X-614-66-212

NASA TM X-55535

DETERMINATION OF ACCURATE TIME ON OSO-1

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GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

MAY 1966

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

FACILITY FORM 602

N66 30358 (ACCESSION NUMBER)

16 (PAGES)

TMX-55535 (NASA CR OR TMX OR AD NUMBER)

(THRU)

1 (CODE)

14 (CATEGORY)

DETERMINATION OF ACCURATE TIME ON OSO-I

By

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For several purposes, such as the measurement of atmospheric absorption, there is a need to determine quite accurately the time at which various events in the data records from OSO-I occur. This report outlines a method of establishing an on board clock which we feel is accurate to better than one second.

On OSO-I there are four different instruments or measurements that can be employed as timing devices. No single device can be consistently employed to determine the exact time. Using a combination of these devices, an accurate method of determining time can be achieved (accuracy ±1 second).

The timing signals available on the strip charts and their various advantages and disadvantages are:

1. Satellite Clock - a 955 cps oscillator impressed on a subcarrier; somewhat unstable, not readable during intervals of R. F. noise, stops during playback.
2. Spectrometer Carriage - one cycle per 1000 seconds;

stops at night, not accurate, but long period bridges the time gap during playback very nicely.

3. Channel 6 Commutator - very accurate, runs all of the time, not finely divided (one synchronizing pulse every 51.2 seconds), pulse has no numeric identification, record missing during playback.

4. Time of Playback Command - not always on record, occasionally wrong. The playback command causes the tape recorder to stop recording data and begin playback. Hence it corresponds to end of data on the strip chart.

The establishment of accurate time on board OSO-I satellite can be outlined as follows: First, once it is known or suspected that the Channel 6 commutator is very accurate, we determine the number of 51 second cycles of Channel 6 from the last synchronizing pulse on one orbit to the last synch pulse on the next orbit. We can count the number of synch pulses on the strip chart record but we must find out how many pulses are missing during the five minute playback gap. This can be done by using the motion of the spectrometer carriage as a clock which takes about seventeen minutes to make one cycle. Second, the Universal Time of the last Channel 6 synch pulse on the strip chart for each orbit is determined by using the satellite clock to cover the small interval of time between the pulse and end of data (Command Time). Third, from the number of cycles between successive last synch pulses and the elapsed time from the second step we can determine precisely the average cycle time between synch pulses. Fourth, these in combination with the finely divided satellite clock can be used to establish the time at any point on the record.

Figure 1 shows the average cycle time between successive synch pulses for each orbit or sometimes a group of orbits if command times or strip charts were missing for some orbits. One observes that the cycle time decreases slowly during the first two months, but there is very little scatter of points. This very small scatter is good evidence for the stability and accuracy of the Channel 6 commutator. This excellent stability also makes it possible to establish the time over up to ten orbits where strip charts or command times may be missing, because the number of intervening pulses must be exactly an integer. In order that the Channel 6 cycle length sould change smoothly, two or three of the command times were assumed incorrect and were changed slightly, e.g., on orbit 281, E was changed from 33955.1 sec. to 33950.8 sec.

To simplify the analysis of the Channel 6 data, two small Fortran programs were written. Some parts of these programs are described briefly below.

The following is a description of symbols used:

