31. TIME (L'HEURE)

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ASTRONOMICAL TIME

A. *Universal time*

The astronomical observatories which actively cooperate in the network of the system of the Bureau International de l'Heure, are, at present, about 70. Most of the astronomical time determinations are carried out by means of Danjon Astrolabes or transit instruments; 10 observatories dispose of a PZT and 5 others are installing or planning to have it. The results of their observations, φ(observed latitude) and ΔT(difference between local U.T.0 and U.T.C.), are collected at the BIH and – contrary to the procedure used until 1967 – used to simultaneously obtain the instantaneous coordinates of the pole (x, y), referred to conventional international origin (CIO), and longitudes origin on the pole equator. As a consequence of the adoption of the above-mentioned conventional pole, the BIH had to change all conventional longitudes in order to keep the origin formerly defined (1967); they are now reported in BIH *Annual Reports*. A further change was operated on the constant of aberration which, at the beginning of 1968, from 20″.47 was changed to 20″.496. The BIH had therefore to operate a step of $+0^s.0020$ to U.T.1, at the beginning of January 1968, and so did the Greenwich Observatory, with a step of $+0.0069$. Global corrections, due to these variations and to others occurred from 1955 to 1968 (in 1958, variation of the polar reference, from Cecchini's to the mean pole of the date; in 1961, adoption of FK4 and of new longitudes), to the data of the past years (until 1968), are reported on Table 8 of the BIH Annual Report, 1968. The formula supplying the correction U.T.2 – U.T.1 remained unchanged, except for the variable t, which is expressed (since 1967) as a fraction of the Besselian year. Finally, stars coordinates in the catalogs used for time service were revised on the basis of observations made during the latest ten years (Neuchâtel, Greenwich and Mizusawa) and a catalog has been prepared, which includes 807 right ascensions for 1960, drawn from 20 catalogs, with more than 185000 observations of the U.S.S.R. (Pulkova) time service, which is also preparing a new catalog of proper motions. The unification of star positions and proper motions is recommended for the PZT.

The BIH considers the accuracy of the results such as to induce the study of the lunar effects on the vertical, and the diurnal nutation effects as well. Particular researches on observation errors in the determinations of time and longitude have been performed at the Observatories of Milan and Potsdam, while the Dresden Observatory is carrying out practical researches on a photographic method and theoretical researches on a photoelectric procedure for eliminating the trembling of the images due to the atmosphere.

B. *Ephemeris time*

While observers of stellar occultations by the Moon are rather numerous and give some thousand observations per year (400 only from Tokyo Observatory – Hydrographic Dept.), observatories which determine E.T. are rather few, not more than half a dozen. Most of them use the occultations method; Besançon, Washington, Uppsala and others use the photographic method to determine the position of the Moon on the stars background, and only Tokyo and Washington carry out meridian observations of the Moon. A. and N. Stoyko have been carrying out researches on E.T., starting from the data of 1900, and researches on lunar positions since 1955. According to A. Stoyko, the difference ΔT.0 = E.T. – U.T.2 varied from $+31^s.575$ in 1955·5 to $+36^s.713$ in 1966·5 and, according to Tokyo observations from $+32\overset{s}{.}90$ in 1962·5 to $+35\overset{s}{.}88$ in 1966·5. From the introduction of the new system of astronomical constants in 1964 and correction of some terms of Brown's lunar theory, E.T.0 time (before 1964) is distinguished from E.T.1 (after 1964): they are connected by the relation

$$\text{E.T.1} - \text{E.T.0} = +0\overset{s}{.}3426 \sin \Omega - 0\overset{s}{.}1084 \sin(2\Pi - \Omega) - 0\overset{s}{.}306 \sin D,$$

where Ω is the longitude of the lunar ascending node, Π the longitude of the lunar perigee and D the difference between lunar and solar longitude. The difference ΔT.1 = E.T.1 − U.T.2, similarly to ΔT.0 varies, according to A. Stoyko, from +30.981 (1955·5) to $+36\overset{s}{.}748$ (1966·5) and, according to the Tokyo Observatory, Hydrographic Dept., from $+29\overset{s}{.}72$ (1956·5) to $+34\overset{s}{.}52$ (1965·5) to $+37\overset{s}{.}13$ (1968·5). E.T.1 eliminates the difference between the results obtained for E.T.0 from occultations at the lunar dark edge and those at the bright edge. The comparison with atomic time proves that E.T.1 (for the short period 1955–66, so far considered), on the contrary of E.T.0, is rigorously uniform; therefore it can be stated that, according to observations of occultations, the Moon represents the most uniform ephemeris time.

ATOMIC TIME

About 20 observatories and laboratories care for time measured by atomic clocks, with approximately 60 standards. Most are caesium clocks but also hydrogen and rubidium clocks are used. Most of these standards are utilized for radiofrequency transmissions emitted by about 40 stations, of which only half are standard frequencies (coming from 16 observatories or laboratories). Differences between relative frequencies $\Delta f/f$ of these standards are of the order of a few units on 10^{12}; hydrogen standards are more stable, considering that two clocks controlled by maser standards do not differ more than 3 ns/day stability and 3 microseconds per year (3×10^{-14}) (NASA Center); for short time intervals also quartz crystal oscillators reach very high accuracies, for intervals from 1 to 10 s they are as accurate as atomic oscillators (NBS Halford).

