Internal Report # 19

OGO-F-20 DATA FORMAT

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June, 1970

Experiment F-20 uses the following data words of OGO-F telemetry:

From the main commutator F-20 has assigned to it words 9, 10, 11, 12, 39, 87, 113, and 114.

From the experiment subcomm (97) F-20 is assigned words 72, 87, and 106.

The interpretation of these data words is given in detail in the following section. Briefly, experiment F-20 is a cosmic ray experiment which is designed to measure the intensity and composition of cosmic rays in the energy range of 1 Mev to 1 Gev per nucleon. The experiment consists of four parts, Range telescope (R), Čerenkov telescope (Č), Flare telescope (F), and Electronics (E). The three telescopes contain varying numbers of solid state detectors (R contains 7, Č contains 2, F contains 2) and passive (F) or active (R & Č) collimators. In the case of the R & Č telescopes active collimation is achieved by use of cylindrical plastic scintillators. In addition, the Č telescope has a photomultiplier (D3') which has a quartz radiator (1 cm thick) fused to the photocathode. These telescopes cover the energy and intensity ranges of interest as follows:

R	1 mev/nucl → 300 mev/nucl	Galactic cosmic rays and low intensity solar flare
Č	350 mev/nucl → 1 Gev/nucl	
F	17 mev → 100 mev protons 70 mev → 400 mev	high intensity solar flare

The OGO-F data is readout in the following format. Each time the spacecraft is readout, one frame of information is said to have been read. A frame (spacecraft readout) consists of 128 words, a word being a 9 bit entity, bits consisting of a binary bit 1 or 0.

Thus the frame may be diagramed as follows:

	Word 2	Word 2	Word 3	Word 4		
Bit 1	1/1	2/1	3/1	4/1	...	128/1
2	1/2	⋮	⋮	⋮		⋮
3	1/3					
4	1/4					
5	1/5					
6	1/6					
7	1/7					
8	1/8					
9	1/9					

Figure 1

A frame contains 9x128 = 1152 bits. Of the 128 words in a frame, Expt F-20 is assigned words 9, 10, 11, 12, 39, 87, 113, 114. In addition the following words which are spacecraft generated are also considered part of F-20 data, words 33, 34, 35, 65, 97. Thus an F-20 data frame (i.e. that part of spacecraft frame which pertains to F-20) is words 9, 10, 11, 12, 33, 34, 35, 39, 65, 87, 97, 113, 114. I.e. 13 words.

The Caltech GSE for F-20 however presents a somewhat different data frame. In this case, the following parts of a spacecraft frame are presented: Words 9, 10, 11, 12, 33, 34, 39, 65, 87, 97, 113, 114. Notice the difference is that the GSE does not present word 35.

Summary of terminology:

1) Frame = readout of the spacecraft = 128 words = 1152 bits (GSE frame = readout of F-20 experiment via simulator).
2) Word = group of 9 bits of correlated information which makes up a segment of data.

3) Bit = one binary bit of information.

The interpretation of the data is as follows:

A) Word 9:

The first four bits of word 9 indicate the type of event which the readout contains. There are four distinct types of events:

9/1	9/2	9/3	9/4	
0	0	0	1	Cerenkov event
0	1	0	0	Range - no Range
0	1	1	0	Range - Range
1	0	0	0	Flare event

Table I

$$\left(\begin{array}{l} 0 \Rightarrow \text{bit off} \\ 1 \Rightarrow \text{bit on} \end{array}\right)$$

Bit 9/5 indicates that there was not a new event since the previous readout.

i.e. if 9/5 = 1 then there was <u>not</u> a new event since the previous readout

if 9/5 = 0 then a new event has occurred and been recorded.

Bits 9/6, 9/7, 9/8 are overflow indicator for the previous readout.

i.e. bits 9/6, 9/7, 9/8 of frame N refer to frame N-1

9/6 is the 10 overflow indicator
9/7 is the 113 overflow indicator
9/8 is the 114 overflow indicator

(see below for explanation of O/F indicators)

$$\text{as with previous bits, if } \left.\begin{array}{r} 9/6 \\ 9/7 \\ 9/8 \end{array}\right\} = \left\{\begin{array}{ll} 1 & \text{overflow occurred} \\ & \\ 0 & \text{no overflow} \end{array}\right.$$

Bit 9/9 is a parity bit. Certain words (9, 10, 11, 12, 113,

114) have a parity bit which is experiment generated. (This is not to be confused with magnetic tape parity). This parity is odd i.e. if there is an even number of bits on (=1) in word 9 (bits 9/1 through 9/8) then, bit word 9/9 will be on, so that overall, there is always an odd number of bits on.