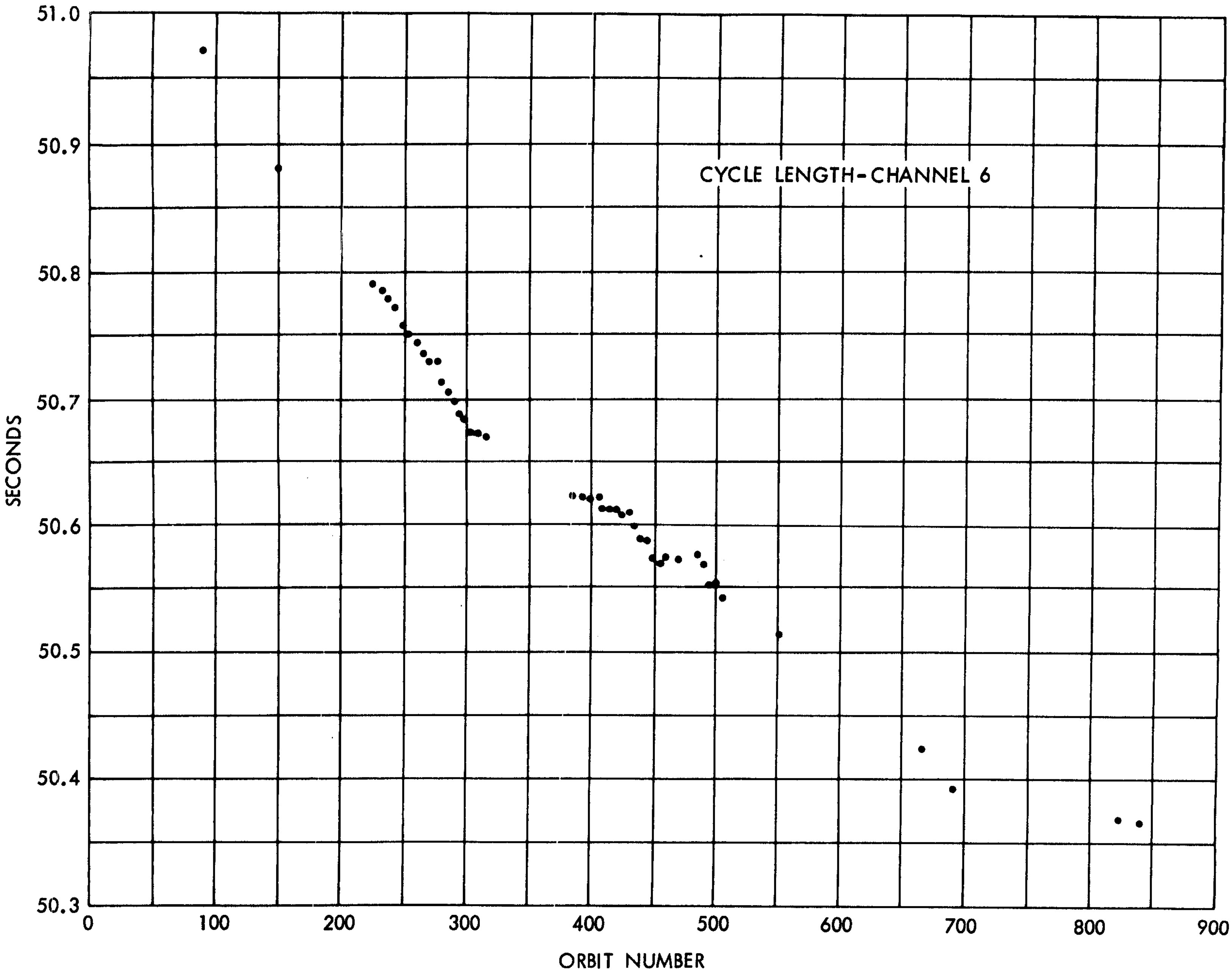

Figure 1. Average cycle time between successive Channel 6 synchronizing pulses for each orbit or group of orbits.

The use of the subscript, A, indicates a floating point number that must be increased to the next integer.

UT	-	Universal Time
SC	-	Satellite Clock Time
CT_{UT}	-	Command Time
$E_{SC/UT}$	-	Last Synchronizing pulse on Channel 6 E occurs within 51.2 seconds of end of data; $E_{UT} = CT_{UT} - (\text{End of data}_{SC} - E_{SC})$
FR_{SC}	-	First synchronizing pulse on Channel 6
C_{SC}	-	Randomly selected synchronizing pulse appearing on strip chart

The uncorrected values of universal time for FR_{SC} and C_{SC} are not accurate because the satellite clock was used over long intervals.

