31. TIME (L'HEURE)

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The Commission deeply regrets the deaths of our colleagues who passed away during the last three years.

INTRODUCTION

This report reviews briefly the works achieved or planned in the triennium from 1979 to 1981 on the subjects to be considered by Commission 31. Reports of contributions furnished kindly from different institutions by many of Commission members were obliged to be partly omitted or abbreviated owing to the limitation of space, for which hearty thanks and apologies as well are to be given.

OBSERVATION OF UT AND ET

Astronomical observations for UT0-UTC have been continued on a routine basis in participating observatories to BIH with PZT's, astrolabes, transit instruments etc. The observations with 35-km interferometer have been made by USNO, and are expected to contribute an important part to future efforts.

Improvements and investigations of astronomical instruments were mainly made in D.R. Germany and in USSR, and those of star catalogues for time observations were made in several observatories especially in USSR.

Results of ET2-TAI were obtained by JHD (Japan) as 30.34, 30.56, and 30.50s for the epochs 1978.5, 79.5, and 80.5 respectively by use of the occultation timing data more than one thousand yearly observed by the JHD.

USE OF UTC

UTC has been used more and more widely without any problems not only as practical time scale for scientific use but also for the basis of legal time, although the situations of the legal aspects are different with countries and of much variety. Leap seconds were inserted once a year at the last 60th second of December, but that in 1980 was postponed to the last 60th second of June in 1981 because of some rate change in the Earth's rotation.

CLOCKS AND T-F STANDARDS

Industrial cesium clocks participating in the formation of TAI have increased in number from year to year, however, laboratories keeping the primary standards and contributing to TAI have not increased, notwithstanding the continuous efforts made in the relevant laboratories. Three new cesium primary standards of NRC have been in continuous operation since December 1979. Three new cesium beam primary standards using quadrupole and hexapole deflection magnets are under construction in PTB. Cesium primary clocks in NRC and PTB and cesium primary standard in NBS have played important roles for the formation of TAI.

While, investigations for various kinds of frequency standards have been intensively made, e.g. hydrogen maser, ion storage devices, optically pumped cesium standards, lasers and etc. in France, Japan, USA, and USSR etc.

INTERNATIONAL TIME TRANSFER

LORAN-C, TV, and portable clocks have been used most widely for international

and also for domestic time comparison. By lack of adequate links with sufficient accuracy, cesium clocks in such area as Asia, Australia, South Africa, and South America have been still excluded from the contribution to TAI. Efforts have been made by laboratories in these area to provide and join the international time comparisons via satellites. Two-way time comparison via satellite SYMPHONIE has been made on a routine basis since 1980 among OP (LPTF), PTB, and NRC with an accuracy of the order of nano-seconds.

TIME SYNCHRONIZATION AND DISSEMINATION

Experiments of time transfer via Navigation Technology Satellite, NTS-1, were made until September 1979 in Brazil, F.R. Germany, Japan (NRLM and RRL), and USA etc. The accuracy was proved to be better than micro-second between Japan and USNO, for instance.

The GPS (Global Positioning System) is now in its concept validation phase. The GPS time transfer receivers have been developed in USA, and a time transfer receiver was placed into routine service by USNO. Six satellites out of 18 are in orbit, however, it seems there are still some problems about the life of atomic clocks on board. Many laboratories are going to equip the GPS time transfer receivers for precise international comparison. The accuracy is estimated as 30 ns or better at present. The GPS is considered to be one of the most promising method for international time transfer with global coverage, instead of LORAN-C.

LASSO (Laser Synchronization from Stationary Orbit) experiments are going to be carried out under the participation of several European countries, Brazil, India, and USA by use of the equipments on board the satellite SIRIO-2 which will be launched in early 1982. The accuracy of time transfer is estimated as 1 ns or better.

Experiments of time transfer via satellite SYMPHONIE were made between China (Shaanxi and Shanghai Observatories) and France (OP), and also between India (NPL) and F.R. Germany (PTB) in 1979. A system study on the one-way time transfer from METEOSAT was made in F.R. Germany (IfAG and PTB) with the estimated accuracy of 30 ns. For time dissemination service, some experiments by use of two GOES (Geostational Operational and Environmental Satellite) and 5 operational TRANSIT satellites have been made in USA (NBS). The accuracy of time recovery is proved as about 50 μs with very low cost receivers. Experiment on frequency and time dissemination via BSE (Experimental Broadcasting Satellite) was made by use of TV signals in Japan (RRL) from 1978 to 1980. Accuracy of 5×10^{-12} in frequency was obtained when corrections for orbital motion was applied. Two-way time transfer, time dissemination, and experiments for relativistic effects of clocks on board etc. are planned by use of Space Shuttles (DFVLR).