Overflow: The information in words 10, 113, 114 is in the form of a 217 shift code counter which counts from 0 to 217 but in a random fashion. That is, the 9 bits code for each number cannot be found from any mathematical formula but must be tabulated. If a rate exceeds 217 counts per sampling method, we have an overflow condition. When this happens the O/F bit in the following word 9 is turned on and the rate counter begins accumulating time in the form of a fixed clock whose frequency is less than 217 clocks/sample interval.

Clock Frequencies & Sample Interval

Rate	Sampling Interval (Words)	Sampling Rate $(\text{frames})^{-1}$	Function of Time Sample	Clock Frequency $(\text{frames})^{-1}$	Clock Pulses per S.I.
D5'D6'	127	1	127/128	192	$(192)(\frac{127}{128}) = 190.5000$
D1D8 D2D8 D2D3D8 D1'D2'D3'D4'	383	1/3	383/384	72	$(3)(72)(\frac{383}{384}) = 215.4375$
	127	1/3	$\frac{127}{384}$	192	$(3)(192)(\frac{127}{384}) = 190.5000$
Rate Comm (114(3) Subcomm) 48 Frame Period	383	1/48	$\frac{383}{6144}$	72	$(48)(72)(\frac{383}{6144}) = 215.4375$

Table II

Thus depending upon which rate has overflowed the clock being accumulated is given in clocks/frame above. Note this number is still encoded in the 217 shift code.

OGO-VI Rate Calculations

Source	Rate	SI(sec) @ 1kbs	@ 8	@ 16	@ 64	O/F Clock Pulses/SI
MC 10	D5'D6'	1.14300	0.14285 142875	0.07143	0.01786	190.50
MC 113(1) (2) (3) MC 114(2)	D1D8 D2D8 D2D3D8 D1'D2'D3'D4'	3.4470	0.43088 .430875	0.21544	0.05386	215.4375
MC 114(1)	D5'	1.1430	0.14285	0.07143	0.01786	190.50
MC 114(3)	D1 D2 D3 D4 D5 D6 D7 D8 D1' D2' D3' D4' D6' D1'D2' clock	3.4470	0.43022	0.21544	0.05386	215.4375

Table III

Using the above tables we can calculate actual rates in counts/sec and if an overflow has occurred, we can find the time to overflow and from that the count rate.

Examples:

1) D5'D6' rate = 112, no O/F Bit rate - 8 kbs.
The count rate is 112 counts/sampling interval. The sampling interval is 127 words out of 128 words and at 8kbs we get

$$SI = \underset{\substack{\uparrow \\ \text{SI} \\ \text{in} \\ \text{frame}}}{\frac{127}{128}} \times \underset{\substack{\uparrow \\ \text{bits/} \\ \text{frame}}}{1152} \times \underset{\substack{\uparrow \\ \text{sec/} \\ \text{bit}}}{\frac{1}{8000}} = 0.143 \text{ seconds}$$

$$\text{thus Rate} = \frac{112}{.143} = 784 \text{ counts/sec}$$

2) D1D8 rate = 25, O/F on Bit rate = 4 kbs

sample interval = 383 words out of 384 words = $\frac{383}{384} \times 3$ frames

$$= \frac{383}{128} \times \frac{1}{64000} \times 1152 \text{ sec}$$

$$SI = .0539 \text{ sec}$$

$$\text{time to } /F = SI\left(1 - \frac{\overset{\text{count}}{25}}{\underset{\text{clock pulses/SI (see chart)}}{215.4}}\right)$$

$$= .0477 \text{ sec}$$

$$\text{thus Rate} = \frac{217}{0.0477} \text{ counts/sec}$$

$$= 4.56\text{x}10^3 \text{ counts/sec}$$

3) What number should the overflow clock monitor in the word 114(3) subcomm read?

Counter will sample 72 count/frame clock after o/F before o/F counter samples 192 count/frame clock. The sampling interval is $\frac{283}{128}$ frame and it will take $\frac{217}{192}$ frames to read o/F

$$\text{therefore} \quad N = \left(\frac{383}{128} - \frac{217}{192}\right) \times 72$$

$$= 134$$

this particular rate will be independent of the bit rate!

4) O/F clock reads 134 O/F on

Rate = 217/TOF

$$TOF = SI\ (1 - \frac{134}{215.4375}) = SI(1-0.62199)$$

$$= 0.43088(0.37801)$$

$$= 0.16288$$

Rate = 1332.27 sec^{-1}

B) Word 10:
The interpretation of word 10 depends upon the type of event as indicated by bits 9/1 through 9/4.

