PRECISE TIME AND TIME INTERVAL DATA HANDLING AND REDUCTION

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ABSTRACT

In the past year, the increase in PTTI data to be reduced to the U. S. Naval Observatory Master Clock and the requirement for its quick dissemination has necessitated development of more efficient methods of data handling and reduction. An outline of the data involved and of the Time Service computerization of these functions is presented.

INTRODUCTION

During the past several years, the instrumentation and operation of many systems which could be used for world-wide synchronization have been discussed. Among them have been Omega, Loran-C and Loran-D, television comparisons, and the Defense Satellite Communication systems. Implicit in all of these systems used for timing is that someone, somewhere is receiving data and giving some feedback to the participating stations. It is the mechanics of this role of the U. S. Naval Observatory Time Service which I plan to discuss this afternoon.

With the rapid development of timing systems, the increase in data input to the Time Service has been tremendous. However, there has not been a corresponding increase in personnel to process the data manually. Because of this fact, in March 1973 it was decided to inauguarate automatic data processing for Precise Time and Time Interval data as much as possible.

As all data from the Defense Satellite Communication terminals were already being received in machine-readable form, i.e., paper tape via TWX, this system was used as the nucleus for the design and implementation of a program to store, calculate and disseminate all PTTI data.

FORMAT

As the first step in this program, a standard format for TWX transmissions was devised. What was desired, at the minimum, was a format which the IBM 1800 Automatic Data Acquisition System could use to distinguish PTTI data from all other incoming TWX messages and yet which would be flexible.

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Additional requirements were the Day, Month, and Year; the local reference or Cesium number; the identification of the monitored systems; the time comparison; a check number; and the date/time of the comparison (Fig. 1).

The addition of 'NOTES' gave flexibility to the format in that any comments and/or questions could be transmitted, in any form, in the same message.

From inception, the computer processing was envisioned as handling all incoming PTTI data. The next figure is of two messages received from the Camp Roberts, California and Futenma, Okinawa Satellite Communication (SATCOM) terminals. They have transmitted a time transfer via satellite, a direct time comparison, and readings of Loran-D and Loran-C, respectively (Fig. 2).

To identify the TWX message as PTTI data, four Y's followed by the location and activity, must be on line 1. Line 2 is for the date, line 3 is the local cesiums and the following lines contain the monitored systems. In the message from Camp Roberts, each of the Cesiums were used: Cs 576 for Loran-D and Cs 550 for a time transfer with Kwajalein, Marshall Islands. Cs 576 is also used in time transfers with Ft. Dix, New Jersey and Brandywine, Maryland.

In addition to the SATCOM terminals which are transmitting data in this format, are such stations as Nasa/Guam; Detachment "Charlie" of the Naval Astronautics Group in Hawaii; and Elmendorf Air Force Base in Alaska (Fig. 3).

```
YYYY LOCATION/REPORTING ACTIVITY
DAY MONTH YEAR
LOCAL REFERENCE/CLOCK
   SYSTEM IDENTIFICATION   READING   CHECK   DATE/TIME

   .
   .

LOCAL REFERENCE/CLOCK
   SYSTEM IDENTIFICATION   READING   CHECK   DATE/TIME

   .
   .

NOTES
   1.  CS _____ TIME DELAY SETTING _____ _____.
   2.  (Any additional information, comments, questions, etc.)
```

Figure 1. Basic PTTI Teletype Format

```
.
.
BT
UNCLAS
YYYY CP RBTS SATCOM
31 OCT 73
CS576
   S7-47        1916.5    3833.0    312200Z
   RDIX          -1.0      -2.0     300150Z
   CS550          2.0       4.0     312200Z
CS550
   KWAJ          10.6      21.2     310900Z
NOTES
   CS576 TIME DELAY SETTING 999980  1999960.
   CS550 TIME DELAY SETTING 999960  1999920.
BT
```

```
.
o
.
BT
UNCLAS
YYYY OKINAWA SATCOM
15 OCT 73
CS447
   HHON          4.0       8.0      152318Z
   CS558         3.5       7.0      152233Z
   SS3/7761     31.23     62.46     152233Z
   SS3/7764     31.05     62.10     152234Z
NOTES
   1.   CS 447 TIME DELAY SETTINGS 265219   530438.
   2.   CS 558 TIME DELAY SETTINGS 316526   632052.
   3.   REF YOUR MSG 111953Z OCT 73. REFER TO TEXAS INST
MAN NO. 83202-9701 DRAWING NO 161904 DETAIL A. WE NEED
A 16 TOOTH PINION GEAR AND A 24 TOOTH GEAR MESHING WITH
IT. PART NO. 161903-1 or 161623-1 AND 169791-1 OF DRAWING
NO. 161905. WE ALSO NEED TAKE UP MOTOR NO. 175148-0001/
115 VAC/ 60 HZ/ 20 RPM
BT
```

Figure 2

```
        o
        o
        o
BT
UNCLAS  FM  STADIR.
YYYY  GUAM  STADIR
09  OCT  73
CS136
    SS3Z        43.1        86.2      0000Z
    CS107       -5.5       -11.0      0420Z
BT
```

```
        o
        .
        .
BT
UNCLAS  //N02400//
YYYY  HONO  DET  C
18  NOV  73
CS118
    S1X/1       16896.7       33793.4
    NWC/2          95.0          190.0   0100Z
    NWC/1          61.1          122.2   0100Z
    NIK/2           6.2           12.4
    CS060          -9.6          -19.2
    CS060/P        47.775        95.550
CS060
    S1X/2       16916.3       33834.6
NOTES
    NIK/1       INOPERATIVE.
    NDT         SCHEDULED MAINTENANCE 172300Z to 180700Z
NOV 73.
BT
```

Figure 3

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Each morning, the complete reel of TWX paper tape is scanned by the Time Service Data Acquisition System and all PTTI data (identified by the 4 Y's) are listed on an IBM 1816 typewriter and punched onto cards for later use in the U. S. Naval Observatory IBM 360/40 general purpose computer. The data punched are the civil date, the computed Modified Julian Date, "Local Reference or Cesium Number", and the time comparison. The check number, which is twice the time comparison, is automatically verified. Any discrepancy is noted on the typewriter as an error.

