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

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TIME SERVICE ANNOUNCEMENT SERIES 14 NO. 7

Plans for An Improved System of Universal Clock Time Dissemination (UTC)

(1) *Introduction.* The distribution of time for public use must necessarily serve many widely different purposes. Commensurate with technological capability, requirements for precision timing have increased. The demands that are now being placed on the currently disseminated time scale, Coordinated Universal Time (UTC), make it necessary to reappraise and optimize the compromise which is necessary to serve all users. In the following, an attempt is made to present the conflicting requirements and to describe the planned solution to this vexing, but far-reaching, and important problem..

(2) *Background.* UTC, the first high precision atomic clock time in general use, is coordinated world-wide by the Bureau International de l'Heure (B.I.H.). It is the logical development of procedures adopted before the existence of atomic frequency standards. UTC is in use by almost all time services. It is usually generated directly by atomic clocks at the major timekeeping observatories and laboratories in the world. The approximation to the astronomical "Universal Time (UT)" is accomplished by the yearly adoption of a fixed frequency in relation to the cesium standard ("offset"). To keep the clock time within an accepted tolerance of 100 ms of the astronomical time corrected for seasonal and polar variation (UT2), occasional steps of 100 ms are made when necessary. For precise measurements and reductions (mostly after the fact), corrections or differences between this disseminated time and other time scales (UT, A.1, ET, etc.), are communicated to the user by radio and by mail.

(3) *Requirements for Time.* Time, in the sense "time of day", is needed as one of the fundamental parameters in astronomical and navigational tables. This, together with the requirements of civil use (scheduling, legal time, etc.), necessitates a close link of time signals with diurnal phenomena, i.e., mean solar time. On the other hand, numerous new global electronic systems demand synchronized operation with a precision of about one microsecond. Some of these systems cannot tolerate the small time steps or frequency changes required in the present UTC system where the frequency of occurrence of both is in the dangerous zone of "too often, but not frequently enough". Aircraft, for example, may soon be using microsecond timing systems which cannot tolerate these changes for either safety or logistic reasons.

In the interest of simplicity and avoidance of confusion, three principles appear to be paramount:

(a) That disseminated time of day must be sufficiently close to mean solar time to prevent gross errors and to leave the greatest number of users unaffected by the actual deviation from mean solar time.

(b) That there should be only one, necessarily a compromise, system of public time distribution.

(c) That carrier phase and pulse sequences must be strictly coherent, i.e. so that phase tracking renders information on clock rate directly.

(4) *Difficulties with Certain Alternatives.* There currently exists a system of "Stepped Atomic Time" (SAT) which is not offset. This system has not found wide acceptance primarily because the steps are too frequent and too small (200 ms). The current UTC system suffers from the same defects, but because the frequency is offset, the problem is not so obvious in respect to steps but it creates difficulties in connection with the frequency changes. Experience has already shown that many users (particularly those needing high precision) do not willingly make time steps or changes in frequency; in fact, when such changes do occur, confusion and errors invariably result, no matter how extensive the advance publicity. Another difficulty is that an increase in the tolerance between UT and the disseminated time of day will introduce timing errors greater than the errors inherent in the astronomical and navigational tables and also greater than the common eye-ear method can render without additional instruments ($0\overset{s}{.}1$).

(5) *Plans.* All modern timing requirements can be satisfied by the dissemination of a clock time scale, stepped in multiples of 1 second, which will not be offset in frequency. Such a solution is not new. It is analogous to the way the Julian calendar makes basically incommensurate natural units commensurate to an acceptable accuracy for long periods. Just as the Julian calendar adds one day every four years to correct a discrepancy of almost one complete solar day, it also seems possible to add or subtract exactly one second to the disseminated time of day whenever necessary.

Since UT1 is required, the quantity ΔUT = UT1 - UTC (Time Signal) must be readily available. One method of providing this information will be in a code form similar to the manner in which U. S. Naval time signals (NBA, NSS, etc.) indicate minutes. (See enclosures (2) and (3).)

(6) *Discussion.* No change in the almanac tables need be made. In fact, no change should be made since, for the sake of conceptional simplicity as well as expediency, the tables must continue to refer hour angle data to UT1 and orbital data to ET directly. For the price of adding 'ΔUT' to the time signals, all clocks and standard frequencies can always remain on the same frequency (no offset) and still satisfy all the basic principles.