Some of these Institutes have established an atomic time scale, for instance: A.3 of Paris BiH, A.T. (F) of Paris CNH, A.T. of Boulder NBS, A.T.1 of Braunschweig PTB, G.A.2 of Greenwich and A.1 of Washington NO, the origin of which differs by fractions of a second, while their times agree within a few μs. The first of these scales has been redefined by the BIH on January 1st, 1969, as the mean of time scales of more than 20 commercial standards (10–16 from the NO, 5 from the French group, 3 from the PTB and 3 from the RGO), continuously compared by synchronized transmissions of Loran-C chains; this is the former mean standard A3 which, until 1968, was based mainly on VLF and LF (frequency and phase difference) transmissions of many laboratories, and is now called international atomic time scale and indicated by A.T. From October 1969, laboratories which contribute to the formation of the A.T. became 7. If all precautions taken to avoid disturbances in the frequency were valid, this standard should secure an accuracy of some parts in 10^{13} over a period of some months. According to what has been said, the two time scales E.T.1 and A.T. are uniform and differ only in the initial epochs: E.T.1 − A.T. = $+31\overset{s}{.}868$ (A. Stoyko).

TIME UNIT

In October 1967, the 13th Conférence Générale de Poids et Mesures, adopted the atomic time second to be the fundamental unit of time in the international system, defining it as the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium atom 133, thus replacing the definition adopted in 1956 of the ephemeris second, and meanwhile inviting organisations and laboratories concerned to continue their researches on the argument.

This decision did not consider a recommendation of Commissions 4 and 31 of IAU on August 1967 in Prague, which requested CGPM to include in the new definition of the international second the phrase: "The ephemeris second, which is part of the IAU system of astronomical constants" (*Trans. IAU*, **13B**, 41), thus causing the protests of competent astronomers (Clemence, Fricke, Sadler, Wilkins) and also an intervention of the IAU President. Fricke suggests that during the next General Assembly, a recommendation is made to use always the form "ephemeris second" when this is necessary to avoid misunderstandings.

COORDINATED TIME

The universal coordinated time scale (U.T.C.) continued to be based on the international atomic time scale of Paris (A.3), according to the definition: U.T.C. $-$ A.T. $= S(t-t_0)+b, |$U.T.2 $-$ U.T.C$|$ $< 0\overset{s}{.}1$, using frequency offsets and time adjustments indicated by the BIH. But preoccupations raised with the introduction of U.T.C., not even mitigated with stepped atomic time (S.A.T.) which completely excludes the frequency offset, have increased and caused deep discussions on the argument, promoted mainly by the CCIR at the Boulder (August 1968) and Geneva (October 1969) meetings, and by the CIPM at the Paris meetings (May and October 1968). The CCIR appointed expressly the working group VII-1 (chairman H. M. Smith) while the CIPM formed the preparatory commission for the international coordination of time scales (chairman L. E. Howlett).

After a first examination the CCIR has proposed in the document VII-70-E some conditions for a solution which included abolition of offset, maximum difference of $0\overset{s}{.}5$ between U.T.C. and U.T.2, time adjustments of exactly 1^s (S.A.T. system) and a simple code incorporated in radio emissions to determine this difference within 10 ms. The similar document CIPM/68-5, after confirming the need to improve conventions concerning U.T.C. and supporting CCIR conclusions, has also proposed that BIH be equipped with all necessary means for the coordination of all the matter relative to U.T.C. This document also invites the CIPM to take the initiatives for reaching an international agreement on U.T.C. As this Committee took care of time unit, it is also expected to take care both of an international time scale and of an atomic time scale based on the new definition of the second, as an international scale should require a governmental agreement.

Only the first item of the two documents (abolition of offset) found nearly unanimous consent while for the others discussions are still open. According to the authoritative intervention of D. H. Sadler and G. M. Winkler, who examined thoroughly the serious dissensions between those concerned with standard frequencies and those who request a time system connected with the Earth's rotation (astronomers, geodesists, navigators etc.) and in particular the world-wide collision avoidance system for aircraft (CAS), which cannot admit stepping time adjustments, serious objections can be made as regards the proposals of the two documents; also because said Commissions ignore the needs of a great minority who cannot prescind from the definition of above mentioned U.T.C. and in particular cannot accept differences greater than $\pm 0\overset{s}{.}1$. It is stated as a necessity that activities concerning time service should be completely independent of the activities of frequency standards laboratories.

Discarding the suggestion (for practical reasons and to avoid confusions) of two time scales, one approaching U.T. (the present U.T.C.) and the other without offsets and adjustments, only three alternatives remain: (*a*) step adjustment of $0\overset{s}{.}1$ or $0\overset{s}{.}2$ to maintain the U.T.C. sufficiently near to U.T.2 to permit to ignore the difference in most of the applications; (*b*) complete disuse of U.T.C. system replacing it with a coordinated uniform time scale without offsets and steps and therefore not approaching U.T.; (*c*) step adjustment of 1^s exactly; anyway only further discussions will solve the problem.