PE_{SC}	-	Synchronizing pulse nearest event
50.93	-	Nominal time lapse between synch pulses as measured by the satellite clock
T	-	Number of pulses (Integer)
Z	-	Actual time interval between synch pulses
I	-	Arbitrarily assigned orbit number
I-1	-	The first orbit preceding I for which data is available

Figure 2 shows the second program that was used. The output for this program is found in Figure 4. The first program was the same as the second with the exception of statements 4 and 5, which in the first program were written

```
COSOCL2 PROGRAM TO CHECK SATELLITE CLOCK
      DIMENSION FR(500), C(500), E(500),
     1          IORBIT(500), U(500), W(500), X(500), Y(500), Z(500), T(500)
      IRANGE=14
      DO 8 K=1, IRANGE
      READ INPUT TAPE 2,101,IORBIT(K),FR(K),C(K),E(K),T(K)
  101 FORMAT (I9,3F10.0,F4.0)
    8 CONTINUE
      I=1
    2 U(I)=(C(I)-FR(I))/50.93
      W(I)=(E(I)-C (I))/50.93
      X(I)=(E(I)-FR(I))/50.93
      Y(I)=FR (I+1)-E(I)
      IF  (Y(I)) 3,3,4
    3 Y(I)=Y(I)+86400.0
    4 Z(I)=(E(I)-E(I-1))/T(I-1)
      IF (Z(I)) 5,5,6
    5 Z(I)=(E(I)+86400.0-E(I-1))/T(I-1)
    6 I=I+1
      IF (I-IRANGE) 2,2,7
    7 WRITE OUTPUT TAPE 3,102,(IORBIT(I),U(I),W(I),X(I),Y(I),Z(I),
     1T(I), E(I), I=1, IRANGE)
  102 FORMAT(I4,4F10.2,2F13.4,1F20.2)
      CALL EXIT
      END
*     DATA
      219    15950.4    16917.9    21553.6    615
      224    46938.1    49484.5    52792.2    121
      225    53134.9    55273.6    58937.8    120
      226    59329.9    62995.7    65033.1    241
      228    71520.0    74523.8    77274.2    608
      234    15949.0    16967.0    21752.1    612
      239    47076.7    49571.2    52829.0    482
      243    71550.4    74603.8    77302.0    366
      247    03629.2    05460.9    09481.6    120
      248    09822.1    11246.6    15572.4    121
      249    15963.5    16981.0    21713.6    614
      254    47024.7    49619.4    52874.7    482
      258    71644.1    74645.1    77336.3    246
      261    83968.7    86155.9    89819.5    119
      262    03760.4    05540.6    09457.8    121
      263    09797.8    11272.7    15597.3    121
      264    15937.2    17056.1    21736.5    121
      265    22127.3    26655.0    27875.5    373
      268    40951.9    43902.1    46801.0    120
      269    47141.9    49683.5    52886.6    726
      276    83969.6    84274.8    89716.8    122
      277    03758.3    05588.7    09505.1    121
      278    09896.8    11370.8    15642.6    121
      279    15982.2    17100.7    21779.7    120
      280    22119.5    26696.2    27865.5    120
```

Figure 2. Second program and typical data input.

4 Z(I) = (E(I + 1) - E(I))/50.93

5 Z(I) = Z(I) + 1696.45

where Z is the approximate number of pulses between transmissions. Note that 1696.45 Channel 6 pulses occur during one day as measured by the satellite clock. The output of the first program can be found in Figure 3.

Let us describe the use of the first program. Conversion of time into seconds per day is recommended for easier handling of the data.

Channel 6 has a synchronizing pulse that was planned to appear at a nominal 51.2 second interval. In viewing the telemetry data, this pulse was measured at a nominal 50.93 second interval with the satellite clock. This number should be changed in the program to be the proper value for the particular group of orbits being examined.

The number of pulses on the strip chart for an orbit is given approximately by

$$X_A(I) = E_{UT}(I) - FR_{SC}(I) \;/\; 50.93$$

This was confirmed by hand counting of the pulses.

$FR_{SC}(I) - E_{UT}(I\text{-}1) \;/\; 50.93 = Y_A$ Pulses not on record.