The VLBI global network operated by DSN (Deep Space Network) is used to measure epoch and rate offset between stations, Australia, Spain, and California. The accuracy of time offset measurement is estimated as 10 ns (JPL).

CCDS MEETING

Wm. Markowitz represented IAU in the 9th Session of the CCDS (Comité Consultatif pour la Définition de la Seconde) held at Sèvres in September 1980. The Session declared that TAI is a coordinate time scale defined in a geocentric reference frame and it can be extended to any point on the vicinity of the geoid by applying first-order General Relativity corrections.

IAU COLLOQUIUM NO.56

A colloquium on Reference Coordinate System for Earth Dynamics was held in Warsaw in September 1980. The colloquium recommended that a working group be established by the Presidents of IAU Commissions 4, 19, 31 and the President of IAG to prepare a proposal for the establishment of a Conventional Terrestrial Reference

System. According to this recommendation, the composition of the working group was fixed by March 1981, and the first meeting was organized during the MERIT workshop held at Grasse in May 1981.

MAILING VOTE ON NUTATION SERIES

Mailing vote was made from January to March 1981 to decide the adoption of the 1980 IAU Theory of Nutation in replacement of the 1979 one which was adopted in the IAU General Assembly in Montreal, among members of IAU Commissions 4, 7, 8, 19, 24, and 31. This action arose from the Resolution 9 of the IUGG General Assembly held in December 1979, which requests that the IAU reconsiders its choice of a nutation series. This unusual procedure of mailing vote was necessary to make a decision available as soon as possible for the preparation of the national ephemerides. Results of voting in our Commission were 46 in favour, 1 against, 2 abstention, and 22 no reply.

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7) Documents in Session A, the XX General Assembly of URSI, 1981.

Report of the Director of the Bureau International de l'Heure (BIH)

FORMATION OF TAI AND UTC

The BIH has continued to produce TAI and UTC under the form of corrections to the master clocks of time keeping laboratories. These corrections are published at 10-day intervals in the monthly Circular D. This rythm seems satisfactory (CCDS, 1980).

Although an increasing number of laboratories effectively participate to TAI (25 laboratories in January 1981, operating 118 clocks), their location is still restricted to North America, Europe, North Africa, by the lack of suitable means of clock comparisons in other parts of the world. The LORAN-C and the TV still provide the basic links. However, the LORAN-C has been replaced across the Atlantic, in the BIH works, by the satellite link using SYMPHONIE (see below).

The stability algorithm, ALGOS, produces a time scale denoted by EAL. Then TAI is derived from EAL by applying a "steering correction" in order to ensure the comformity of the TAI unit interval with the second at sea level as determined by primary time standards. The steering correction appears as a frequency offset between TAI and EAL, varying by steps of 0.2×10^{-13} at intervals not shorter than two months.

The definition of TAI in the general relativity theory has been completed by the CCDS in 1980, which stated in a declaration that: "TAI is a coordinate time scale defined in a geocentric frame of reference having as scale unit the SI second as realized on the rotating geoid". In practice, this definition applies to TAI and to its previous forms at BIH since 1955, the corresponding corrections having been used when needed on account to the measurement precision.

The operation of the UTC system did not raise any particular problem. The acceleration of the Earth's rotation by almost 1×10^{-8}, which took place at the end of 1979 diminished the frequency of the introduction of leap seconds.

SYMPHONIE TIME COMPARISON

The operational two-way time comparisons by SYMPHONIE have been initiated in 1978 July between NRC and OP (LPTF); the PTB joined the project in 1980. The participation of the BIH consists in evaluating the final time differnces between NRC and OP. This new time link across the Atlantic, checked by clock transportations and local loop measurements, has been found much more stable than the LORAN-C link, and was therefore used instead of the latter since the 1st of January 1979 (mean of NRC-OP and NRC-PTB since January 1980).