Some people will find the proposed simple code still too difficult to use: therefore, a table of extrapolated corrections will be supplied quarterly in addition to the transmitted high precision code information. No change is anticipated in the distribution of final observed values of ΔUT. On the other hand, the steps proposed here are so large and infrequent that the impact on all atomic time users is minimized. Also quite important to physicists, this improved coordinated time will have only "standard" time intervals (1^s).

It cannot be overemphasized, however, that the vast majority of users of standard time signals today still consists of about 200,000 worldwide users of nautical, geodetic and astronomical almanacs, which must be protected from errors of possible fatal consequences. It is, therefore, the agreed judgment *that 1 second steps represent an optimum compromise* at the present time.

(7) *Details of the Implementation.*

a. Enclosure (1) is a copy of Resolution 1 of Commission 31 (Time) of the XIV General Assembly of the International Astronomical Union (IAU) held in Brighton, 1970. This document spells out details of the recommended implementation which will be followed by the U. S. Naval Observatory (USNO) and the time/frequency transmissions of the U. S. Navy.

b. The ΔUT code is not yet decided in every detail but will most likely consist of a scheme as depicted in enclosure (2). The seconds indicating ΔUT information will be emphasized by making the ticks slightly longer than the other ticks. As reference, enclosure (3) gives the present Time Code used by U. S. Naval radio stations.

c. Those electronic systems which are not giving complete information on hours, minutes and seconds and which are not directly useful to the celestial observer (Loran-C, Omega, Transit, etc.) but which are useful for highest precision synchronization will not be stepped. At the appropriate times updated "Time of Coincidence" Tables will be issued by USNO for these systems to become effective at the moment of step. In other words these electronic systems will operate without discontinuities and users will not need to make any physical adjustments other than replacing these reference tables and stepping their clocks, showing the time of day, by 1 second.

(8) Comments and questions are invited and should be directed to:

Superintendent
U. S. Naval Observatory
Attention: Time Service Division
Washington, D. C. 20390.

(9) It is to be noted that there will be no change in the dissemination of clock time during 1971. The implementation of the proposed changes will take place on 1 January 1972.

GERNOT M. R. WINKLER
Director
Time Service Division

Encl:
(1) IAU Resolution #1, Commission 31 (24 August 1970)
(2) Proposed U. S. Naval Time Signal Code for ΔUT
(3) Time Code for U. S. Naval Radio Stations (21 October 1970)
(4) Designation of Epochs Near the Moment of Step

XIV GENERAL ASSEMBLY IAU — BRIGHTON 1970

Commission 31 - Resolution #1 - 24 August 1970

Commission 31 makes the following recommendations:

1. That the frequency offset of UTC be made zero, effective 0^h January 1972.

2. That step adjustments shall be exactly 1^s. When a step adjustment is made it shall be at 0^h on the first day of a month with preference for 1 January or 1 July. These step adjustments will be decided upon and announced as early as possible by the BIH.

3. The maximum difference $|UTC - UT1|$ will be less than $0^s.7$ unless there are exceptional variations in the rotation of the Earth.

4. Special adjustment. The BIH will also announce a unique fraction of a second adjustment to be made at 0^h 1 January 1972, so that UTC and the International Atomic Time Scale (IAT, in French TAI) will differ by an integral number of seconds.

5. The emission times of time signals from co-ordinated stations shall be kept as close to UTC (BIH) as feasible with a maximum tolerance of 1 ms.

6. Nomenclature.

   6.1 Clocks in common use will indicate the minutes, seconds and fractions of UTC (French: TUC).

   6.2 The terms "G.M.T." and "Z" are accepted as the general equivalents of UTC in navigation and communications.

7. The term ΔUT is defined by: $\Delta UT = UT1 - UTC$. Extrapolated and final values of ΔUT will be issued by astronomical observatories and the BIH, and will be given the widest possible distribution.

8. All standard time signal emissions must include information which will enable a user to obtain UT1 with a precision of at least $0^s.1$.

9. Designation of the epoch of steps in UTC

   9.1 If UTC is to be advanced, then second 00 will follow $23^h\ 59^m\ 60^s$ of the previous day.

   9.2 If UTC is to be retarded, then the second of the previous day $23^h\ 59^m\ 60^s$ will be followed by the next second $0^h\ 00^m\ 00^s$ of the first day of the month.

