Accuracy of *Ginga* Time Assignment

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1 Introduction

Questions about the reliability of *Ginga* time assignment have arisen from an investigation into alignment of optical and X-ray pulse profiles in PSR 0540–69 (Deeter *et al.* 1995). Consistency in the alignment of the pulse profiles over the entire span of *Ginga* observations requires 23 ms offset from true UTC in absolute time assignment of *Ginga* data prior to July 1988. Furthermore, by comparing the time ("ticks") kept by the on-board *Ginga* CPU clock with the time kept by the KSC ground clock, both recorded in all the *Ginga* data, many unexpected offsets in time assignment were detected (Deeter 1995). Deeter (1995) suspected that those offsets were adjustments in the KSC ground clock.

Here, we describe how the KSC ground clock had been maintained, and, using records of the KSC clock, demonstrate that all the offsets found in the above "clock comparisons" were offsets resulting from accidents (or incorrect resets) of the KSC clock and intentional time adjustments after that. Finally, we provide information by which data with incorrect time assignment will be corrected.

2 Maintenance of the KSC Ground Clock

The KSC ground clock has been maintained by Shimomura, a technician in KSC. A shift of the clock from true UTC is recorded automatically at 00:00:00 (UT) everyday, as shown below, using disseminated signals of Loran (Long Range Navigation) C. The below example shows that the KSC clock lagged behind true UTC by 2 μs (not s), and the time of receiving a "TOC" maker was at 23:56:01 on 1987 February 11. The TOC maker is a signal to distinguish master and/or slave stations of Loran C, and sent with the signals.

```
************ DATA
 U1987 FEB 12
       00:00:00            MS
              1CH -000.002 S
```

```
                    2CH -000.002
                    3CH -000.002
TOC
U1987 FEB 11
      23:56:01 ******
```

He had adjusted (reset) the clock to true UTC if an absolute value of a shift was larger than a few tens μs, or if an accident due to, for instance, a power outage occurred. All the resets and most of important operations had also been recorded[1]. All the records of daily shifts and these operations are kept on file (hereafter referred as the KSC note). Those records are summerized in the right columns of Table 1–5. In the left columns of the same tables, adjustments found in the clock comparisons (Deeter 1995) are also listed.

Shifts recorded everyday almost simply increased or decreased in time between two resets of the clock. This allows us to evaluate a shift at any time from the tables. For instance, the shift at 00:00:00 on 1988 April 22 was -0.001 μs (Table 2), which was noted as "-0.001 $\sim$" in the next line of 1988 April 21 on the table. The shift on 1988 June 22 was -0.083 μs. From these, one can evaluate a shift, for instance, on May 22 to be -0.042 μs. The shift really recorded on the day was -0.038 μs (-0.040 μs on May 23).

It was possible to maintain the clock to 1 μs accuracy by the above operations. However, there are at least two possibilities that the clock was incorrectly reset. One case is that signals of Loran C were not received well. The other case is that the clock was reset only by hearing a time signal from a telephon, or by using JJY, and no fine tunning had been done. This would result in an offset from true UTC by tens or hundreds milliseconds. (This *might* really occur, for instance, when an accident occurred in Shimomura's absence, and someone else at KSC would reset the clock.) According to Shimomura, in the first case, e.g., if a "TOC" marker was not received, a shift would not be recorded at 00:00:00 automatically. In the second case, a shift from true UTC would be recorded (at least at 00:00:00). Thus, the records in the KSC note provide enough information about shifts from true UTC with the accuracy of 1 μs.

In fact, an accident occurring on 1988 July 23 and the followed reset shifted the KSC clock by -466 ms, which was recognized not only in the adjustment of the *Ginga* clock but also in the record of the KSC clock (Table 2). By the next reset, the shift seems to be canceled out. Note, however, that this is the only clear example showing that the adjustment of the *Ginga* clock was consistent with the record of the KSC clock.

[1] A resetting command can be found in the KSC note as a pair of commands, "`TEST ON`" and "`TEST OFF`".

3 Accidents and Adjustments of the KSC Clock

The KSC clock occasionally lost the absolute time by power outages. The clock also seems to have been losing the absolute time in the following cases. "`ALARM`"s were outputted (recorded) in asking the (channel) status of the clock, or "`TIME ERROR ON/OFF`" and "`POWER ERROR ON/OFF`" were recorded. "*err*"s in the tables mean these cases.