SEASONAL VARIATIONS

We have found that most of time scales based on sets of industrial cesium clocks show a seasonal variation with respect to the primary clocks NRC CsV and PTB Cs1, which agree fairly well together. The amplitude of this variation is of the order of 1 μs in time and 1×10^{-13} in normalized frequency. Numerous investigations on this effect, at BIH and elsewhere, did not lead to a definitive identification of its source.

USE OF PRIMARY CLOCKS, ALGORITHM, PROPERTIES OF TAI

The highly accurate primary clocks of NRC and PTB seem to be especially fitted for establishing reference time scales such as TAI, since their accuracy provides the very long term stability, which is of major interest. However other types of clocks can provide a useful flywheel, a safeguard, and their participation to TAI is a guarantee of the worldwide unification of time. By the steering process, TAI rests ultimately on the primary clocks, together with the primary frequency standards operated in a discontinuous mode (such as NBS-6), which ensure the accuracy and the stability over averaging times of a few years and more. For shorter term stability the primary clocks participate in the TAI computation in the same way as the industrial clocks.

Researches on the influence of the algorithms have been made on simulated and real data. In an ALGOS-type algorithm, many parameters should be considered, such as the averaging time for evaluating the stability, the durations involved in the prediction of rates, the test duration for new clocks....The optimum choice is strongly influenced by the existence of systematic variations of the frequencies, seasonal variations and drifts. The long averaging intervals involved in the computation of TAI have also a beneficial effect in reducing the systematic errors. We have found no compelling reason to modify them.

The evaluation of the accuracy and stability of TAI is very much dependent on the confidence in the results of primary clocks. The following conservative estimate is based on the assumption that the primary clocks are free from seasonal frequency variations. Since the frequency adjustment of 1977 January 1, the maximum error of the TAI frequency is 1×10^{-13} on yearly averages; for two month averages excursions up to 1.5×10^{-13} can take place. The stability for τ larger than two months is smaller than 1×10^{-13}.

OTHER RESEARCHES

LASSO, proposed by BIH to the European Space Agency, has been accepted in 1979, and will fly on the SIRIO-2 geostationary satellite to be launched in early 1982. The BIH participated to the preparation of the experiment and will perform the current evaluation of the time differences.

A study of synchronization method using simultaneous range measurements of a satellite carrying a stable clock, and involving an orbit determination has led to promising results (Capitaine and Gambis, 1981). This method could be tested using the GPS satellites.

COOPERATION

Since the problem of the representation of China at IAU received a solution,

the BIH has established a cooperation with Chinese time-keeping laboratories in Beijing, Shaanxi, and Shanghai. The worldwide participation to the BIH work is now complete. The cooperation with the organizations of the Meter Convention (CIPM, BIPM) continues in a fully satisfactory way.

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Reports of Observatories and Laboratories

A. AUSTRALIA. DIVISION OF NATIONAL MAPPING, CANBERRA.

The lunar laser ranger became operational in 1978, and continued in operation throughout the period. In mid-1981, ranging was suspended to allow development of a 3-cm precision satellite and lunar ranging facility. This system should be operational by 1984, and contribute to the 1983-84 MERIT campaign.

The PZT at Mount Stromlo has been in continuous operation. Gradual refurbishment of this instrument is being undertaken without taking the instrument off-line and incurring data loss.

The National Mapping cesium ensemble was maintained continuously throughout this period. Progression from NTS satellite time transfer to GPS one did not take place during this period, but is expected during 1982.

Future plans; 1) development of collocated satellite and lunar ranging with high precision (1983), 2) cooperation in programs of intercontinental time transfer using satellite technology (1982), and 3) cooperation in programs for comparison of LLR, SLR, and PZT data.

B. BELGIUM. OBSERVATOIRE ROYAL DE BELGIQUE, UCCLE/BRUSSELS.

Astronomical observations for the determination of UT were discontinued in January 1979. The main reason is the very few number of good nights, 50 per year, and the lack of man-power requested for the Danjon astrolabe.

The Doppler tracking station integrated into the DMATC Polar Monitoring Service and MEDOC has continued permanent operation. For the time scaling of the Doppler tracking network the satellite time marks are recorded during all passes.