STORAGE AND REDUCTION

The punched cards are then used as input to the IBM 360/40. All permanent storage and all calculations are done here because of the greater capacity and flexibility in data manipulation. Since only SATCOM time transfers, direct comparisons and some television comparisons are used in this system currently (although expansion is being planned) only the data used are stored on the disk pack. The calculations to reduce all the data to the difference U.S. Naval Observatory Master Clock (USNO MC)—Local Reference or Monitored system are then made.

In Figure 4, we can see not only the links or series of additions necessary to reduce the data to USNO MC but also the worldwide precise time synchronization possible through the SATCOM terminals.

The connecting link between all terminals and the USNO MC is the terminal at Brandywine, Maryland (coded MBWE). To ensure that its relationship to USNO MC is well known, portable clock visits are scheduled, at a minimum, bimonthly. Additional data are provided by a microwave link which is read Monday through Friday.

Timing access to the Pacific is possible through the Honolulu terminal (HHON/HHEL) (Fig. 4). Through this path, precise time reference stations have been established at Guam and Okinawa. After modifications to the equipment at Thailand (SSEA) are completed, a precise time reference station will also be possible there. If a station can be established at either Northwest Cape (ACAP) or Woomera (WOOM), Australia an important link will have been established for the control of the Naval Communication Station, NWC.

As seen in Figure 4, the Northwest Pacific Loran-C chain (SS3) is monitored by Okinawa, Nasa/Guam, and SATCOM/Guam. Such redundancy can provide great reliability to the reported values of SS3.

USNO MC

MBWE

HHON/HHEL

GMOG   SSEA   OFUT

ACAP   GFIN   TAGU   SS3

VLF   SS3   NASA VIA TV   OLIO USAF   VLF   FUCHU

FUCHU   SS3

FUCHU

1 P.2   2 P.2

MBWE-BRANDYWINE MD.
HHON/HHEL-HELEMANO HAWAII
DETC-WAHIAWA HAWAII
GMOG-FINEGAYAN GUAM
SSEA-THAILAND
OFUT-FUTENMA OKINAWA
S1X-CENTRAL PACIFIC LORAN-C
SLAVE STATION
ACAP-NORTHWEST CAPE AUST
GFIN-FINEGAYAN GUAM
TAGU-KOREA
SS3-NORTHERN PACIFIC LORAN-C
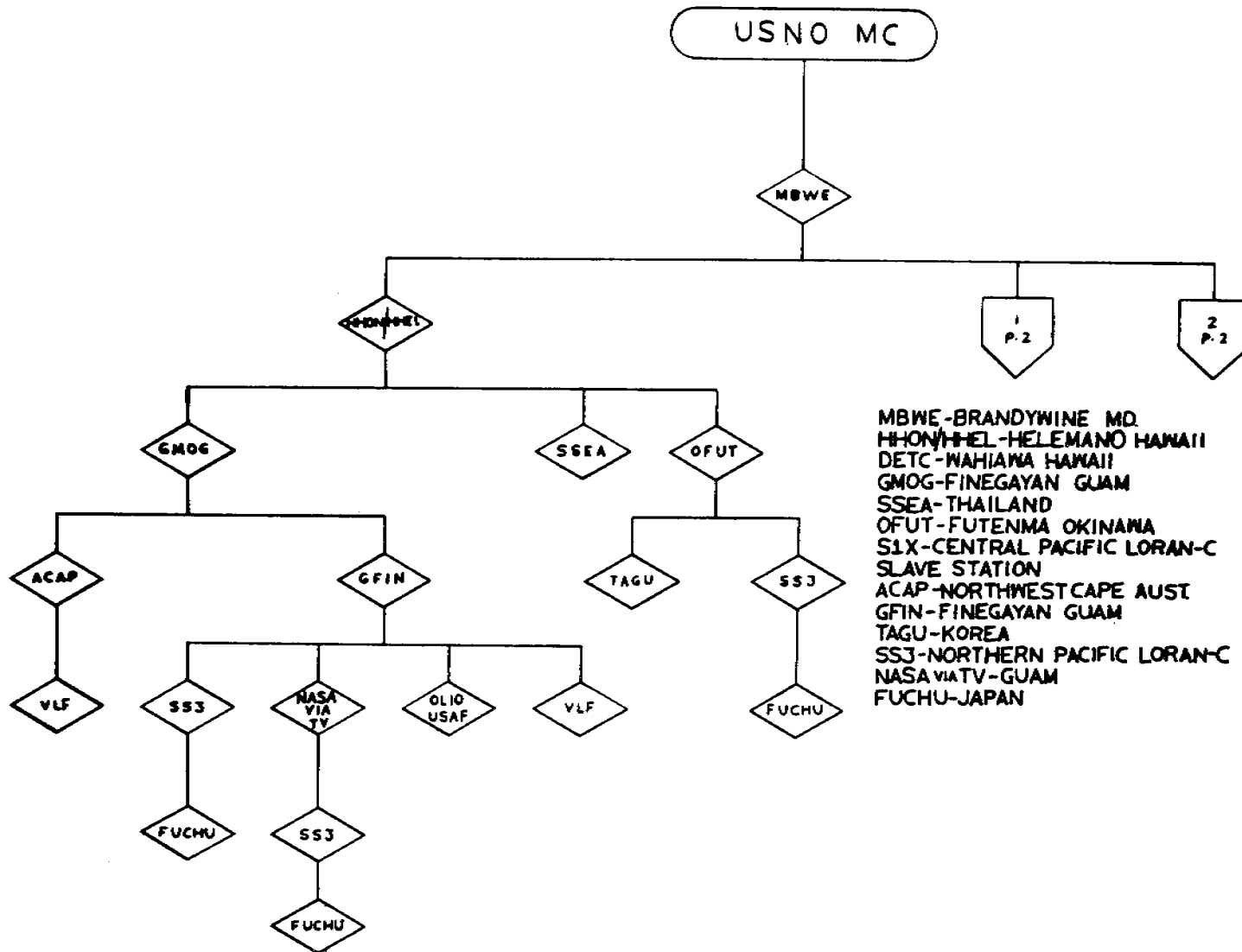NASA via TV-GUAM
FUCHU-JAPAN