1) If word 9 indicates a Čerenkov event, $\overset{9/1\ \ 9/4}{(0001)}$ then word 10 contains the HTC content from detector D1'. (This is called HTC I).
The interpretation of the bits in word 10 is as follows:
Bits 10/1 through 10/8 contain a shift code (255) counter output. This can be converted to a decimal by looking up a shift code table.
Bit 10/8 is the least significant bit
10/1 is the most significant bit
Interpretation of an HTC shift code counter is illustrated:

Word 10 = 11000110

↑ ↑

10/1 10/8

look up this combination of bits in shift code table get

HTC1 = 120

2) If word 9 indicates a Range - D1 event $\overset{9/1\ \ 9/4}{(0100)}$ then word 10 contains the HTC output from detector D1. (This is called HTC1).
The interpretation of word 10 is the same as for a Čerenkov event.

3) If word 9 indicates a Range-Range $\overset{9/1\ \ 9/4}{(0110)}$ then word 10 contains the range information. This information comes in the

form of indicator bits as described in the table:

Bit	Disc.
10/1	$D7_H$
10/2	$D6_H$
10/3	$D5_H$
10/4	$D4_H$
10/5	D7
10/6	D6
10/7	D5
10/8	D4

Table IV

e.g. if the following discriminators were triggered D4, D5, D6, $D4_H$ then word 10 is:

00010111

↑ ↑

10/1 10/8

9/1 9/4

4) If word 9 indicates a Flare event (1000) then word 10 contains rate information.
Now, bits 10/1 through 10/8 contain a 217 shift code counter output (as opposed to the 255 SCC for HTC information)
Once again bit 10/8 is the least significant bit
10/1 is the most significant bit
the output is converted to a decimal by looking up in a table.
Illustration:

Word 10 = 11000110

↑ ↑

10/1 10/8

look up this combination of bits in shift code list
get D5'D6' rate = 61.

The last bit of word 10 i.e. 10/9 is a parity bit. Regardless of the interpretation given to bits 10/1 through 10/8, bit 10/9 is always set. So there will will be an odd number of bits = 1.

C) Words 11 & 12:

Words 11 & 12 always contain HTC information in the form of 255 shift code counters. The detectors with which these HTC's are connected depends upon the type of event.

Event	Bit 9/1-9/4	Word 11 HTC2	Word 12 HTC3
Cerenkov	0001	D2'	D3'
Range D1	0100	D2	D3
Range D1	0110	D2	D3
Flare	1000	D5'	D6'

Table V

As with word 10, the bits 11/1 through 11/8
12/1 through 12/8
are to be interpreted in terms of a shift code table. Bits 11/9 and 12/9 are parity bits.

D) Words 33, 34, and 35

Words 33, 34, and 35 make up the time data. This in spacecraft supplied data. The interpretation of this data is straightforward binary as illustrated in the GSFC bulletin #F-52, revised 3/30/68.

Bit	Value
35/9	2^0
35/8	2'
35/7	.
35/6	.
35/5	.
35/4	
35/3	
35/2	
35/1	
34/9	
34/8	

Bit	Value
34/7	
34/6	
34/5	
34/4	
34/3	
34/2	
34/1	
33/9	
33/8	
33/7	
33/6	
33/5	
33/4	
33/3	2^{24}
33/2	not used
33/1	not used

The accumulated time thus obtained is in units of 1.152 seconds.

E) Word 39:

Word 39 is the analog D8 rate. This information is originally in analog form as a voltage from a ratemeter in the F-20 experiment. The spacecraft analog to digital converter then digitalizes this analog level, and the result is in word 39 in binary form.
(Note this is the instantaneous rate at the time of sampling).

Bit	Value
39/1	0 (always)
2	2^7
3	2^6
4	2^5
5	2^4
6	2^3
7	2^2
8	2^1
9	2^0

Note: No parity for Word 39.
Conversion of this binary number to actual rate is not done here.

F) Word 65:

Word 65 is a spacecraft generated word and it gives the experiment sub-commutator position. That is, in a frame, one word (= #97) wil contain different information for each frame. The information in word 97 repeats every 128 frames, i.e. word 97 is sub-commutated. Word 65 tells us which piece of information is in word #97. The number in 65 is in binary form as follows:

Bit	Value
65/1	2^6
2	2^5
3	2^4
4	2^3
5	2^2
6	2^1
7	2^0
8	Not Used
9	Not Used

when word 65 = n, word #97 will contain the (n+1) (Modulo 128) variant.

e.g. WD 65 = 113

WD 97 = 97 (114)

G) Word 87:

Word 87 is the analog D4' rate and has the same interpretation as word 39. As with word 39, the binary number from the ADC is not converted into an actual rate at this time.