   9.3 The stepped second will be commonly referred to as a "leap" second (in French: intercalaire).

   9.4 The time of an event given in the old scale, before the leap second, will be given as a date in the previous month, exceeding 24^h if necessary. The time of an event given in the scale after the step will be given as a date in the new month, with a negative time, if necessary.

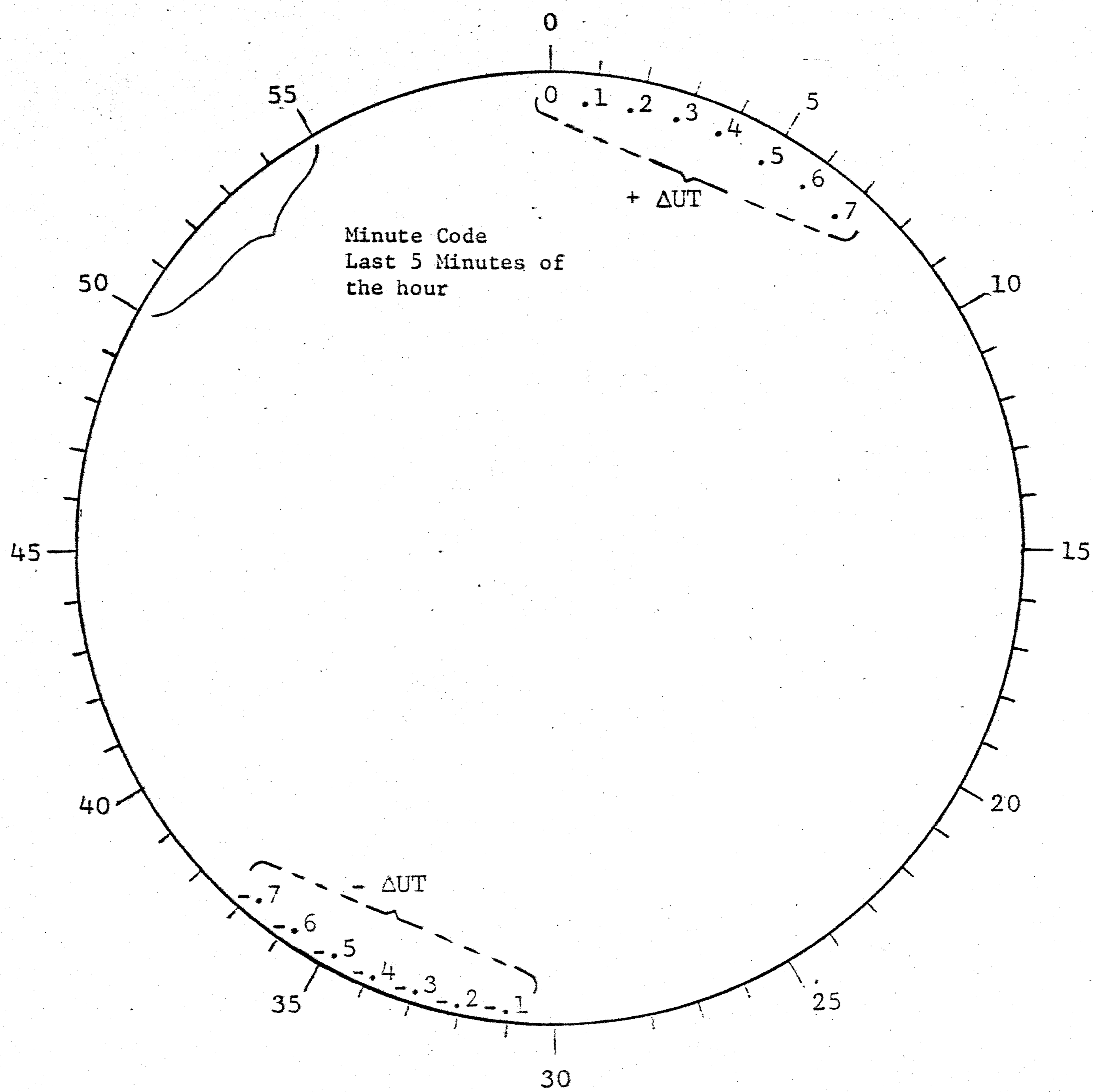
Note: Commission 31, taking into account the conflicting requirements of the various users of UTC, including the large number of those requiring immediate knowledge of hour angle, consider that the above represents the optimum solution.