$E_{UT}(I) - E_{UT}(I\text{-}1) \;/\; 50.93 = T_A$ Number of pulses

Check: $X_A + Y_A = T_A$

At this point T will not be exactly an integer. The corrected integer value can be determined by following the first step outlined on page 2. Alternatively,

ORBIT	U	W	X	Y	Z	T
219	19.00	91.02	110.02	25384.50	613.36	615
224	50.00	64.95	114.94	342.70	120.67	121
225	41.99	71.95	113.94	392.10	119.68	120
226	71.98	40.00	111.98	6486.90	240.35	241
228	58.98	54.00	112.98	56202.50	1216.47	1220
239	48.98	63.97	112.95	37200.20	845.33	848
247	35.97	78.95	114.91	340.50	119.59	120
248	27.97	84.94	112.91	391.10	120.58	121
249	19.98	92.92	112.90	49930.50	1092.14	1096
258	58.92	52.84	111.77	6632.40	245.11	246
261	42.95	71.93	114.88	340.90	118.56	119
262	34.95	76.91	111.87	340.00	120.55	121
263	28.96	84.91	113.87	339.90	120.54	121
264	21.97	91.90	113.87	390.80	120.54	121
265	88.90	23.96	112.86	13076.40	371.60	373
268	57.93	56.92	114.85	340.90	119.49	120
269	49.90	62.89	112.80	31083.00	723.15	726
276	5.99	106.85	112.85	441.50	121.51	122
277	35.94	76.90	112.84	391.70	120.51	121
278	28.94	83.88	112.82	339.60	120.50	121
279	21.96	91.87	113.83	339.80	119.49	120
280	89.86	22.96	112.82	394.70	119.57	120
281	82.87	28.95	111.82	6978.10	250.83	252
283	59.91	53.91	113.81	6526.20	241.94	243
285	82.84	30.95	113.80	639.00	120.46	121
286	36.94	70.97	107.91	6704.20	237.92	239
288	61.85	44.44	106.29	441.50	122.44	123
289	54.89	58.88	113.77	491.10	124.43	125
291	43.91	70.88	114.79	339.20	118.46	119
292	35.92	75.87	111.79	389.70	120.44	121
293	29.94	82.85	112.79	338.90	120.44	121
294	22.95	90.83	113.78	338.80	119.43	120
295	90.83	21.95	112.78	19294.90	492.61	495
299	51.90	61.86	113.76	12654.90	360.20	362
302	28.92	82.80	111.72	6571.90	240.78	242
304	53.87	57.88	111.74	6673.70	242.78	244
307	36.90	74.84	111.74	12653.00	360.17	362
310	90.79	20.94	111.74	19341.00	492.48	495
314	51.88	60.84	112.72	6423.80	240.76	242
316	38.87	75.76	114.63	6475.30	241.71	243
318	62.82	51.76	114.57	19085.30	484.41	0

Figure 3. Program 1 output. Computation of the nominal number of Channel 6 cycles between data transmissions (Z). The number of synch pulses (T) is hand calculated (Not computer output).