The beginning times of such accidents or errors were unknown because the clock lost the absolute time. Thus, all the data (passes) to which correct or incorrect time was assigned during an accident can not be restricted completely. In some cases, the first, reliable time recorded on the KSC note is footnoted in the tables. If an accident once occurred, the clock was reset numerous ($\gtrsim 5$) times. The time of the final reset either after the accident or on the day and the term "reset" are listed in the columns of "Operation" of the tables. Even during the accident, if an adjustment was detected, the time of a reset just before the detection is also listed in parentheses. In case a shift from true UTC was recorded after the final reset (usually within a few minutes), the recording time, instead of the resetting time, and "reset *value*" are shown in the tables, where *value* is a shift recorded, and usually 0 or -0.001 (μs).

Either "`TOC SET`", "`SYNC LOCAL`" or "`EXT STD ON`" was also occasionally recorded, not together with the resetting command, "`TEST ON/OFF`", as was usually used. In that case, its time and the record are also listed in the tables. Sometimes, shifts were adjusted by only one of them without any reset. According to Shimomura, it might be possible if the clock was in an auto-adjustment mode. The clock had not been in such a mode, and had been nearly always reset manually. In case some of these records were found after the final reset or a record of a shift, they are footnoted.

We can find from the tables that all of the adjustments in the *Ginga* clock were detected after accidents (errors) or resets of the KSC clock. So, we have confirmed the conclusion by Deeter that the adjustments or offsets in time assignment are due to the maintenance of the KSC clock.

4 Sets of Adjustments and Reliability of Clock Shifts from true UTC

Deeter (1995) pointed out that most of the adjustments could be grouped into pairs and blocks which sum to a near zero offset, that is, accidental adjustments followed by correcting resets. We next verify this possibility in comparison with the records of the KSC clock.

The data in 1987, however, will be discussed later. Because in 1987 the KSC clock had not had its battery and the power supply of the clock was unstable. It seems that these resulted in many accidents and complex sets of time offsets. Unfortunately, nobody remembers since when the clock have been equipped with the battery[1].

4.1 series of adjustments in one accident

More than half of the adjustments (offsets) in 1988–1991 resulted from accidents or incorrect resets of the KSC clock. Such offsets were cancelled out by adjustments in the first pass after the final reset of the clock. This pattern can be seen in series of adjustments on 1988 July 23 – 26, mentioned before, 1990 July 1 – 4, September 30 – Oct. 1, and December 8 – 10. The three cases in 1990 were caused by power outages.

In the case on 1990 July 1 –4, a shift from true UTC at 01:36:51 on July 4 was +87.789 ms, which was almost the same magnitude (and on the opposite sign) as the final adjustment at 02:07:46, -92 ± 2 ms. Two adjustments before the final adjustment, especially the first adjustment at 20:04:02 on Jul. 1, can not be estimated exactly and might have much larger uncertainties than those in Deeter's estimation because of large ambiguity of a local *Ginga* clock rate (Deeter 1995, cf., Deeter and Inoue 1990). Taking these into account, the final adjustment is thought to have cancelled out a net offset of the first two adjustments though the net offset in Deeter's estimation, -57 ± 49 ms, was relatively smaller than the expected one, +88 ms. In the cases on Sep. 30 – Oct. 1 and Dec. 8 – 10, net offsets of these series of two adjustments are +21 ?$\pm$55 ms and -47 ± 49 ms, respectively, which are consistent with zero offsets, though exact adjustments on Sep. 30 and Dec. 9 are also hard to be estimated. The two adjustments in both the cases are an offset resulting from the power outage and a cancelling event after the final reset. Shifts were recorded at 00:00:00 between resets unrelated to the adjustments, and do not help our understanding.

Series of two adjustments on 1991 April 7 – 8 (the net offset of $+68\pm45$ ms) and three adjustments on April 10–17 ($+117 \pm 49$ ms) may be this pattern of adjustments though records of the KSC clock have not been left. Small adjustments on 1988 Sep. 10 (-18 ± 2 ms) and on 1990 Jan. 22 (-14 ± 2 ms) were found after resets for some accidents. From the above facts (patterns), we suspected that those adjustments would cancel out offsets in remote orbits where accidents occurred. The offsets could not be detected because of large uncertainty of adjustment of the first contact passes, 8809100619 (09:02:52) and 9001220619 (09:08:55), $\pm$20 ms.

[1] The time of the equipment seems to be since 1988.

4.2 series of adjustments over two or more accidents

The above series of adjustments were solved within a few or several days, and consistent (or, not inconsistent) with shifts from UTC recorded by the KSC clock. There are, however, another group of adjustments in which significant offsets lasted one month or more and apparently inconsistent with recorded shifts.