The PTB has expressed indeed the urgent need that a Consultative Committee for Time Scales be created by the CIPM, being charged with the preparation of the time scale definition work and giving outlines to a laboratory working under these auspices, at best the BIH. This proposal, supported by the members of the PTB, with a long report by G. Becker, at the meetings held in autumn 1969 by the URSI (Ottawa), CCIR (Geneva) and CIPM (Paris) has been recommended in a resolution of the URSI, which also definitively adopted the S.A.T. system, to be commenced before 1st January 1971, with the explicit statement that the definition of astronomical time scale does pertain to the IAU. But only one month after, in October 1969 at the Geneva meeting, the working party VII-1 in its documents 1004 and 1008 rediscussed the question and decided to submit to the next

Plenary Assembly of CCIR (New Delhi, January 1970) both the offset and the S.A.T. system (the latter to be commenced in January 1972), for a final decision, asking in the meanwhile also the opinion of the Scientific Unions concerned, among which the IAU. The variation of the BIH statute, ventilated during the discussions, did not obtain the approval of the astronomers and the only result obtained was the appointment of a BIPM member to the BIH directing Board.

TIME SIGNALS AND SYNCHRONIZATION

An intense activity is devoted to the problems of synchronization of the different time scales, for the near, the far and the very far ones. Most of the emitting stations, i.e. about 40, even when based on atomic standards, transmit the coordinated time scale (U.T.C.) by radiofrequencies; only a few stations emit the A.T., while some emission is made simultaneously in A.T. for carrier frequency and U.T. for time signals. Comparisons among different standards are still carried out in most cases by very low frequencies (VLF); about 10 institutes use the Loran-C chains system, and ten others the television system. Undoubtedly the two latter methods are destined to be largely developed due to their higher accuracy (100 ns for time and 10^{-12} for frequency) and some pairs of atomic standards are now periodically synchronized utilizing television programs, as for instance, since 1968 the standards of the Paris Observatory and of the Prague Electronic Radiotechnical Institute, and since 1969 those of the PTB (Braunschweig) and DHI (Hamburg). But the limited range (maximum distance 1500 km) and difficulties of connection require further researches on equipment and wave propagation in these methods. On the other hand the PTB pointed out that the VLF transmissions, besides being the only method for intercontinental continuous synchronizations, can give results not at all inferior to the above-mentioned, such that for certain experiments they have been used together with the flying clock method, as equivalent procedures.

Some institutes have carried out experiments of synchronization based on the reflection of the waves by artificial satellites, by meteor ionized trails and recently by the Moon. After the experiments with Telstar I (1962) and Relay II (1965), synchronizations have been performed in 1968 between California and Hawaii with the satellite ATS-1. For comparisons similarly based on meteor trails (produced by collisions of meteors with air particles), discontinuity of the phenomenon apart, analogous equipments are available which give similar results, but for distances not exceeding 2000 km (due to the limited altitude of the trail); on the contrary the experiment with the Moon has been performed between Canberra and Goldstone stations. These methods are advantageous because they use the VHF system for the transmissions, requiring a very simple and not expensive equipment securing on the other hand an accuracy of the microsecond.

Finally direct comparisons by flying clocks have proved satisfactory, especially over great distances. Clock transportations organized by Hewlett Packard all over the world with stops and comparisons up to 53 stations, covered about 100000 km and at the end, relative differences amounted to a few microseconds, corresponding to an offset of 10^{-12} in the standard frequencies.

More recently the USNO organized travels with a Caesium standard, which supplied the difference between the U.T.C. (USNO) and the U.T.C. (local) of the laboratories visited; for Paris, for instance, the difference was, in 1968, April 18: $+130\mu s$, in 1969 February 24: $+113\mu s$, i.e. a variation of $-17\mu s$ over 1 year. A similar travel was realized by the PTB to Paris, in 1968, which made possible a continuous comparison, with an uncertainty lower than $1\mu s$. Even more efficient seem to be the experiments of flying over, where the time scale of the clock on board is sent to the ground station from the aeroplane, possibly on the vertical of the station at a constant altitude, avoiding stops, unloading and transshipments of materials: the application of the SINFRAL (Synchron. Franco-Allemande) since 1969 between the BIH in Paris and the PTB in Braunschweig, foresees accuracies of the order of $0{\cdot}1\mu s$.

RELATIVITY

It is known that relativistic phenomena take place in clocks with relative motion or in different gravitational fields and their entities become measurable only when remarkable velocities and sensible potential differences are involved. Therefore only effects measurable by space flights (artificial satellites and space probes) can be expected. As regards the difference between atomic time considered as proper time, in a system connected with the Earth, and ephemeris time, considered as coordinated time in an inertial system with respect to which the Earth moves, after the researches carried out by Aoki and Clemence, who calculated an annual variation of semiamplitude of $0\overset{s}{.}0017$, there are only theoretical researches (Hudson, Becker). Similar researches concern the motion of clocks around the Earth (Polishchuk, Takagi and Hara). On the contrary as regards the only mass effect on the frequencies, there are some experiments (Mungel, Sadeh and collaborators) carried out by means of comparisons between VLF signals and the results of comparisons with HP flying clocks which, anyway, have not yet given reliable results. A satisfactory answer on these problems will come from numerous and long series of ET observations and from rigorous measures of the differences of the above-mentioned times.

REPORTS OF OBSERVATORIES AND LABORATORIES

Australia. Canberra

PZT observations for U.T.0 have been continued, improved star places and proper motions being adopted from 1st July, 1968.