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Figure 4

Through the Camp Roberts terminal (CRBT) (Fig. 5), links to Kwajalein, Marshall Islands; tentatively to Woomera, Australia; and to Shemya, Alaska are possible. With a link to Shemya and by portable clock visits to Elmendorf Air Force Base, the Northern Pacific Loran-C chain (SH7) which is monitored by Elmendorf, can be related to USNO MC.

In the East, synchronization to USNO MC is also provided by the SATCOM terminals: going from Brandywine through Ft. Dix, New Jersey to Norfolk, Virginia and then to Guantanamo Bay, Cuba. Another path is through Ft. Dix to Naples, Italy or to Landstuhl, Germany where equipment modifications are now being made.

The method and equipment used in time transfers between SATCOM terminals have been discussed at past PTTI meetings (PTTI Planning Meetings, 1971 and 1972).

OUTPUT: LISTINGS AND GRAPHS

The daily output of this program are six pages of computer listings. The first two are a summary of the data reduced to USNO MC. While beginning and ending dates are variable, the usual list is for the current month with about an eight-day over-lap. The remainder of the listings contain all the raw data received. Using the lists (Fig. 6), discontinuities and/or discrepancies are located and problems resolved when possible. If necessary, clarification from the terminals is requested. The problem most often encountered is the transmission of the wrong sign.

On the summary sheets (Fig. 7), the difference of USNO MC—Local Reference or Monitored System is given as well as the calculated rate of change in parts in 10^{13} in respect to USNO MC.

Our goal is to keep the cesiums within ±10 microseconds and also with a rate of change of less than ±12.0 parts in 10^{13} in respect to USNO MC. From the following plots, using data stored on disk, the steps made in controlling the cesiums at the SATCOM terminals may be seen.

In the graph of Norfolk, Virginia/Cs 351 (Fig. 8), the measurements obtained in late July and early August gave a time difference USNO MC-VNOR/CS 351 first of -9.8 microseconds and then of -12.0 microseconds. A control message, based on these time differences, was sent requesting a 15 microsecond retard. Immediately after the step, frequent data were received which gave a rate of -15.9×10^{-13} for Cs 351 in respect to the USNO MC. Therefore, a second control message to decrease the frequency was sent. Since then (September 10), Cs 351 has remained within 1 microsecond of USNO MC.
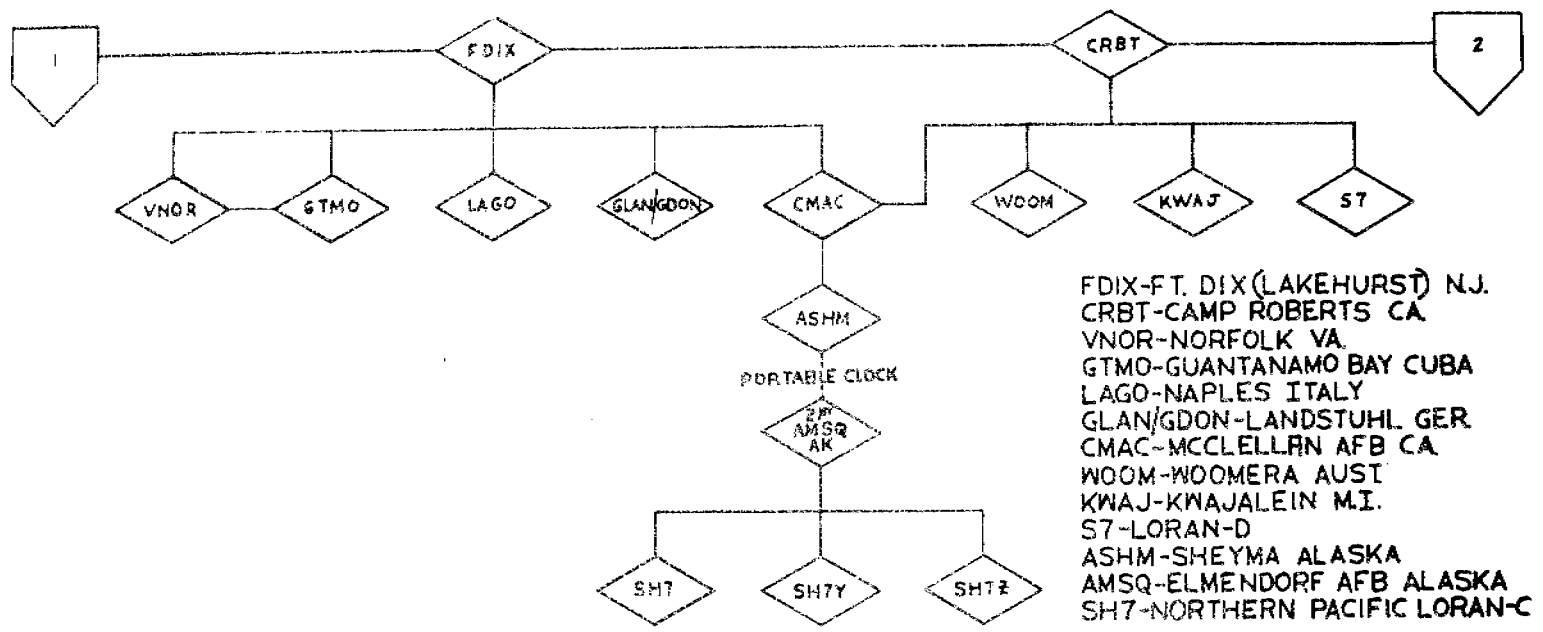
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FDIX-FT. DIX (LAKEHURST) N.J.
CRBT-CAMP ROBERTS CA
VNOR-NORFOLK VA.
GTMO-GUANTANAMO BAY CUBA
LAGO-NAPLES ITALY
GLAN/GDON-LANDSTUHL GER
CMAC-MCCLELLAN AFB CA
WOOM-WOOMERA AUST
KWAJ-KWAJALEIN M.I.
S7-LORAN-D
ASHM-SHEYMA ALASKA
AMSQ-ELMENDORF AFB ALASKA
SH7-NORTHERN PACIFIC LORAN-C