Two adjustments on 1988 October 20 and November 24 are separated by more than 1 month. The net offset is -96 ± 50, and (marginally) consistent with zero. The large offset of about 1 s and related resets compel us to regard them as one set of adjustments, accidental and cancelling events. Such a long, separated series of adjustments can be also seen in three adjustments on 1989 Jul. 12 and Oct. 12 (two steps), of which a net offset is $+34 \pm 20$ ms. Resetting the clocks as much as 9 times on July 12 suggest that some problem occurred in the clock and resulted in an offset of -99 ± 2 ms. The shift from UTC at 11:20:47, +66.871 ms, is barely consistent with the final adjustment at 12:33:31, -73 ± 2 ms. This and the adjustment at 10:52:43 (the first pass in this accident) imply that there was an offset of -139 ± 20 ms before the accident. Furthermore, the reset on July 13 was in a remote orbit, and two resets on July 31 and Sept. 13 were in contact orbits. Thus, small is ambiguity in estimating adjustments (± 20 ms) for these resets. In conclusion, there were no adjustments to cancel out the offset on Jul. 12 till Oct. 12, and there had been about 100 ms offset from Jul. 12 to Oct. 12.

The above conclusions completely conflict with shifts recorded at 00:00:00 within those intervals. All the shifts are much smaller than expected from adjustments. As mentioned before, shifts recorded by the clock present offsets from true UTC as long as the clock receive TOC makers[2]. On 1991 Mar. 19 and Apr. 08, the times of receiving TOC markers were 00:00:00, suggesting that shifts recorded were incorrect. In fact, the shifts were recorded, but inconsistent with related adjustments.

The above groups of adjustments, however, can not be explained unless shifts of the clock presented incorrect values. Adjustments on 1987 Apr. 21 and May 1 indicates that there had been about +15 s offset between them. Shifts within the interval were, however, only +65 ms. Shifts at 12:24:55 on 1990 Dec. 9 (see no. 9 footnote in Table 4) and on 1991 Mar. 20 – 21 also conflict with related adjustments. From these facts, we cannot help concluding that shifts of the clock does not always present offsets from true UTC even if

[2] According Shimomura, shifts *never* present wrong offsets. Forethermore, 1 s offset, if existed for more than 1 month, (the case of 1988 Oct.–Nov.) would be pointed out by other groups (or institutes such as NASDA) which also used the time of the KSC clock. 0.1 s offset (the case of 1989 Jul.–Nov.) would be also noticed by time lags, in resetting the clock, between sounds of signals from Loran and the time of the clock.

TOC markers were received.

Once the fact (speculation) about the wrong presentation of shifts is accepted, three adjustments on 1987 April 6, 21 and May 1 (the net offset of -43 ± 35 ms) would be regarded as one set of adjustments followed by a correcting reset. A series of 8 (or 9) adjustments from 1987 March 16 (or 13) to October 17 (+208, or +150 ? $\pm$75 ms) would be also regarded as one or some sets of adjustments. This implies that absolute time assignments within this interval were accurate to within only a few hundred milliseconds. Even if offset corrections are made using this information, the accuracies will be improved only to several ten milliseconds because the adjustments within the interval have large uncertainties (see Table 1).

If shifts were often incorrect not only in 1987 but in the later years, a series of 4 adjustments from 1991 January 22 to March 21 (-96 ± 53) can be regarded as sets of adjustments. The two series of adjustments, on 1991 April 7–8 and on 1991 April 10–17, may be also one large set of adjustments (188 ± 67 ms). It seems to be, however, somewhat difficult to consider that all these sets of 10 (or 8) adjustments in 1991 is one set of adjustments. Because no adjustments were detected between these two sets of adjustments though there were a few accidents and resets within the interval. (Most of the other accidental adjustments were cancelled out by adjustments due to the next resets or to the accidents followed by resets.) In this respect, the possibility can not be denied that the two series of adjustments on 1990 July 1–4 (-149 ± 49 ms) and Sept. 30 – Octo. 1 ($+162 \pm 3$ or $+20? \pm 55$ ms) is one set of adjustments as Deeter proposed (Deeter 1995). In conclusion, there are two or more possibilities in these sets of adjustments.

The above possibilities may suggest that shifts did not present absolute offsets from true UTC throughout the life of the satellite, but relative offsets from the time with an offset in resetting the clock. However, the fact that the origins of most the groups of adjustments were accidents of the KSC clock indicates that there is no reason why we positively doubt time assignment in the reset of the data. The success in grouping adjustments and the stability of the frequency of the KSC clock lead to the conclusion that time assignment of the rest of the data was accurate to within a few milliseconds even if recorded shifts were not offset from true UTC.