The clock system includes a commercial caesium beam frequency standard and two crystals which have kept the time without loss of continuity since 23rd September 1967. The scale for U.T.C. was compared with overseas scales by means of portable clocks, and the rate is recorded continuously against VLF transmissions from overseas stations and NWC in Western Australia. Time comparisons are also made continuously by courtesy of the deep space stations at Goldstone in California and Tidbinbilla near Canberra, these being linked by signals that are reflected from the Moon. The standard error of the comparisons is about 5 μs, Preliminary time comparisons by means of television transmissions are being carried out against an atomic standard at the National Standards Laboratory, Sydney.

Belgium. Uccle

L'Observatoire Royal a fait l'acquisition de deux standards de fréquence; un standard au rubidium, Rohde & Schwarz et un standard au césium, Hewlett Packard, respectivement mis en service en avril et en décembre 1968.

En outre deux oscillateurs à quartz, 1 Mc, sont asservis par des régulateurs de fréquence depuis 1969; la précision à long terme est comparable à celle d'un rubidium. Un comparateur de fréquence a été mis en service en avril 1968. Une seconde chaîne de réceptions horaires comportant un récepteur Racal, un oscilloscope et un compteur d'intervalle de temps a été installé en janvier 1968. Un second Astrolabe de Danjon sera installé dans le courant de l'année 1970.

Observations effectuées à l'Astrolabe; 1966: 90 séances, 1800 étoiles; 1967: 148 séances, 2777 étoiles; 1968: 123 séances, 2458 étoiles. Réceptions horaires: 20 par jour, soit 7200 par an. Les résultats des observations astronomiques sont publiés dans le BULLETIN HORAIRE de l'Observatoire et dans le *Annual Report* du BIH.

Brasil. Rio de Janeiro

The astronomical time determinations are being performed by two transit instruments, the installation of a PZT and the possibility of an equatorial astrolabe station at Bélem, 2 °S of the Equator, is being studied.

The time service has continued the cooperation with the BIH, sending time signals through the PPE station and checking the quartz clocks by HF and VLF signals from the network of time stations. A caesium beam standard, to be installed in 1970, has been ordered.

Canada. Ottawa

Three commercially built caesium atomic clocks are now in use at Ottawa, two in the time laboratory, and one to replace the rubidium standard formerly used as time and frequency source at CHU. Travelling clocks under the auspices of Hewlett Packard and then of U.S. Naval Observatory have visited Ottawa; and in 1967 the Swiss atomic clock visited Ottawa en route to Expo 67 Montreal. A Lorchron receiver, acquired in 1969, permits a continuous comparison with Loran C. Time service bulletins giving the results of PZT observations and time signal comparisons continue to be published quarterly.

Chile. Santiago

According to an agreement with the ESO, a Danjon Astrolabe is in operation at the National Astronomical Observatory on Cerro Calán (Lat. $-33\overset{\circ}{.}4$). The equipment comprises a Rohde & Schwarz, three quartz clock battery, an Ebauches integrating chronograph and a Rohde & Schwarz VLF receiver, which makes phase comparisons between the local oscillators and WWVL or NBA.

Results are sent weekly to BIH, and monthly to IPMS. Time and latitude bulletins were published quarterly up to 1968. Since 1969, they are published monthly. The yearly results in time and latitude are being published in Publicaciones del Departamento de Astronomía (PDA), Santiago de Chile.

Czechoslovakia. Prague

The new television method for microsecond clock comparison (*Trans. IAU*, **13A**, 663, 1967) was regularly used. During 1968 and 1969 a series of experiments were carried out using TV programs for the time comparison between Prague and Paris. Some of these experiments involved several institutions in Switzerland, German Federal Republic and Italy. The timing resolution of the order of 10 ns was shown. Weekly comparisons are made between Prague and Potsdam. A PZT is to be installed by the Ondřejov Observatory. The OMA signals give Coordinated Time since 1964.

France. Besançon

Le programme d'observations à l'Astrolabe Danjon OPL No. 31 a été poursuivi sans modification.

Le temps des éphémérides est determiné par photographies de la Lune sur le fond des étoiles. La photographie est faite par un dispositif spécial à l'astrographe de Secrétan-Couder de l'Observatoire. La mesure des clichés au mesureur Zeiss et leur exploitation sont effectuées à l'Observatoire et au Laboratoire de calculs de la Faculté des Sciences.

Jusqu'à la fin de l'année 1966, le programme quotidien des réceptions comportait la mesure de 30 signaux sur oscilloscope. A partir de 1967, sur la suggestion de Monsieur le Directeur du BIH le programme a été réduit et limité, après essais, aux 3 signaux HBG et MSF (5 MHz et 10 MHz); en outre, la publication du bulletin horaire mensuel a été suspendue.

Depuis le 1er Mars 1969, nous recevons par coaxial la fréquence d'un rubidium C.S.F. appartenant à l'École Nationale Supérieure de Chronométrie et de Micromécanique de Besançon.

Contrôle en état:

le 6 Octobre 1967 avec une "horloge volante" Hewlett Packard venue de Genève;

le 25 Février 1969 avec une horloge au rubidium de l'Observatoire de Paris.