Figure 5

Figure 6

DATE		1 USNOMC -BRNDYWINE	2 USNOMC -HONOLULU	32 USNOMC -PC112	3 USNOMC -CP ROBERT	22 USNOMC -CS550	4 USNOMC -GUAM	17 USNOMC -GMOG	5 USNOMC -LAKEHURST	6 USNOMC -LANDSTUHL	7 USNOMC -OKINAWA
731023	41978	1.5		0.4			6.3				
731024	41979	1.6									
731025	41980	1.6	13.9								0.2
731026	41981	1.6		0.7	-5.7	-4.3					
731027	41982	1.6	-4.1				6.2				
731028	41983										
731029	41984	0.3									
731030	41985	0.3					6.1				
731031	41986	0.3	-4.1						-6.8		
7311 1	41987	0.3									
7311 2	41988	0.4	-4.1	1.0	-6.4	-4.2			-6.7		
7311 3	41989	0.4									
7311 4	41990	0.4	-3.9						-6.6		
7311 5	41991	0.4					6.0				
7311 6	41992	0.4		1.2							
7311 7	41993	0.4	-3.6						-6.5		
7311 8	41994	0.5									
7311 9	41995	0.5	-3.1	1.4					-6.4		
731110	41996	0.5					6.1				
731111	41997	0.5									
731112	41998	0.5	-2.8	1.5							
731113	41999	0.5					6.0	-0.5			
731114	42000	0.6									
731115	42001	0.6									
731116	42002	0.6	-2.3		-7.4	-3.8			-6.1		
731117	42003	0.6									
731118	42004	0.6									
731119	42005	0.6	-2.2						-6.0		
731120	42006	0.7									
731121	42007	0.7									
731122	42008	0.7									
731123	42009	0.8	-1.9		-8.0	-3.6			-5.9		
731124	42010	0.8									
731125	42011	0.8									
731126	42012	0.9									
731127	42013	1.0					1.0	-0.8			
731128	42014	1.0	-1.1	2.4			1.2				
731129	42015	1.0									
731130	42016	1.1	-0.8	2.5							
RATE OF CHANGE PARTS IN 10^{13}			+9.0 27 days	+5.7 24 days	-9.0 147 days	+2.6 36 days	+2.0 34 days	-2.5 55 days	+4.9 93 days		-2.9 234 days

Figure 7

UTC (USNO MC) VS. NORFOLK VNOR/CS 351
731126
US NAVY
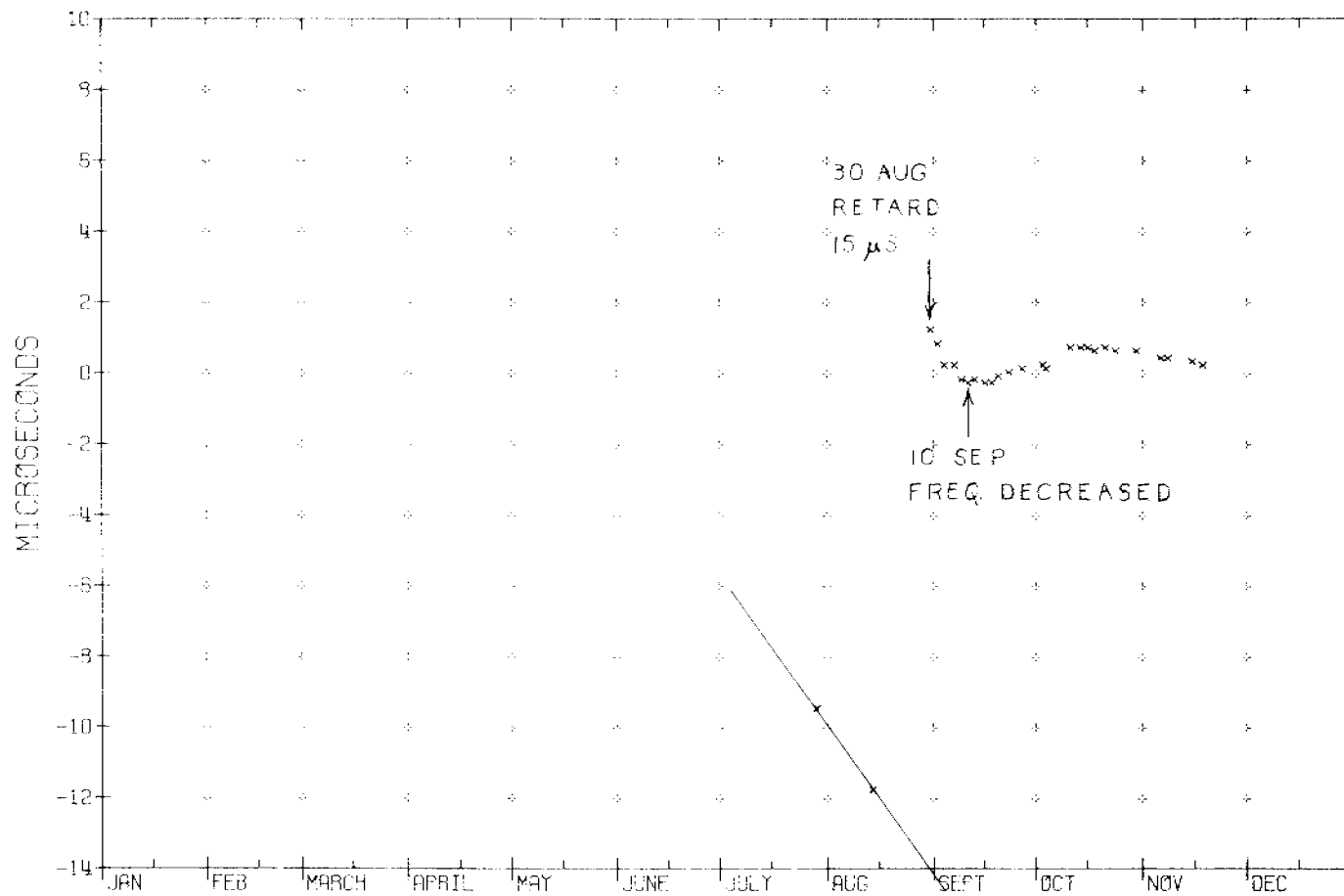
Figure 8