Finally, we consider the adjustment on 1988 Octo. 14. There were no adjustments with which a net offset is consistent with zero. One possibility is that an offset occurred in the reset on Sept. 27, and the offset can not be detect in the first pass after the reset on Octo. 3, on which adjustment has an uncertainty of $\pm$140 ms.

5 Summary and Substantial Data for Further Corrections

We have shown that about 13 (max. 26) % time assignment suffered from accidents or incorrect resets of the KSC ground clock. Resultant offsets were cancelled out by adjustments of the clock to true UTC usually within a few days later, occasionally more than 1 month later, after the accidents occurred. Most of these accidental and cancelling offsets were detected as the adjustments in the clock comparisons by Deeter (1995).

Absolute time assignments of significant portions of the data were accurate to within a few milliseconds. The accuracy would be dominated by fluctuations of the *Ginga* CPU clock rate (Deeter and Inoue 1990), not by maintenance of the KSC clock. Incorrect time assignments in the reset of the data can be corrected with accuracies of a few milliseconds or a few ten milliseconds, which depend on uncertainties in estimating adjustments. Time assignments in 1987 March – October, however, suffered from many clock accidents so that correction of the time assignments is difficult. As a result, the time assignments within the interval are accurate to about 0.1 second (c.f., Deeter et al. 1995). These results except in 1987 are summarized in Table 6. Correcting offsets, in case of that shifts recorded by the KSC clock were always (usually) correct, are shown in the left-side (middle) of the table. There are some intervals where the necessities to correct time assignments are unclear because of the unreliability of shifts recorded by the KSC clock and large uncertainties of adjustments. Correcting offsets within those intervals are shown in the right side of the table.

Together with these, arrival timing analyses of pulsers such as PSR B0540-69 (Deeter et al. 1995), or simultaneous observations with other missions within these intervals will be great helpful to know real offsets in these intervals. Further investigation into adjustments is also encouraged.

references

Deeter, J.E., Inoue, H. 1990, "Temperature dependence of the *Ginga* clock rate", ISAS Research Note No. 430

Deeter, J.E., Nagase, F., & Boynton, P.E. 1995, "Further *Ginga* observation of PSR B0540-69", in preparation

Deeter, J.E. 1995, report "Reliability of *Ginga* Time Assignment"

TABLE 1 (1987)

Date (yy.mm.dd)	KSC clock			*Ginga* clock		
	Shift at 00:00:00 (ms)	Operation hh:mm:ss	item	Adjustment hh:mm:ss	(ms)	
86.12.24	(KSC note available)					
86.12.27		(05:26:59	reset 0.001[1])			
		06:37:07	reset[1]			
$\wr$	−0.002 ~					
87.02.06	−0.001		———- *Ginga* was lunched. ———-			
$\wr$	−0.001 ~					
87.02.16	−0.002	05:51:58	reset[a]			
$\wr$	−8.502					
87.03.09	−8.502			available		
87.03.10						
$\wr$	no data[b] (Mar. 10 – Apr. 5)					
87.04.05						
87.04.06		06:55:19	reset 0[b]	22:38:10 ?	+93	(20)
$\wr$	−0.001 ~					
87.04.21	−0.007	08:57:52	*err*[c], reset[2]	19:18:07	+14,924	(20)
$\wr$	+65.009 ~					
87.05.01	+65.004	04:34:36	reset[3,c]	10:14:39	−15,060	(20)
$\wr$	+54.709 ~					
87.05.13	+54.703	02:03:11	reset 0[(d)]	04:49:02	−50 ?	(20)
$\wr$	−0.839 ~					
87.05.16	−0.841	(06:45:33	*err*[d], reset)	06:52:14	+116	(2)
		08:02:30	(*err*[d],) reset	08:34:38	+90	(2)
87.05.17	+2.999					
87.05.18	+2.998	01:09:08	reset 0			
$\wr$	−0.001 ~					
87.06.03	−0.015	09:51:09	*err*[e], reset	17:47:07	−510	(20)
87.06.04	−7.524	00:53:15	sync local[e]			
$\wr$	+15.047 ~					
87.06.11	+15.042	23:55:46	reset −0.001			
$\wr$	−0.001 ~					
87.06.27	−0.016		*err*[4,f]			
87.06.28			*err*[4,f]	05:21:46	+180 ?	(47)
		10:16:19	(*err*[4,f],) reset	10:26:34	+69	(2)
87.06.29	+49.498		*err*[5,f]	05:28:42	+163	(20)
				12:15:38	+200	(2)
87.06.30						
$\wr$	no data (Jun. 30 – Dec. 31)					
(87.10.15)				01:18:24	−282	(20)
(87.10.17)				01:31:44	+182	(45)
87.12.31						