France, Paris. Bureau International de l'Heure (BIH)

As the work of BIH for 1967 and 1968 was presented in the *Annual Reports*, we shall give here only general information and some complements.

Universal Time and Coordinates of the Pole

The computations are based on 58 series of U.T.0 measures and 44 series of latitude measures (October 1969). Observations of each star group (or sometimes each night) are dealt with individually in order to give a rough solution for every consecutive 5-day interval. Definitive values of U.T.1 − U.T.C., x, y, for the month m are published at the beginning of the month $m+2$ months in Circular D.

We computed U.T.1 − U.T.C., x and y, for 1964·0–1968·0 period, referred to the new system of the BIH and to the new aberration constant: these results were published, for every 1/20 of a year and without smoothing, in the *Annual Report* for 1967.

These new methods of computation will be extended back to the period 1955–64, so that we shall obtain an homogeneous series of values of U.T.1, x, y, since the atomic time exists. This work is in process. The 1962·0–1964·0 period will be available in 1970.

On the request of some laboratories, we supplied short-term extrapolations of x and y and also provisional values of U.T.1. We studied the possibility to establish an "express-service", giving U.T.1 to about 3 ms with a delay reduced to a few days.

Atomic time

The mean atomic time of the BIH, denoted here A.T., is linked to the so-called coordinated time U.T.C. by a rigorous formula; therefore we shall consider them as equivalent in this section of our report. Until the end of 1968, A.T. was computed by using the VLF transmissions as explained in the Annual Reports. From the 1st January 1969, we used the only time standards (or groups of standards) which are linked at intervals shorter than a few days, with an approximation of a few 0·1 μs. This is presently obtained by the reception of the Loran-C pulses by ground wave and of the television pulses. In October 1969, 7 laboratories contribute to form A.T.

Coordinated time

This time gives an approximation of U.T.2 to ± 100 ms. The laboratories and observatories i keep generally a coordinated clock which gives an approximation U.T.C. (i) of U.T.C.; Circular D of the BIH gives the differences U.T.C. − U.T.C. (i) when they are known to an accuracy of 1 μs or better.

France. Paris. Laboratoire de l'Heure

La Commission Nationale de l'Heure, en France, a fédéré les étalons atomiques possédés par l'Observatoire de Paris, le Centre National d'Études des Télécommunications, le Centre National de la Recherche Scientifique, le Laboratoire de l'Horloge atomique à Besançon. Les comparaisons faites par l'intermédiaire des impulsions de télévision permettent de construire une échelle moyenne atomique T.A.(F), indépendante. Cette échelle participe aux travaux du BIH.

A l'Office National d'Études et de Recherches Aérospatiales (ONERA), Besson et Cumer (1969) ont développé une méthode de synchronisation précise du temps de bases simplement survolées.

France. Sèvres

Une action du Comité International des Poids et Mesures concernant l'échelle de temps physique peut être justifiée par les arguments suivants:

(1) une échelle internationale nécessite un accord entre gouvernements;

(2) le Bureau International de l'Heure s'occupe déjà des échelles atomiques, mais il lui manque l'appui d'un organisme scientifique international qui donnerait un patronage plus officiel à son activité;

(3) les effets relativistes ne seront plus négligeables dans un proche avenir. Il faudra donc, par un accord international, définir un temps coordonné conventionnel pour les besoins des mesures de temps à la surface du globe ou en proximité.

France. Paris. Stoyko

Longitudes et leur variation. – Mme A. Stoyko a fait la discussion des résultats de la détermination des longitudes obtenus pendant l'AGI et la CGI (Troisième Opération des Longitudes Mondiales). Cette discussion a fait l'objet du mémoire (369 pages), publié dans les Annales de l'AGI, contenant les résultats de la détermination de longitudes de 54 stations avec 97 instruments pour la détermination de l'heure.

D'après les résultats des trois Opérations des longitudes mondiales Mme Stoyko a trouvé qu'il existe un rapprochement entre l'Europe et l'Amérique du Nord de l'ordre de $0\overset{s}{.}0005$ par an. M. N. Stoyko a trouvé aussi l'existence de ce rapprochement en étudiant la période de 1871 à 1965. Ce résultat a été à nouveau confirmé par Mme Stoyko et M. Stoyko d'après l'étude des services horaires permanents de 1925 à 1967.

Germany, Braunschweig. Physikalisch-Technische Bundesanstalt (PTB)

A caesium beam standard (CS1), newly developed at the PTB, was put into operation early in 1969. Its principles of construction are: Hexapole magnets, magnetic field homogeneous to within 4×10^{-4} and in parallel to the beam, a new resonator, interaction length 79 cm, the high frequency magnetic field vector in the beam direction.

In June 1966, the second hydrogen maser of the PTB was put into operation.

A contribution to an international comparison of hydrogen masers by means of a flying clock experiment has been published in 1968. Atomic clock research has been done at the PTB since 1967 in a well equipped "Atomuhrenhaus".

Early in 1967, the PTB, taking into account the theory of general relativity, found necessary to define, for different purposes, two separate coordinate system time scales, "Temps terrestre" and "Temps céleste".

G. Becker made an inquiry in the Federal Republic of Germany about the usefulness of the proposed 1-s-S.A.T. system. The opinions received were of the kind: The 1-s-S.A.T. system can be used, but being a "compromise time system" it has some disadvantages for both types of users (A.T. and U.T.). It was considered to be preferable to distribute independently A.T. and U.T.

