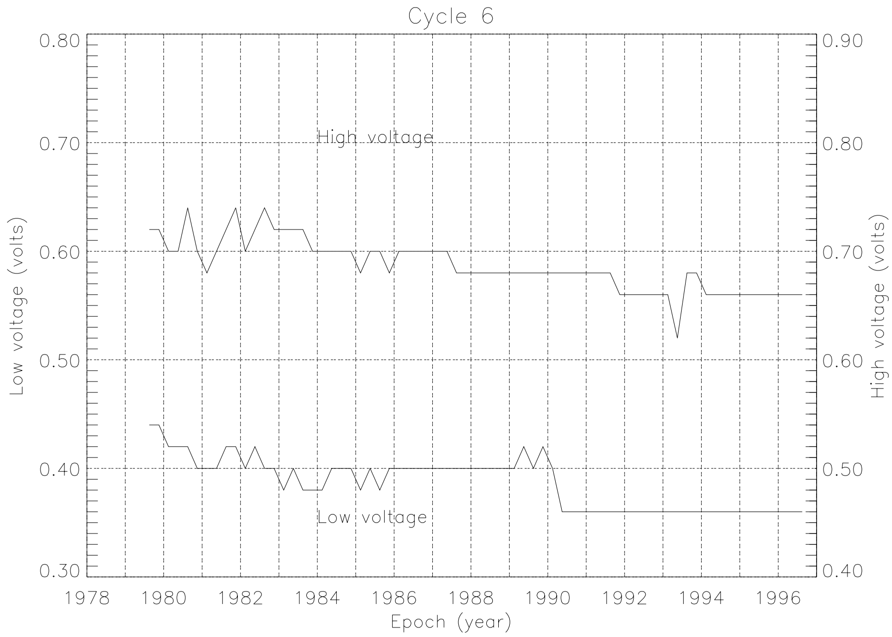

Figure 5-40. History of Cycle 6 output.

- **Cycle 7.** (Figures 5-41 and 5-42)
  Measures degree of COS/MOS saturation of an N-channel device.

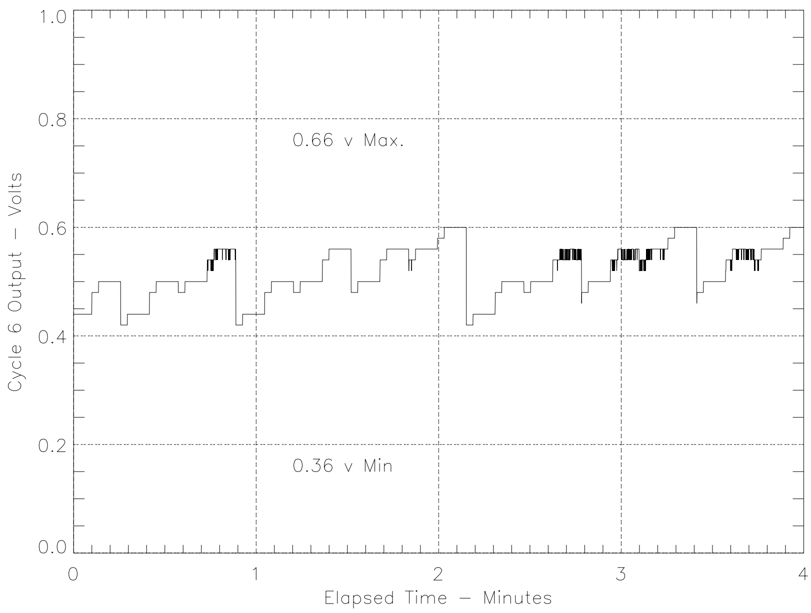

Figure 5-41. Cycle 7 output.

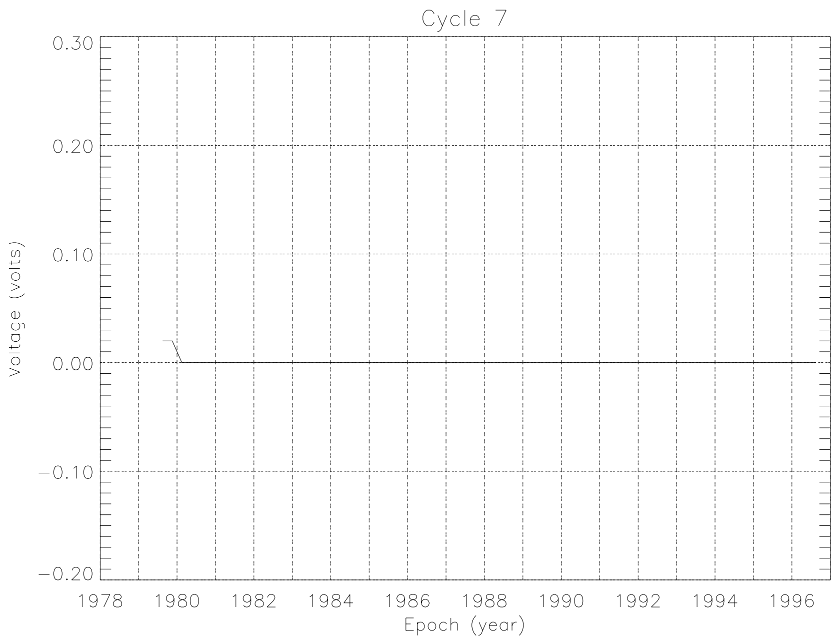

Figure 5-42. History of the Cycle 7 output.

In summary, all of the chips have deteriorated 3 % or less except for the chip utilized during cycle five. This chip has deteriorated approximately 13 % since launch at a slow rate of approximately 0.02 to 0.04 volts per year.