1. After the reset at 06:37:07, "`TOC SET`" at 06:40:51
2. It seems that operations to reset the clock had not been finished. After the reset, outputs of "`TIME OFF`" was incompletely recorded (see copy *c*), and also "`EXT STD ON`" at 09:12:33 and "`TOC SET`" at 09:14:36.
3. After the reset, "SYNC LOCAL" three times (finally at 04:36:01).
4. The first, reliable recorded time was 05:34:33 on June 28. There were 4 passes during the accident from 8706280411 (05:21:46), 870628712 (10:26:34).

5. The records of the KSC clock on June 29 were truncated (and there were no records till the next year).

TABLE 2 (1988)

Date (yy.mm.dd)	KSC clock			*Ginga* clock		
	Shift at 00:00:00	Operation		Adjustment		
	(ms)	hh:mm:ss	item	hh:mm:ss	(ms)	
88.01.01						
≀	no data (Jan. 1 – Jan. 10)					
(88.01.09)				cold *Ginga* clock ?		
88.01.10						
88.01.11		08:03:26	*err*[1,g], reset 0			
88.01.12	±0.000					
88.01.13	±0.000	08:24:26	TOC set			
≀	±0.000 ∼					
88.01.17	−0.001	06:53:37	sync local			
≀	−0.001 ∼					
88.04.21	−0.052	05:23:49	reset 0			
≀	−0.001 ∼					
88.06.22	−0.083	01:54:37	reset			
≀	−0.003 ∼					
88.07.13	−0.016	(14:55:28	ext std on)			
≀	−0.016 ∼					
88.07.23	−0.020	06:38:44	*err*[h], reset	07:53:50	−449	(20)
≀	−466.393 ∼					
88.07.26	−466.394	11:38:36	reset[2,h]	13:15:42	+467	(2)
≀	±0.000 ∼					
88.09.10	−0.019	13:11:40	*err*[3,i], reset 0	14:07:40	+18	(2)
≀	−0.001 ∼					
(88.09.23)						
88.09.27	−0.009	06:26:03	reset			
≀	−0.011 ∼			no data (Sep. 23 – Oct. 2)		
(88.10.02)						
88.10.14	−0.054	01:31:45	reset[4,j]	17:02:18	−93	(20)
≀	−0.002 ∼					
88.10.20	−0.017	02:08:18	reset 0[j]	14:04:42	+933	(20)
≀	−0.002 ∼					
88.11.21	−0.091	05:42:35	reset			
88.11.22	−3.004	05:44:01	reset			
88.11.23	−0.002					
(88.11.24)	−0.005			20:00:09	−1,029	(45)[5]
≀	−0.008 ∼					
88.12.10	−0.050					
88.12.11						
≀	no data (Dec. 11 – Dec. 26)					
88.12.26						
88.12.27						
≀	±0.000					
88.12.31	±0.000					

1. The records of the KSC clock began from 04:35:01. There was one pass during the accident; 8801110413 (06:22:48).
2. The clock was reset 6 times from 10:40:38. There was one pass after this first reset; 8807260724 (11:33:34).

3. The recorded time when the error was first detected was 00:11:20. There were three passes during the accident; 8809100619 (09:02:52), 8809100722 (10:44:11) and 8809100825 (12:26:19).
4. After the reset, an incomplete "TEST OFF" record can be seen, also "TOC SET" 5 times and "EXT STD ON" 2 times (finally, "TOC SET" at 01:40:46).
5. This was the first pass after the reset on Nov. 21. (The time of the last pass before this pass was 04:14.01 on Nov. 21.)

TABLE 3 (1989)