The daily time of emission of the standard time and frequency transmission DCF 77 (77·5 kHz) has been extended to 16 hours a day since 1st December 1969.

A 24h daily emission time is expected to start 1st April 1970. 1-s time signals of the PTB will then be emitted following the time system S.A.T.

A monthly DCF 77 bulletin distributed to users and published in the *Nachr.-Techn. Zeitschrift* (NTZ) communicates the daily time differences and the phase time differences in 0·1 μs between DCF 77 and A1 (PTB) and as well the fractional daily frequency difference in 10^{-12}. DCF 77 is synchronized to WWVB (NBS) through the BIH. Publications in *PTB-Mitteilungen* 77–79 (1967–69).

Germany, Hamburg. Deutsches Hydrographisches Institut

Determination of U.T. with PZT were continued. The times of reception, versus U.T.2, of time signals were published quarterly.

A Hewlett Packard caesium beam clock was installed at the DHI in August 1968. It has been compared with the atomic time scale of the PTB, Braunschweig, using the Loran-C and television methods.

The radio time signals of the DHI have been synchronized with U.T.C. (BIH) to 1/10th of a millisecond. From October 1967 onward, a time signal of the English type has been transmitted via DAO, 2775 kHz, following the "Onogo" time signals at 0^h and 12^h U.T.

The DHI took part in three flying clock experiments of the U.S. Naval Observatory. Loran-C measurements have been used to keep available to a few microseconds, at the DHI, the U.T.C. of the U.S. Naval Observatory.

Germany. Potsdam. Zentralinstitut Physik der Erde

Yearly, about 250 astronomical time observations have been made with a Danjon prismatic astrolabe and with 2 transit instruments. Their results related to the time systems U.T.C.-Potsdam and U.T.2-Potsdam were published every two months in bulletins together with the results of oscillographic measurements of time signals.

The visual observations of star occultations were continued.

The coordinated time signal DIZ (4525 kHz) is controlled by the time service. By means of television method of clock comparison and using the results of the flying clock comparisons the time system U.T.C.-Potsdam of this time signal could be brought in coincidence within 0·1 ms with the time system T.U.C. of the BIH.

Italy. Milan. Astronomical Observatory

Determination of the ephemeris time by visual occultations has been carried out by means of the Zeiss refractor. Astronomical time determinations have been secured with the transit instrument AP100 and with the Danjon astrolabe; the clock equipment includes a rubidium standard and three quartz oscillators. Comparisons of time and frequencies, and synchronization by HP flying clock in 1967 and by USNO flying clock in 1969, have been realized.

All the results are published in the Circulars of the Observatory. In May 1968 the Observatory has organized a colloquium on time problems, the results of which are published in Proceedings of the Colloquium on the Problems of Time Determination, Keeping and Synchronization (350 pp., 1968).

Italy. Rome. Astronomical Observatory

The present observation program is the same in use at Brera (Milan) Observatory; a new program based on FK4 star pairs symmetrical with respect to the zenith is under development and test. The reference clock is the rubidium standard of the Istituto Superiore Poste e Telecomunicazioni (Rome) which controls the U.T.C. transmitter IAM.

Italy. Turin. Istituto Elettrotecnico Nazionale (IEN)

The present definition of frequency and time at the IEN, is obtained by means of two caesium atomic resonators and eight piezooscillators; frequency and time unit result known with an uncertainty of $\pm 2 \times 10^{-11}$.

The IEN time scale resulting is based on the mean of five oscillator-clock systems completely independent the one from the other.

Check cycles executed by Hewlett Packard with a flying standard in 1966 and 1967, and by U.S. Naval Observatory, showed differences lower than 100 μs over a period of about 18 months. After a cycle of measurements proposed and initiated by Czechoslovakia, the IEN and the ISPT (Rome) time scales are compared weekly by means of TV signals, which secure a resolution better than 0·1 μs.

The examination of the effects of the intrinsic noise of frequency standards is now being studied, with particular reference to those which are reflected on time scale preservation. In order to obtain a better continuity in the synchronization, a new automatic system for the regulation of a piezoelectric standard on an automatic resonator, is being studied.

Japan. Mizusawa

We pursued the astronomical time observations by both PZT and Danjon astrolabe throughout this period. We installed the Caesium Atomic Clock made at the Hewlett Packard Co., in November 1969. Since then, the frequency comparison among the VLF time signal radio waves (WWVL, NSS, GBR) are pursued regularly every day and these results are sent to the BIH.

Japan. Tokyo Astronomical Observatory (TAO)

The astronomical observations for time and latitude were continued with the PZT, using the star system α 59/δ 66.

Two caesium beam tube oscillators made by the Hewlett Packard Co. (C1 and C2) were installed at the end of 1967 and 1968 respectively. The U.T.C. (TAO) has been kept with the master clock (C11) driven by the oscillator C1. A step adjustment of $-100\mu s$ was applied to the master clock at 00^h U.T. on July 1st, 1969, in order to bring the U.T.C. (TAO) in a closer agreement with the U.T.C. of the BIH.