At this point, I'd like to present the Control Messages which were sent to Norfolk (Figs. 9 and 10). The first message initiated the step. To do this, it was necessary to change the thumbwheel settings which control the amount of delay in the system. Since USNO MC-Cs 351 was negative, we wished to retard it or, in other words, to increase the delay in increasing the thumbwheel settings. In each Control Message sent, the USNO gives the current thumbwheel setting and then the new setting we desire. Each unit change is equivalent to 1 microsecond. After the change is made, an acknowledgement is sent by the SATCOM terminal, giving the old setting, the new one, and the date/time of the change.

In like manner, a change in frequency is introduced. Here, the change is accomplished by adjusting the C-field setting of the cesium beam. Since the rate of change in USNO MC-Cs 351 was negative, we knew that the frequency of Cs 351 was high in respect to USNO MC. We therefore decreased the C-field setting, each unit change in the setting being approximately equal to a change in frequency of 5.0 parts in 10^{13}.

In contrast to the ease in which Cs 351 was controlled, the graph of USNO MC-GMOG/Cs 529 (Fig. 11), shows the worst case in that a number of corrections were necessary to bring Cs 529 (located in Guam) into the tolerances desired.

The first time comparison was made by portable clock visit in April 1973. The difference was better than 40 microseconds and the frequency was quite low as indicated by subsequent data from time transfers made with the Honolulu terminal. The frequency rate of change with respect to the USNO MC was +45.7 x 10^{-13}.

A Control Message to advance by 50 microseconds and to increase the frequency by a number of major divisions was sent. No C-field setting was specified as it was not known at that time. Unfortunately, the frequency was changed by too great an amount. Additional messages were sent and since September 1, the difference USNO MC-GMOG/Cs 529 has been less than 1 microsecond.

As an example of the best case is the plot of USNO MC-OFUT/Cs 447 at Okinawa (Fig. 12). After an unexplained jump of approximately 6.0 microseconds in mid-February, Cs 447 has been very stable. Its rate of change in respect to the USNO MC, over 234 days, has been -2.9 parts in 10^{13}. The two portable clock measures made in April and October gave rise to an unexplained discrepancy of approximately +0.4 microseconds in the sense SATCOM time transfer-Portable Clock measurement. This difference, appearing also in the comparison of measurements made at Guam and Thailand, has not however appeared in any other comparisons of SATCOM time transfers and portable clock measurements. The discrepancy is still being discussed and will be investigated further.

TIME

TO: REFERENCE STATION

```
    .
    .
    .
TO NAVCOMMSTA NORFOLK VA
BT
UNCLASS  //N02400//
ADJUSTMENT OF VNCR/CS 351
1.   INCREASE THUMBWHEEL SETTING FM 920 383
CK 1 840 766 TO 920 398 CK 1 840 796.
2.   REQ DATE/TIME ADJUSTMENT PERFORMED.
BT
```

FROM: REFERENCE STATION

```
    .
    .
    .
TO RUEBPAA/NAVORSY WASHINGTON DC
BT
UNCLAS //N02300//
1. 301538Z AUG 73
CS 351 THUMBWHEEL SETTING CHANGED FM 920 393 CK
1 840 766 TO 920 398 CK 1 840 796.
BT
```

Figure 9. Control Messages

FREQUENCY

TO: REFERENCE STATION

```
.
.
.
TO NAVCOMMSTA NORFOLK VA
BT
UNCLASS //N02400//
ADJUSTMENT OF VNOR/CS 351
1.   DECREASE C-FIELD SETTING FM 700 CK 1400
TO 696 CK 1392.
2.   REQ DATE/TIME ADJUSTMENT PERFORMED.
BT
```

FROM: REFERENCE STATION

```
.
.
.
TO RUEEPAA/NAVOBSY WASHINGTON DC
BT
UNCLAS //N02300//
1. 101712Z SEP
CS 351 C-FIELD CHANGE FROM 700 CK 1400 TO
696 CK 1392.
BT
```