Date (yy.mm.dd)	KSC clock Shift at 00:00:00 (ms)	Operation hh:mm:ss	item	*Ginga* clock Adjustment hh:mm:ss	(ms)	
89.01.01						
≀	±0.000 ∼					
(89.01.05)				11:36:47	223	(200)
89.01.18	−0.004	2:00–10:40	power outage[1,k]			
		11:11:09	reset[1,k]			
≀	−0.004 ∼					
89.02.01	−0.010	01:05:00	reset 0			
≀	±0.000 ∼					
89.02.08	−0.001	07:48:16	reset			
≀	−0.001 ∼					
89.02.17	−0.006	23:55:28	reset 0			
89.02.18	±0.000	23:41:02	reset 0			
89.02.19	±0.000					
89.02.20	−0.001	23:40:33	reset			
89.02.21	±0.000					
89.02.22	−0.001	23:40:58	reset			
≀	±0.000 ∼					
89.03.03	−0.006	00:57:07	reset 0			
≀	±0.000 ∼					
89.03.28	−0.006	01:06:26	reset 0			
≀	−0.001 ∼					
89.04.11	−0.026	06:22:57	reset 0			
≀	−0.002 ∼					
89.04.17	−0.008	00:31:32	reset 0			
89.04.18	−0.004	00:30:09	reset 0			
89.04.19	−0.002	00:18:57	reset 0			
≀	−0.002 ∼					
89.04.24	−0.007	02:27:16	reset −0.001			
≀	−0.002 ∼					
89.05.06	−0.014	00:32:57	reset 0			
≀	−0.002 ∼					
89.05.15	−0.015	01:25:54	reset −0.001			
≀	−0.002 ∼					
89.06.14	−0.054	05:31:51	reset −0.001			
≀	−0.002 ∼					
89.06.23	−0.019	04:56:36	reset[2]			
≀	−0.001 ∼					
89.07.12	−0.042	07:07:51	reset 0[3,l]	07:44:00	−99	(2)
89.07.13	+0.001	02:36:21	reset			
≀	−0.002 ∼					
89.07.31	−0.045	00:38:12	reset −0.001			
≀	−0.003 ∼					
89.09.13	−0.127	04:58:51	reset −0.001			
≀	−0.003 ∼					

TABLE 3 (1989) *continued*

Date (yy.mm.dd)	KSC clock			Ginga clock		
	Shift at 00:00:00	Operation		Adjustment		
	(ms)	hh:mm:ss	item	hh:mm:ss	(ms)	
89.10.12	−0.086		power outage^{4,m}			
		(10:50:52	err^m, reset^5)	10:52:43	+206	(20)
		11:24:32	(err^m,) reset 0	12:33:31	−73	(2)
≀	−0.002 ∼					
89.12.31	−0.259					

1. It seems that this power outage did no harm to the data. The reset at 11:11:09 seems not to work.
2. After the reset, "SYNC LOCAL" at 04:56:45.
3. The clock was reset as much as 9 times (usually a few times).
4. "BATT OFF (due to the electric power outage)" was described with a pencil on the record paper. The first, reliable recorded time was 10:50:52.
5. After the reset at 10:50:52, a shift at 10:52:05 was +12.399 with "TOC" being unset. A shift at 11:20:47 was +66.871 with "TOC" being set.

TABLE 4 (1990)

Date (yy.mm.dd)	KSC clock			*Ginga* clock		
	Shift at 00:00:00	Operation		Adjustment		
	(ms)	hh:mm:ss	item	hh:mm:ss	(ms)	
90.01.01	-0.262					
90.01.02	-0.265	00:26:50	reset 0			
≀	−0.003 ∼					
90.01.22	−0.066	(10:46:18	*err*[1,n], reset)	10:49:59	+14	(2)
		11:12:08	*err*[1,n], reset			
≀	−0.002 ∼					
90.02.21	−0.057	04:56:42	reset 0			
≀	±0.000 ∼					
90.03.08	+0.003	04:41:11	reset 0			
≀	+0.001 ∼					
90.03.23	+0.005	01:20:17	reset 0			
≀	±0.000 ∼					
90.04.06	+0.003	08:10:26	*err*[o], reset[2]			
90.04.07	±0.000					
90.04.08	±0.000	05:58:20	reset[3,o]			
≀	±0.000 ∼					
90.05.17	+0.005					
90.05.18						
≀	no data (May 18 – Jun. 7)					
90.06.07						
90.06.08		01:38.04	reset 0			
≀	±0.000 ∼					
90.07.01	−0.011		power outage[4,p]	20:04:02	+213	(45)
(90.07.02)			*err*[4,p]	19:45:06	−270	(20)
90.07.03			*err*[4,p]			
90.07.04		(01:52:20	*err*[5,p], reset 0)	02:07:46	−92	(2)
		08:23:41	*err*[5,p], reset			
90.07.05	±0.000					
90.07.06	−0.001	01:22:21	*err*[p], reset			
≀	−0.001 ∼					
90.07.10	−0.002	06:43:13	reset 0			
≀	−0.001 ∼					
90.07.25	−0.012	01:27:13	reset			
≀	−0.001 ∼					
90.08.28	−0.030	02:17:20	reset 0			
≀	−0.001 ∼					
90.09.11	−0.013	06:10:33	reset[6]			
≀	−0.001 ∼					
90.09.30	−0.020		power outage[7,q]	23:24:14	−141 ?	(55 ?)
		23:59:48	reset 0[8,q]			
90.10.01	±0.000[8]	02:32:15	reset 0[8,q]	02:44:30	+162	(3)
90.10.02	−0.002	00:40:23	reset			
≀	−0.003 ∼					