International clock comparisons among U.T.C.'s of the TAO, the RRL, and the USNO were made with flying clocks by the USNO party 5 times in 1968–69.

Reception of Loran-C signal emitted from Iwôjima, master station of the north-west Pacific chain, was begun tentatively in April 1969 in order to connect the U.T.C. (TAO) internationally with high precision.

Radio Research Laboratories (RRL). – Three caesium beam tube oscillators made by the Hewlett Packard Co. were installed in January 1965, May 1967 and September 1968 respectively. The U.T.C. (RRL) has been kept by the master clock driven by the oscillator 2. Loran-C signal emitted from the Iwôjima master station has been received from the beginning of 1969 for connecting the U.T.C. (RRL) internationally.

Rumania. Bucarest. Observatoire Astronomique

On a effectué des séries fixes d'observations de passage, des réceptions des signaux horaires par la méthode oscillographique avec une installation de trois oscillateurs Rohde & Schwarz, des synchronisations avec le Hewlett Packard flying clock en décembre 1967, et comparaison de phase avec fréquence de 17·8 kH de la station NAA. On est en train de terminer l'installation pour la comparaison entre Bucarest et Prague avec la méthode télévision. L'Observatoire rédige un bulletin T.U.C. pour le BIH et pour Mizusawa.

South Africa. Johannesburg

In October 1966 a Hewlett Packard caesium beam frequency standard was installed. Being adjusted to furnish atomic time rather than universal time, it was initially used as a reference standard only, for checking the frequencies from the older quartz crystal oscillators. As from April 1967, however, all ZUO carrier frequencies have been derived directly from the caesium standard, i.e. without offset, while the ZUO time signals and audio frequencies have continued to be derived from an offset frequency, so as to define U.T.C.

Daily VLF phase comparisons have been continued throughout the period, using the signals from GBR, NBA and, since January 1967, Omega Trinidad.

Flying clock comparisons, combined with the results obtained from daily VLF phase comparisons, have made it possible to keep the ZUO signals within about 1/10 ms of U.T.C. for most of the time. As far as the radio signals are concerned, there is at present no particular need for a higher accuracy, and no attempt has therefore been made to maintain the difference to a lower value.

Some tentative studies have been made in connection with the possible installation of a photographic zenith tube in South Africa.

Spain. San Fernando

Time observations are made since April 1968, with the Danjon astrolabe. The study of the 11 fundamental groups of stars used in time and latitude programs is expected to be complete by 1970. Time bulletins (now time and latitude bulletins) are published yearly.

The number of observed occultations of stars by the moon has been increased in the past three years. More than 250 times of occultations were sent to RGO for analysis in the interval September 1967 to September 1969.

Crystal clocks are maintained in synchronization within $\pm 0\overset{s}{.}0001$ with the coordinated scale of time for the needs of astronomical observations. During 1968 propagation delays of time signals used for the above purpose were confirmed by the visit of a BIH portable rubidium clock.

Switzerland. Neuchâtel

A la fin de l'année 1969, l'Observatoire de Neuchâtel possède 3 horloges atomiques dont 2 au césium. Cette batterie d'horloges permet de maintenir un temps atomique avec une uniformité de $\pm 2 \times 10^{-13}$. Le temps est coordonné avec le BIH. Les moyens de comparaison sont: (*a*) le transport d'une des horloges par voiture entre Neuchâtel et les instituts intéressés; (*b*) la mesure de phase des transmissions à ondes très longues (NSS, NAA, NBA, Oméga Trinidad); (*c*) le système Loran-C (chaînes méditérranéenne et norvégienne).

L'exploitation de l'émetteur HBG sur 75 kHz, débutée le 1er Janvier 1966, s'est poursuivie. Les signaux horaires suivent le temps coordonné avec un écart inférieur à 100 μs, la fréquence porteuse est maintenue à sa valeur nominale avec un écart inférieur à 2×10^{-12}.

Les mesures ininterrompues depuis 1956 au moyen de la lunette zénithale photographique Grubb Parsons se sont poursuivies. Les résultats sont communiqués mensuellement au BIH et à l'IPMS et publiés dans un bulletin.

U. K. Royal Greenwich Observatory

Time determinations have continued with the PZT. The observations made in the years 1958–67 were analysed, and from 1968, January, the results were based on revised star co-ordinates. Although the total effect on U.T. throughout the year of using these revised values is zero, there was a discontinuity on January 1st, such that U.T. (Herstmonceux) became earlier 4·5 ms.

The Cape astrolabe ceased operation on April 30, 1969, and it will shortly be returned to Herstmonceux, where it is adopted to convert it to a reflecting astrolabe incorporating a CER-VIT prism.

It was decided to adopt an atomic time scale, G.A.2, with a constant difference from G.A. such that G.A. − G.A.2 = $0\overset{s}{.}957700$, which is in close accord with A.T., the atomic time scale of the BIH. G.A.2 is determined from the mean of the caesium beam frequency standards at the Royal Greenwich Observatory.

The differences between the Earth's rotational time system U.T.2 and the atomic time scale G.A.2 have been published quarterly in the Greenwich Time Reports (formerly Royal Observatory Bulletins).