Figure 10.   Control Messages

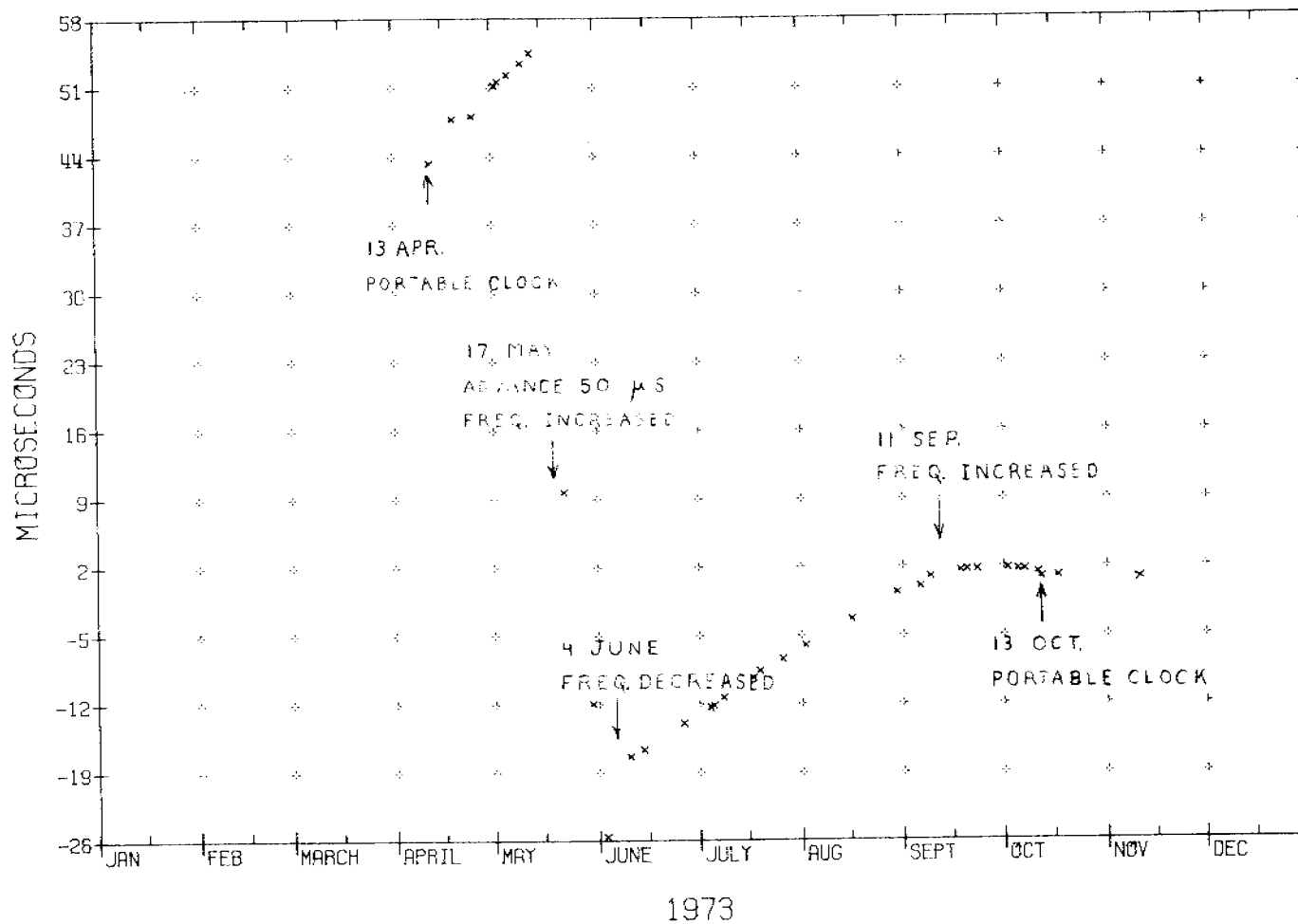UTC (USNO MC) VS. GMOG/CS 529
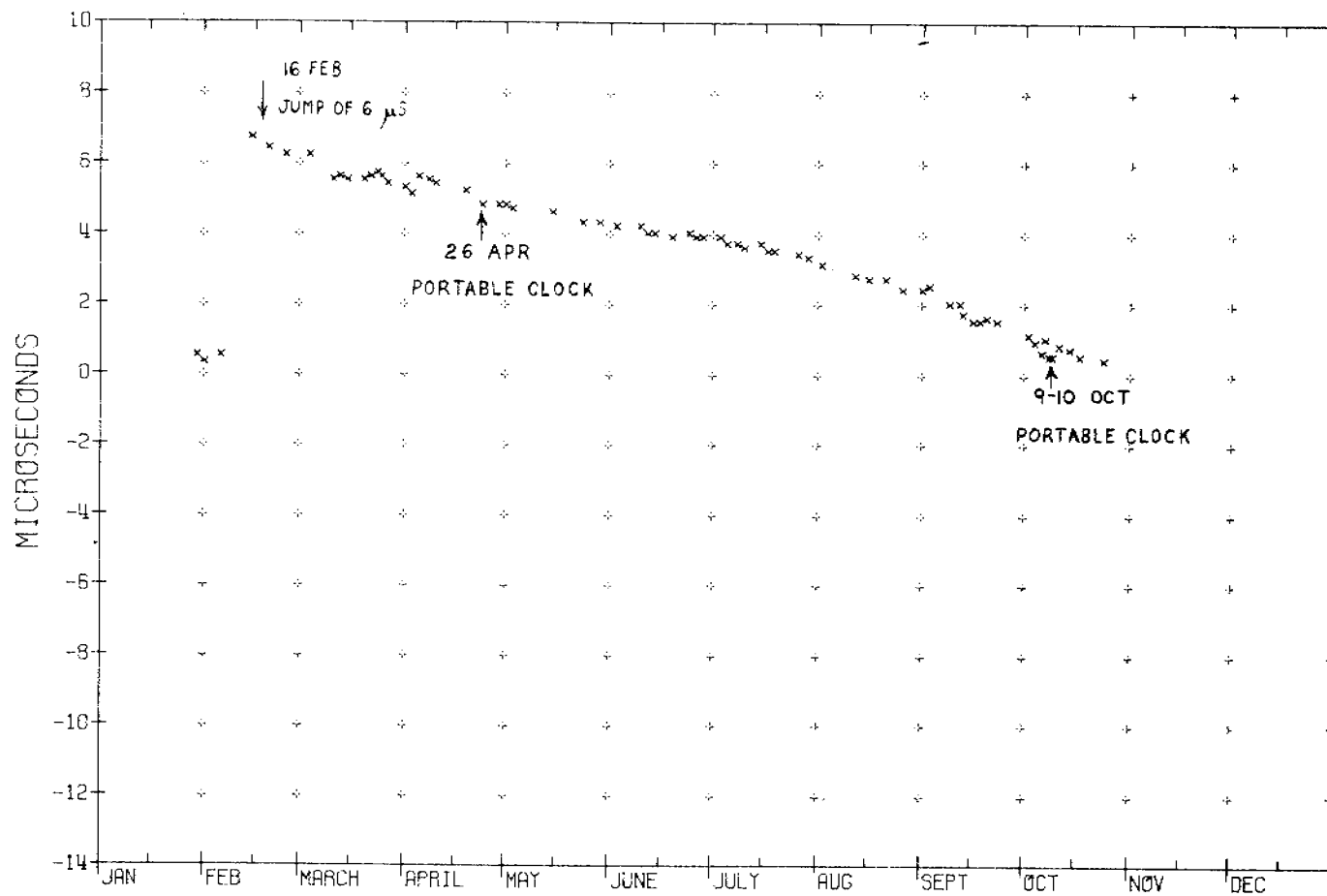731109   US NAVY