TABLE 4 (1990) *continued*

Date (yy.mm.dd)	KSC clock			*Ginga* clock		
	Shift at 00:00:00 (ms)	Operation		Adjustment		
		hh:mm:ss	item	hh:mm:ss	(ms)	
90.12.08	−0.086		power outage[9,r]			
90.12.09		(12:04:54	*err*[9,r], reset)	12:08:26	-146	(45)[9]
		23:59:07	*err*[10,r], reset			
90.12.10	+268.915[10]	10:47:53	*err*[10,r], reset 0	11:42:18	+99	(20)
90.12.11	−0.002	13:29:28	*err*, reset 0[11]			
90.12.12	−0.004	10:36:11	*err*, reset 0			
90.12.13	−0.001	06:30:48	*err*, reset 0[12]			
		23:20:44	reset			
≀	−0.001 ∼					
90.12.18	−0.005	08:18:13	reset 0			
≀	±0.000 ∼					
90.12.21	±0.000	02:14:24	reset			
≀	+0.001 ∼					
90.12.31	+0.003	04:57:22	reset			

1. After the first reset at 08:58:52, there was one pass, 9001220619 (09:08:55). After that, the clock was reset many times till 11:12. (The next pass was 9001250411 (05:12:07).)

2. After the reset, "TOC SET" at 08:15:29, "SYNC LOCAL" at 10:01:27.

3. After the reset, "TOC SET" at 06:27:41, "SYNC LOCAL" at 08:02:51.

4. The electric power outage due to a thunder. The clock were seriously damaged, and no records were found till 07:07:26 on July 3. Passes during the accident were 14 passes from 9007011341 (20:04:02) to 9007040205 (02:07:46).

5. An offset value recorded at 01:36:51 was +87.789 ms. The clock was reset again 3 times from 06:46:03, and another accident occurred. The reset at 08:23:41 seems to be for the latter accident.

6. After the reset, "SYNC LOCAL" at 06:10:33.

7. The electric power outage for 11 hours due to the 20th typhoon. There was only one pass, 9009301547 (23:24:14), during the accident. The first, reliable recorded time was 23:35:16.

8. The clock might be correctly reset at 23:59:48 on Sep. 30. However, "correct 4 s lags" was described with a pencil over the record of the reset at 02:32:15 on Oct. 1 (see the copy *q*)

9. The cause of the power outage was unknown. The first recorded time was 11:48:51 on Dec. 9. A shift at 12:24:55 on Dec. 9 was ±0.000, which was recorded after the reset at 12:04:54. There were 5 passes during/after the accident (from 9012090825 (12:08:26) to 9012091238 (18:49:14)).

10. An accident occurred probably late on Dec. 9 (The first recorded time was 23:52:34), and the clock was correctly reset at 10:47:53 on Dec. 10.

11. After the reset to 0, the clock was reset three times (final; 13:38:00).

12. After the reset, there were 5 passes from 9012130721 (10:24:10) to 9012131135 (17:04:42). The clock was reset again at 23:20:44.

TABLE 5 (1991)

Date	KSC clock			*Ginga* clock		
	Shift at 00:00:00	Operation		Adjustment		
(yy.mm.dd)	(ms)	hh:mm:ss	item	hh:mm:ss	(ms)	
91.01.01	+0.004		leap sec ADJ			
≀	+0.004 ∼					
91.01.16	+0.008	07:01:10	reset			
≀	+0.008 ∼					
91.01.22	+0.010		power outage[1,s]			
		10:14:26	*err*[1,s], reset 0	13:55:51	+90 ?	(20)
≀	±0.000 ∼					
91.03.04	+0.008	07.44.20	reset 0			
≀	±0.000 ∼					
91.03.18	±0.000		*err*[t]	08:48:22	−70 ?	(45)
		09:16:14[2]	*err*[t], reset[2]	10:25:58	−219	(2)
≀	−452.113[3]					
91.03.21	−452.113		reset ?[4,t]	08:41:58	+103	(20)
91.03.22		no data[4,t]				
91.03.23		05:46:37	(*err*[t],) reset			
91.03.24	±0.000	08:54:13	*err*[t], reset			
91.03.25	−0.001	04:20:32	reset 0			
≀	−0.001					
91.03.29	−0.001	02:37:33	*err*, reset[5]			
≀	±0.000					
91.04.01	±0.000	09:43:30	TOC set			
≀	±0.000					
91.04.06	±0.000		*err*[6,u]			
91.04.07		20:02:21	*err*[6,u], reset	23:27:17	−320	(45)
91.04.08	−49.048[7]	(05:41:28	*err*[u], reset[7])	06:04:38	+388	(2)
91.04.09						
≀	no data (Apr. 9 – Apr. 18)					
(91.04.10)				10:21:34	−982	(45)
(91.04.16)				17:47:00	−501	(20)
(91.04.17)				00:20:38	+1600	(2)
91.04.18						
91.04.19		11:45:27	reset 0			
91.04.20	−0.001	11:12:28	*err*, reset			
≀	−0.001 ∼					
91.06.23	+0.003[8]					
≀	+0.002 ∼					
91.08.07	−0.004	23:06:41	*err*[9], reset			
≀	±0.000 ∼					
91.10.29	−0.019			17:11:41	(final contact)	
91.10.30	−0.019	02:21:33	reset			
91.10.31	±0.000					
91.11.01	−0.001		———- *Ginga* disappeared. ———-			