A new series of monthly circulars commenced in July 1967, containing the daily readings of the relative phase difference between U.T.C. (Herstmonceux) or G.A.2, as appropriate, and the received carriers of selected LF and VLF radio emissions. From April 1969, measurements have been made of Loran-C from Sylt and the results published in the monthly circulars. Co-ordination with the U.S. Naval Observatory has been maintained to a microsecond by means of travelling clocks.

U.K. National Physical Laboratory, Teddington

The long caesium beam continues in operation as the national standard, together with two H.P. caesium beam equipments as working standards. The long standard has been improved by the incorporation of an oven and detector at each end enabling the direction of the beam to be reversed and any error due to phase difference to be eliminated (Essen and Sutcliffe, 1969).

U.S. Naval Observatory

The determination of Universal, Ephemeris and Atomic Times was continued at Washington, D.C. and Richmond, Florida, utilizing the PZT, Danjon Astrolabe, Dual-Rate Moon-Position Camera, and atomic clocks.

A PZT is being constructed in the Observatory shop to be used in Washington for experimental purposes. A stepping motor will be used to drive the plate carriage and will eliminate the use of contacts for the timing. This PZT will be used in Washington concurrently with the existing PZT No. 3.

A new hydrogen maser has been installed at the Naval Observatory to improve the short and intermediate term uniformity of the Observatory clock time scales. The long term stability of the time scales will still be determined by the means of about 16 caesium beam frequency standards.

The Loran-C chains of the U.S. Coast Guard are controlled in time to 5 micro-seconds and frequency to 1×10^{12}. The carrier frequency of Omega VLF stations are controlled to 1×10^{-11}.

The precise Time Synchronization Service of the U.S. Naval Observatory carries time to one microsecond world-wide and frequency to 1×10^{-12} world-wide. Caesium-beam portable clocks are used. The results of clock comparisons with observatories and standards laboratories are published weekly as part of the *U.S. Naval Observatory Time Service Bulletin*, Series 4.

The difference A.1 − U.T.C. (USNO) is listed together with other time information (U.T.2 − U.T.C., etc.) on *Time Service Bulletin*, Series 7. The formula which is currently (1969) in use is: A.1 − U.T.C. (USNO) $= 7{\cdot}0859497 + (\mathrm{MJD} - 40221) \times 2592\ \mu s$.

U.S.A. Milwaukee. Physics Department

Monitoring of Loran-C, VLF and Omega was continued. The daily probable error in phase of the antipodal VLF station, NWC, Australia, was 2 microseconds. W. Markowitz found, in a differential Loran-C experiment, that the received frequency of radio transmission is independent of distance.

U.S.S.R.

12 Observatoires et laboratoires de l'U.S.S.R. ont effectué les déterminations astronomiques du temps, en employant surtout les instruments photo-électriques de passage et les astrolabes à prisme Danjon.

Les calculs des moments des émissions de signaux horaires dans le système T.U.1 se sont fait d'après le traitement mathématique des données des observations de tous les services horaires de l'U.S.S.R., de deux Services horaires de la République socialiste de Tchècoslovaquie, du Service horaire de la RDA, de la Pologne, de la Bulgarie, de la République démocratique populaire du Corée, qui ont participé au travail du Service horaire de l'U.S.S.R. à titre de libre coopération. Les résultats définitifs ont été publiés dans les bulletins mensuels "L'heure étalon aux moments moyens des émissions des radiosignaux".

Les stations radio de l'U.S.S.R. ont effectué l'émission des signaux horaires dans le système du temps atomique uniforme (T.A.C). On a déterminé les valeurs des décalages de fréquence pour l'approximation du T.U.2 selon les études des mesures de rotation de la Terre, qui se faisaient régulièrement à VNIIFTRI, et compte tenu des récommendations du BIH. Pour les années 1968 et 1969 la valeur du décalage de fréquence adopté est $+300 \times 10^{-10}$.

Pour ne pas avoir la différence excédant 50 ms entre T.A.C et T.U.2 on a effectué le 1er avril 1969 la correction des moments des émissions pour + 90 ms.

Deux instruments photoélectriques de passage de construction originale, munis de l'isolement thermique renforcé et d'autres modifications, sont actuellement en cours de fabrication dans les ateliers de l'Observatoire de Poulkovo. Quelques services horaires travaillent sur le perfectionnement des appareils pour l'enregistrement photoélectrique de passage des étoiles.

Les listes des travaux, concernant à la détermination du temps universel, les mouvements du pôle et la rotation de la Terre, sont publiées régulièrement dans les numéros de décembre du bulletin "L'heure étalon" à partir de 1967. La bibliographie des travaux nationaux accomplis dans ce domaine avant cette date est en cours de préparation pour l'édition.

Yugoslavia, Belgrade

Le Service de l'Heure de l'Observatoire de Belgrade disposait en 1967, 1968 et 1969 d'une batterie de trois horloges à quartz Rohde & Schwarz et se servait d'un oscilloscope cathodique pour la réception de signaux horaires.

On recevait en moyenne 26 émissions de signaux horaires, on déterminait l'heure demi-définitive et on l'envoyait au BIH.

Dès le 1er Janvier 1969, on déterminait les mêmes données pour les besoins de l'Observatoire même et on envoyait chaque semaine T.U.0 – T.U.C. au BIH. Tous les résultats sont publiés périodiquement dans le bulletin de l'Observatoire.

F. ZAGAR
President of the Commission