MICROSECONDS

13 APR.
PORTABLE CLOCK

17 MAY
ADVANCE 50 μS
FREQ. INCREASED

11 SEP.
FREQ. INCREASED

4 JUNE
FREQ. DECREASED

13 OCT.
PORTABLE CLOCK

1973

Figure 11

Figure 12

As of 1 November, time transfers between Okinawa and Honolulu have been temporarily suspended to permit equipment modification at Okinawa. However, Loran-C (SS3) data as well as time comparisons between the cesiums at Okinawa are still being received. Although not reduceable to USNO MC, the data will indicate if any jumps occur in either the LORAN-C station or in the Okinawa cesiums numbered 447 or 558.

Eventually, cesiums will be installed at approximately 28 SATCOM terminals, each of which will be a precise time reference station.

DISSEMINATION

The final output of the automatic processing is the Time Service Announcement Series 16, issued every 10 days. The last figure (Fig. 13) is of the last issue. While Series 16, which is prepared by the IBM 360/40, began solely as a Satellite Communication Time Transfer Report, it has developed into a report of all timing information received from the terminals (with the exception of Loran-C and Loran-D) and is distributed to more than 65 organizations. The data reported include direct comparisons made between cesiums at the terminals, television measurements and microwave measurements. This report, as well as the other Announcements of the Time Service, are available upon request.

CONCLUSION

As the need for greater world-wide synchronization and more Precise Time Reference stations increase, so will the requirements for faster data handling, reduction and dissemination of PTTI data. To fulfill those requirements, the USNO has begun using automatic data processing in this field. The program for which the Defense Satellite Communication system served as the nucleus, is currently being expanded and soon will be able to process all data received, including VLF and Loran-C and Loran-D.

ACKNOWLEDGEMENT

Credit is due to Mr. P. E. Lloyd who operates the IBM 1800 and IBM 360 for these programs and to Mr. L. T. Tillery who did the lettering for the figures.

U.S. NAVAL OBSERVATORY
WASHINGTON, D.C. 20390

26 NOVEMBER 1973

COMMUNICATION SATELLITE REPORT SERIES 16   NO. 37

THE REPORT LISTS UTC(USNO MC) - UTC(REFERENCE CLOCK) REFERRED TO 0000 UTC,
UNIT IS ONE MICROSECOND.   ESTIMATED ACCURACY IS ± 0.3 MICROSECOND.

MBWE	BRANDYWINE, MARYLAND	HHEL/HHON	HELEMANO, HAWAII
P.C.	HELEMANO, HAWAII	DETC	WAHIAWA, HAWAII
CRBT	CAMP ROBERTS, CALIFORNIA	A	CAMP ROBERTS, CALIFORNIA
GFIN	FINEGAYAN, GUAM	GMOG	FINEGAYAN, GUAM
NASA	GUAM	FDIX	FT. DIX (LAKEHURST), NEW JERSEY
OFUT	FUTENMA, OKINAWA	B	FUTENMA, OKINAWA
VNOR	NORFOLK, VIRGINIA	KWAJ	KWAJALEIN, MARIANA IS.
LAGO	NAPLES, ITALY	GTMO	GUANTANAMO BAY, CUBA

DATE 1973	MJD	MBWE CS 531	HHEL/ HHON CS 561	P.C. (3) CS 112	DETC (3) CS 118	CRBT CS 576	A (3) CS 530	GFIN (3) CS 107	GMOG CS 529
NOV. 11	41997	0.5	....	....	....	....	....	....	....
12	41998	0.5	-2.8	1.5	3.3	....	....	....	....
13	41999	0.5	....	....	....	....	....	6.0	-0.5
14	42000	0.6	....	....	....	....	....	....	....
15	42001	0.6	....	.... (5)	....	....	....	....	....
16	42002	0.6	-2.3	....	3.4	-7.4	-3.8	....	....
17	42003	0.6	....	....	....	....	....	....	....
18	42004	0.6	....	....	....	....	....	.... (7)	....
19	42005	0.6	-2.2	....	3.5	....	....	....	....
20	42006	0.7 (2)	....	....	....	....	....	....	....
21	42007	0.7	....	....	....	....	....	....	....
22	42008	0.7	....	....	....	....	....	....	....
23	42009	0.7	-2.0	....	3.4	-8.1	-3.7	....	....
24	42010	0.7	....	....	....	....	....	....	....
25	42011	0.7	....	....	....	....	....	....	....