H) Word 97 (Experiment Sub-Comm)

As mentioned earlier, F-20 uses words 97(72) 97(87) & 97(106). These positions on the sub-comm are identified by looking at word 65 - the sub-comm counter.

1) 97(72)

This word contains the impulse command status of the experiment and a position counter for the 113-114 sub-comm which is explained later.

The command status is as follows:
F-20 has 6 impulse commands - C1-C6 and a reset command C7. The status of commands C1-C6 (i.e. on or off) is indicated by the first 6 bits of 97(72).

Bit	Command	
97(72)/1	C1	The meaning is as follows: if a bit is on, it means that the command is not on. (not sent). Thus in the reset condition (i.e. if on is sent) bits 1-6 will be on (=1)
2	C2	
3	C3	
4	C4	
5	C5	
6	C6	

Table VI

The interpretation of the commands is as follows:

Command	Meaning
C1	Flare telescope disable
C2	D1'D3' analysis enable
C3	D2'D3' analysis enable
C2 & C3	Čerenkov telescope disable
C4	D1 analysis disable
C5	D3 analysis enable
C6	D2 analysis enable
C5 & C6	Range telescope disable

A truth table will clarify the above.

A) Flare telescope:

97(72)/1	Flare event means
1	D5' D6' coincidence
0	telescope disabled

B) Čerenkov telescope

97(72)/2	97(72)/3:	Čerenkov event means
1	1	D1'D2'D3'$\overline{\text{D4}}$' coincidence
0	1	D1'D3'$\overline{\text{D4}}$'
1	0	D2'D3'$\overline{\text{D4}}$'
0	0	telescope disabled

C) Range telescope

97(72)/4	97(72)/5	97(72)/6	No Range event means	Range event means
1	1	1	(D1VD2D3)$\overline{\text{D8}}$	(D1VD2D3)(D4VD5VD6VD7)$\overline{\text{D8}}$
0	1	1	(D2D3)$\overline{\text{D8}}$	(D2D3) (")$\overline{\text{D8}}$
1	0	1	(D1VD3)$\overline{\text{D8}}$	(D1VD3) (")$\overline{\text{D8}}$
1	1	0	(D1VD2)$\overline{\text{D8}}$	(D1VD2) (")$\overline{\text{D8}}$
0	0	1	(D3) $\overline{\text{D8}}$	(D3) (")$\overline{\text{D8}}$
0	1	0	(D2) $\overline{\text{D8}}$	(D2) (")$\overline{\text{D8}}$
1	0	0	Telescope	
0	0	0	disabled	

Notes: "V" means logical or
( ) ( ) means logical and

The commands C5 and C6 will also change the meaning of several rates which are discussed below:

The two remaining bits in 97(72) give the position of another commutator. That of words 113 & 114.
These bits - 97(72)/7 & 97(72)/8 are called x & y respectively.
The table of x y values and the 113, 114 commutator position is given:

x	y	113, 114 SC
1	1	1
0	1	2
1	0	3

Table VIII

Bit 97(72)/9 is a parity bit.

II) 97(87) and 97(106)

These words are the analog Range telescope temperature and Čerenkov telescope temperatures. The information is given as a binary number decoded as follows:

Bit	Value
/1	not used
/2	2^7
/3	2^6
/4	2^5
/5	2^4
/6	2^3
/7	2^2
/8	2^1
/9	2^0

These numbers are not actual temperatures and must be further decoded by comparison with calibration. However, this is not done here.

I) Words 113 & 114

Words 113 and 114 are digital rates. They are jointly commutated on a modulus 3 basis. I.e. there are 3 rates which appear alternately in word 113 and 3 rates which appear alternately in Word 114. Which of these rates is present at any given time is determined by a counter which counts modulo 3 and is synchronized with xy from word 97(72).

These rates are encoded by a 217 shift code counter, as the flare rate is. Thus the interpretation of the rates as decimal number is done through a table.

Bit 8 is the least significant bit

    1 is the most significant bit

thus if Word 113 = 11000110

$$\begin{array}{cc} \uparrow & \uparrow \\ \text{bit 1} & \text{bit 8} \end{array}$$

this rate is 61.