ORBIT	U	W	X	Y	Z	T	E
219	19.00	91.02	110.02	25384.50	0.	615.0000	21553.60
224	50.00	64.95	114.94	342.70	50.7945	121.0000	52792.20
225	41.99	71.95	113.94	392.10	50.7901	120.0000	58937.80
226	71.98	40.00	111.98	6486.90	50.7942	241.0000	65033.10
228	58.98	54.00	112.98	25074.80	50.7929	608.0000	77274.20
234	19.99	93.95	113.94	25324.60	50.7860	612.0000	21752.10
239	48.98	63.97	112.95	18721.40	50.7792	482.0000	52829.00
243	59.95	52.98	112.93	12727.20	50.7739	366.0000	77302.00
247	35.97	78.95	114.91	340.50	50.7639	120.0000	9481.60
248	27.97	84.94	112.91	391.10	50.7567	121.0000	15572.40
249	19.98	92.92	112.90	25311.10	50.7537	614.0000	21713.60
254	50.95	63.92	114.86	18769.40	50.7510	482.0000	52874.70
258	58.92	52.84	111.77	6632.40	50.7502	246.0000	77336.30
261	42.95	71.93	114.88	340.90	50.7447	119.0000	89819.50
262	34.95	76.91	111.87	340.00	50.7420	121.0000	9457.80
263	28.96	84.91	113.87	339.90	50.7397	121.0000	15597.30
264	21.97	91.90	113.87	390.80	50.7372	121.0000	21736.50
265	88.90	23.96	112.86	13076.40	50.7355	373.0000	27875.50
268	57.93	56.92	114.85	340.90	50.7333	120.0000	46799.00
269	49.90	62.89	112.80	31083.00	50.7300	726.0000	52886.60
276	5.99	106.85	112.85	441.50	50.7303	122.0000	89716.80
277	35.94	76.90	112.84	391.70	50.7238	121.0000	9505.10
278	28.94	83.88	112.82	339.60	50.7231	121.0000	15642.60
279	21.96	91.87	113.83	339.80	50.7198	120.0000	21779.70
280	89.86	22.96	112.82	394.70	50.7150	120.0000	27865.50
281	82.87	28.95	111.82	6978.10	50.7110	252.0000	33950.80
283	59.91	53.91	113.81	6526.20	50.7099	243.0000	46729.70
285	82.84	30.95	113.80	639.00	50.7074	121.0000	59051.60
286	36.94	70.97	107.91	6704.20	50.7025	239.0000	65186.60
288	61.85	44.44	106.29	441.50	50.7008	123.0000	77304.10
289	54.89	58.88	113.77	491.10	50.6967	125.0000	83539.80
291	43.91	70.88	114.79	339.20	50.6984	119.0000	89877.10
292	35.92	75.87	111.79	389.70	50.6958	121.0000	9509.90
293	29.94	82.85	112.79	338.90	50.6934	121.0000	15643.80
294	22.95	90.83	113.78	338.80	50.6926	120.0000	21777.60
295	90.83	21.95	112.78	19294.90	50.6892	495.0000	27860.30
299	51.90	61.86	113.76	12654.90	50.6840	362.0000	52948.90
302	28.92	82.80	111.72	6571.90	50.6765	242.0000	71293.80
304	53.87	57.88	111.74	6673.70	50.6736	244.0000	83556.80
307	36.90	74.84	111.74	12653.00	50.6750	362.0000	9521.50
310	90.79	20.94	111.74	19341.00	50.6732	495.0000	27865.20
314	51.88	60.84	112.72	6423.80	50.6705	242.0000	52947.10
316	38.87	75.76	114.63	6475.30	50.6690	243.0000	65209.00
318	62.82	51.76	114.57	19085.30	50.6601	0.	77519.40

Figure 4. Program 2 output. Computation of the average length of Channel 6 cycles (Z)

by looking at the values of Z from the second program, a simple prescription for determining T can be devised.

Since successive playbacks of recorded data occur slightly more than one orbit apart, approximately every fifteenth data record no. (orbit no.) will be missing. Also, it is recommended that the number of consecutive missing orbits should be kept as few as possible.

When all of the proper integers, T, have been found, we are ready to run the second program. We now compute

$(E_{UT}(I) - E_{UT}(I-1)) / T = Z(I)$ Actual time lapse between pulses, which is plotted Figure 1.

Having established the value of Z at any time, we can now find the time of any actual event by calculating

$$U_A = (E_{UT} - PE_{SC}) / 50.93$$

which should be very close to an integer. Calling the integer U we can now calculate

$$PE_{UT} = E_{UT} - (U * Z(I))$$

Interpolation between PE_{UT} and the event using the satellite clock is necessary.

The errors that remain can be caused by:

1. End of data is not always clearly defined.
2. Heat causes the satellite clock oscillator to run faster. During the sunlit portion of the orbit the clock will run a bit faster than when in the earth's shadow.

3. The method of putting the data on the strip chart can be affected by RF noise.

ACKNOWLEDGEMENT

I wish to thank Mr. C. R. Curry of Lawrence Radiation Laboratory, Livermore, California and Dr. Wm. Hess of Goddard for information regarding the Channel 6 commutator and data format. I also thank Mr. Wm. Nottingham and associates at the Martin Marietta Corporation, Baltimore, Maryland for several discussions of the timing problem. I wish to express special appreciation to Mr. Charles Condor of Vitro Corporation who did most of the detailed investigation of the defects and advantages of the various methods of timing without which this method could not have been developed. He also read from the strip charts the times of the various events which were used to develop and establish the method.