1. The cause of the power outage was unknown.

2. This is the first, reliable time so that an accident might occur before (the 1st pass) 9103180618 (08:48:22).
3. On Mar. 19, the time received a TOC-maker was 00:00:00 on Mar. 19.
4. The clock might be reset at about 6 o'clock on Mar. 21 ("EXT STD ON", 05:55:39). After that, the records were truncated, and there were no data on Mar. 22.
5. After the reset, "SYNC LOCAL" at 03:43:46.
6. The first recorded time was 19:34:32 on Apr. 7. There were 5 passes on Apr. 6; from 9104060102 (00:41:58) to 9104060515 (07:19:50), and the only one pass on Apr. 7; 9104071547 (23:27:17).
7. The time of receiving a TOC-maker was 00:00:00. After continuous resets from 05:04:19 to 07:08:21, the records were truncated. On Apr. 8, there were continuous 4 passes from 9104080103 (01:06:45) to 9104080412 (06:04:38), and 9104081546 (22:49:42).
8. Shifts increased till this day, and decreased later.
9. The first, reliable recorded time was 23:00:22. There were 5 passes on Aug. 7; from 9108070617 (08:10:24) to 9108071030 (14.42.56).

Date (yy.mm.dd)	hh:mm:ss	Correction (ms)		
88.07.23	07:53:50			
		-466.394 ± 0.001		-484 ± 3
88.07.26	13:15:42			
				-18 ± 2
88.09.10	09:02:52			
		-18 ± 2		
88.09.10	14:07:40			
88.09.27	(06:26:03)			
		$+93 \pm 2$		
88.10.14	17:02:18			
88.10.20	14:04:42	$+933$		
			$+949 \pm 18$	
88.11.24	20:00:09	$-1,029$		
89.07.12	07:44:00	-99		
			-99 ± 2	
89.10.12	10:52:43			
		$+67.871 \pm 0.001$	$+73 \pm 2$	
89.10.12	12:33:31			
90.01.22	09:08:55			
		-14 ± 2		(0)
90.01.22	10:49:59			
				$+14 \pm 2$
90.01.25	05:12:07			
90.07.01	20:04:02			
		$+334 \pm 18$		$+202 \pm 18$
90.07.02	19:45:06			
		$+87.789 \pm 2$		-70 ± 4
90.07.04	02:07:46			
				-162 ± 3
90.09.30	23:24:14			
		-162 ± 3		
90.10.01	02:44:30			
90.12.09	12:08:26			
		-107 ± 18		
90.12.10	11:42:18			
91.01.22	13:55:51	$+90$		
			$+80 \sim +130$	$(+90 \pm 20)$
91.03.18	08:48:22			
		$+116 \pm 20$		$-120 \sim -20$ [0]
91.03.18	10:25:58			
		-103 ± 20	$-90 \sim -140$	$-340 \sim -240$ [-219 ± 2]
91.03.21	08:41:58			
				$-240 \sim -120$ [-116 ± 20]
91.04.07	23:27:17			
		-388 ± 2	$-460 \sim -360$	$-560 \sim -460$
91.04.08	06:04:38			
			$-70 \sim +30$	$-170 \sim -70$
91.04.10	10:21:34			
		-1080 ± 18	$-1080 \sim -1120$	$-1120 \sim -1080$
91.04.16	17:47:00			
		-1600 ± 2	-1600 ± 2	-1600 ± 2
91.04.17	00:20:38			