As already mentioned, which rate depends upon the sub-comm position:

113(1)	113(2)	113(3)	114(1)	114(2)	114(3)
D_1D_8 rate	D_2D_8 rate	$D_2D_3D_8$ rate	D_5' rate	Č rate	Comm rate

In addition to this 3 position commutator, 114(3) is sub-commutated with 16 positions. Thus it takes 48 frames for all the data about rates to be read.

114(3)	sub-comm	
1	D1	rate
2	D2	"
3	D3	"
4	D4	"
5	D5	"
6	D6	"
7	D7	"
8	D8	"
9	D1'	"
10	D2'	"
11	D3'	"
12	D4'	"
13	D6'	"
14	$D1D2\overline{D8}$	"
15	192 pulse/frame clock	
16	all zeros (sync)	

Note: A rate of all zeros (before SCC conversion) is a unique state which cannot be reached by a SCC. Thus it identifies position 16 of the 114(3) sub-comm. The D2D8 rate counter and the D2D3D8 rate counter will take on different meanings when impulse commands have modified the normal range system operation. The following table gives the proper interpretation of these rates.

C5 97(72)/5	C6 97(72)/6	$D2\overline{D8}$ Rate Means	$D2D3\overline{D8}$ Rate Means
1	1	$D2\overline{D8}$	$D2D3\overline{D8}$
0	1	$D2\overline{D8}$	$D3\overline{D8}$
1	0	$D2D3\overline{D8}$	$D2\overline{D8}$

Further Note: The D5' rate (114(1)) upon overflow resets to 192 rather than 0. Therefore an overflow count of 192 → 217 is really given by subtracting 192 and a count of 0 to 167 is given by adding 25.

NUMBERS OF INTEREST

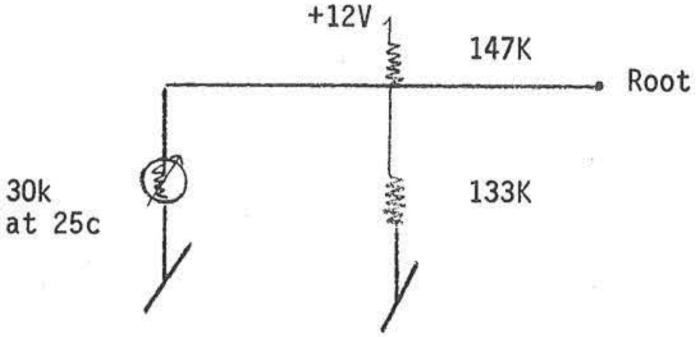
OGO-F

Bit Rate sec^{-1}	Bit Period sec	Word Length sec	Frame Length sec	Frame Rate sec^{-1}	Sub-Comm Frame Length sec	Sub-Comm Frame Length sec^{-1}	Notes
(1000)	1.10^{-3}	9.10^{-3}	1.152	0.87	147.5	0.0068	Not used on OGO-F but available from GSE for ground use.
(4000)	250.10^{-6}	2.25.10^{-3}	0.288	3.47	36.86	0.027	
8000	125.10^{-6}	1.125.10^{-3}	0.144	6.74	18.43	0.056	Rate used most often on OGO-F
10000	62.5.10^{-6}	562.5.10^{-6}	0.072	13.7	9.22	0.11	
64000	15.625.10^{-6}	140.625.10^{-6}	0.018	55.6	2.30	0.43	

OGO-F-20

Conversion for SC 97(87) & SC 97(106)

These data words contain analog temperatures as read from the following circuit:



Root (Volts)	Temp (°C)
.80	49.5
1.00	41.5
1.20	35.9
1.40	31.3
1.80	23.2
2.00	19.6
2.20	16.2
2.40	13.1
2.60	10.4
2.80	7.4
3.00	4.5
3.20	1.6
3.40	-1.3
3.60	-4.2
3.80	-7.2
4.00	-10.1

$$E_r = \sqrt{\left(\underset{\substack{\Big\downarrow \\ \frac{1}{\sqrt{N}}}}{\begin{matrix}\text{Statistical}\\ \text{Error}\end{matrix}}\right)^2 + \underset{\substack{\Big\downarrow \\ \frac{T_c R}{P_{SI} \quad -T_c R}}}{\left(\frac{\text{Clock Error}}{2\sqrt{\pi}}\right)^2}}$$

gaussian
(law of
large
numbers)

T_2 = clock period (Frames)

R = rate (Frames)

$$P_{SI} = \frac{\text{clock pulsers}}{\text{sampling interval}} = \left[\sum (T_c \times \text{S.I.})\right]$$

S.I. =

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