Figure 13

QUESTION AND ANSWER PERIOD

DR. WINKLER:

Thank you, Ms. Fisher.

Questions for the paper, please?

ENS WHITE:

Is the observatory's current position to assume the kind of clock control that you demonstrated for the SATCOM terminals and to extend it to other organizations? Say, control over a cesium that we might have at one of our sites? Are you in a position to assume the control of that in terms of adjustments and one thing and another.

MS. FISHER:

I would defer that to Dr. Winkler.

DR. WINKLER:

I cannot commit ourselves without knowing exactly the situation, and I would like to invite you for a discussion on that. The possibility exists, technically, because the system is designed as developed by Ms. Fisher to handle 30 messages a day or 100 messages a day. It doesn't make any difference in that regard.

The greatest problems which exist are in training; sign convention, for instance, is a major headache for us. It does require a considerable amount of training. I think we have to at least initially take into account the human interface. That is why we appreciate having so many actually operating people here in the audience, so we can get into some direct contact.

I think after that has been established, after we have collected considerable experience, we will have a very smoothly running system.

There is another question.

MS. FISHER:

I would also like to mention that any kind of analysis of error on any of these transfers is not gone into yet. We are only establishing the system. It has only been started since March of 1973, and it is just now being done by the computer.

Right now, we are just trying to get a data set, something to work with. I think in the three graphs that you did see, the time transfers do indicate a great deal of consistency, and you can extrapolate and predict these values for some time ahead.

Question, please?

MR. MITCHELL:

Tom Mitchell, Kwajalein Missile Range.

In regard to the sign convention which Dr. Winkler mentioned, when we first started out we weren't sure of our sign convention, and possibly we had some errors.

My primary question here concerns the first reading that I sent in. This was 73 microseconds, which we disagreed with, and we did not change. Now, to this date we have not been able to determine where the 73 microsecond reading came in. However, it was a consistent reading, but because of the magnitude we were able to determine that it was a bad reading.

Should the reading be of a lower magnitude, and we get consistent readings like that, how would we determine whether we have had a jump in our clock, or whether there is a mistake in the reading that we are getting.

MS. FISHER:

Well, the procedure we would like to follow is to contact the terminal itself and ask for another time transfer just to confirm it. In your case, we did not have any readings at all from Kwajalein before that first one. It was so far off, that we sent a control message right away.

Now, again, here, if I recall, you immediately made another time transfer with Camp Roberts that showed that the first reading was in error. Why that would occur, I don't know. Perhaps somebody more involved in the equipment, involved in time transfers could tell you that.

DR. WINKLER:

Again, let me remind you also that the quickest way to find out is to look at another time source, e.g. Loran or send a portable clock, and we are left again to our main means to calibrate the validity of the overall procedure. We cannot be entirely without it.

MS. FISHER:

I think there is going to be another paper later on about the Defense Satellite Communications scheduling, in precise time transfers. The system will be very good, world wide, but we do have the problems of scheduling, and the precise time transfers are very low priority, unfortunately.

DR. WINKLER:

There is another comment that I want to interject here, and that is, at the present time there are roughly 28 satellite ground stations which are or will be available. Out of these 28, DCA, and the services have approved 10 designated stations to serve, in addition to their regular use as precise time reference stations.

Some of these 10 designated stations are Camp Roberts, Hawaii, Okinawa, Guam, and there will be others.

However, since it is an operational system which utilizes in a piggy-back way a communications system, a gigantic communication system, we must preserve the utmost flexibility.

But we will be in a position to serve, to provide time service wherever the action is, because that is where the terminal is going to be.

MS. FISHER:

Any more questions?

MR. MITCHELL:

Yes.

In the remote location that Kwajalein is in, and our mail service is rather poor out there --

DR. WINKLER:

It is poor here, too.

(Laughter.)

MR. MITCHELL:

Well, due to the combination of it being poor here and worse out there, we are receiving the bulletins rather late.

Has any consideration been given to having a teletype feedback on the data, rather than having to wait for the service bulletin to come out?

MS. FISHER:

As far as I know, you are the first one who has brought this up. I don't know whether it would be feasible or not.

DR. WINKLER:

I think it would be. As in everything else we do, we need requirements, we need documented requirements. I would encourage you to get it into your channels. I think the possibility exists, but we need requirements. We used to, three or four years ago, have our Series 4 daily phase values, on composite broadcast transmitted twice daily over some 35 frequencies, worldwide. Now, that was instituted based on the requirement which we got at that time, and our evaluation of these. We think that it was a very good idea.

But after a half year, when we had to document how many people were still using it, we could not justify the continuation of that service.

So, it is always a question of documenting your requirements, and I would only encourage everyone who feels that our service should be improved to let us know in writing, please.

MS. FISHER:

I might also mention one more thing to the gentlemen from Kwajalein. It was due to your suggestion, that we incorporated in the reports some of the other cesiums at SATCOM terminals. For example, I think you asked, since you were transferring with 550, if we would report the time difference between master clock and 550. As you saw on the last slide, we just started. I think maybe two or three issues ago, we started to include, for example, detachment Charley, the two cesiums at Okinawa, and the two cesiums at Camp Roberts.

We do appreciate any comments from anyone who is using the data, and any suggestions that you might have.

DR. WINKLER:

I think we will have to move on. Thank you, Ms. Fisher.

I would like to call now on Mr. Robert Easton, to give us his paper on Submicro-second Time Transfer between the United States, United Kingdom, and Australia via Satellite.

Mr. Easton, please.