Enclosure (2)

PROPOSED ΔUT CODE

U. S. NAVY TIME SIGNAL

$\Delta UT = UT_1 - UTC$



NOTE: Seconds indicating ΔUT information will be emphasized by making them slightly longer than the other ticks.

Enclosure (3)

Time Code for U. S. Naval Radio Stations

The time signals sent out by the Naval radio stations are all transmitted on continuous waves. They can be heard only with receivers designed to receive such transmissions. These stations transmit time signals during the last five minutes of certain hours only.

Time signals (dashes) are transmitted for each second of the five minute period with the following exceptions;

a. No signals are transmitted on the 29th second of any minute.

b. No signals are transmitted on certain seconds at the end of the minutes as shown by the following table, to permit minute identification.

Minutes	Seconds										
	50	51	52	53	54	55	56	57	58	59	60
55	--		--	--	--	--					--
56	--	--		--	--	--					--
57	--	--	--		--	--					--
58	--	--	--	--		--					--
59	--										---

NOTES:

(1) The dashes indicate the seconds on which signals are transmitted.

(2) The seconds marked "60" are the zero seconds of the following minute.

(3) The signal at the end of the 5 minute period, i.e. on the beginning of the hour (shown as 59 minutes 60 seconds above) is much longer than the others.

(4) In all cases the beginning of each dash indicates the beginning of a second.

(5) The ends of the dashes are without significance.

(6) Schedules and frequencies are available as Time Service Announcements Series 2, upon request.

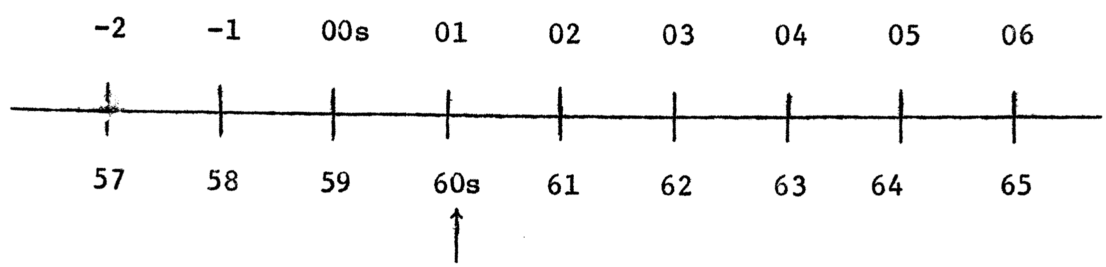
Enclosure (4)

DESIGNATION OF EPOCHS NEAR THE MOMENT OF STEP

1. UTC to be advanced:

"New" Scale:

First day of new month, 0^h0^m

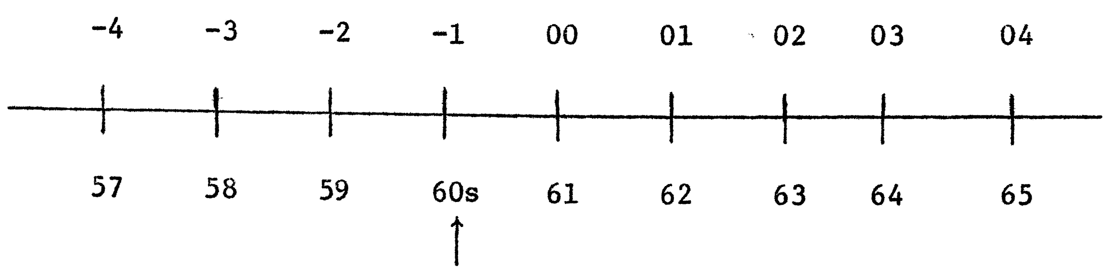


"Old" Scale, Last day of previous month, $23^h\ 59^m$.

2. UTC to be retarded (this case presently occurs more often):

"New" Scale:

First day of new month, $0^h\ 0^m$



"Old" Scale, Last day of previous month, $23^h\ 59^m$.

NOTE: The arrow designates the *standard* moment of transition from old scale to new scale. Either scale may be used, however, under the provisions of enclosure (1), para 9.4.