The Brussels Time Service is provided with 1) 2 HP 5061A cesium standards, 2) a visual LORAN-C receiver operating on SYLT, and 3) a TV receiver used for daily time comparisons between the Observatories of Brussels and Paris. According the method used to realize the time synchronization: TRANSIT satellites, LORAN-C or TV signals, the precision is respectively 10, 0.20, 0.05 μs.

C1. BRAZIL. OBSERVATORIO NACIONAL, RIO DE JANEIRO.

For time keeping, 2 HP 5061A cesium standards with a TRACOR 304D and a HP 5065A rubidium standard are used at Rio de Janeiro. Another HP 5065A is at our installations at Brasilia. Moreover, 6 HP cesiums, 2 Ebauche cesiums, and 9 rubidium standards from other institutions are compared by clock transportation and line-10 TV method.

Comparisons of UTC were performed during visits with portable clocks, received from ONBA, USCG, SAO, and NASA. using a receiver loaned by US Naval Research Laboratory, successful time transfer experiment was performed receiving the signals from NTS-1 during 7 months in 1979.

Efforts are being made to take part in the LASSO experiment and the GPS, and

reception of GOES satellite will be started soon. Reception of VLF and Omega stations are being continued.

C2. BRAZIL. DEPARTAMENTO DE FISICA. CAMPUS UNIVERSITARIO, NATAL-RN.

The UFRN (Universidade Federal do Rio Grande do Norte) will start the time observation with an astrolabe which was sent from the greenwich Observatory, in near future. The observed time will be connected to the atomic clocks in the National Observatory of Brazil through the time signal PPE. Occultation of stars by the moon will be observed to make comparison between ET and UT.

The general relativistic effects on the clock synchronization is now being investigated to be applied to the VLBI observation and to the synchronization of clocks on the Earth via satellites.

D. CANADA. NATIONAL RESEARCH COUNCIL, OTTAWA, (NRC).

The NRC primary cesium standard CsV has been operated continuously since May 1975, and since January 1, 1976 the NRC time scales have been derived directly from CsV. Since the $1x10^{-12}$ change in TAI frequency of January 1, 1977 the rates of TA(NRC) and UTC(NRC) have been that of CsV with only a -0.97 ns/day adjustment for the correction to sea level.

Three new cesium primary frequency and time standards, CsVIA, B, and C have been in continuous operation as clocks since December 1979. Their short term stability is comparable with that of CsV, with $\sigma(2, 1\ day) = 2x10^{-14}$. The frequencies of all three, after full evaluation in December 1980, agreed with CsV to a few parts in 10^{-14}.

Two-way time transfer between NRC, OP, and PTB via the SYMPHONIE satellite are continuing twice each week. These transfers have shown the CsV(NRC) and Cs1(PTB) agree in frequency to within $5x10^{-14}$ for the past two years, and their relative stability is $1x10^{-14}$ for periods of 300 days.

Preliminary experiments using pairs of low power CW tones for two-way satellite time transfer have been successful. The two satellite ground stations are located at the NRC laboratory, and are small in size (3-m antennas) and low power (1 W). The transfer is via the Telesat Canada commercial satellite Anik A1 in the 6/4 GHz band.

E. CHILE. DEPARTMENT OF ASTRONOMY. UNIVERSITY OF CHILE, SANTIAGO.

The time service of the Department of Astronomy, University of Chile Santiago, has been in progress throughout the last years. Astronomical determinations of UT0 are being made with a Danjon astrolabe at the National Astronomical Observatory in Cerro Calán, Santiago. The astrolabe is operated under a joint research project between the European Southern Observatory and the University of Chile. Time and latitude results obtained with the astrolabe are sent to the BIH and IPMS.

The local UTC is based on a cesium time standard HP 5061A which since 1973 has been synchronized yearly through a flying clock with USNO's UTC. The flying clock facilities are kindly provided by NASA's Spaceflight Tracking and Data Network Station of Santiago. Frequency control of the local atomic standard is made through phase comparisons of VLF station NLK (18.6 kHz) using a Tracor VLF receiver 599K and a MSK converter 599 J/K.

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F. CZECHOSLOVAKIA. ASTRONOMICAL INSTITUTE, PRAGUE

The UT0 has been regularly determined by the classical methods at four stations each of which being equipped with one instrument. The respective instruments are

a visual transit instrument, two circumzenithals, and a PZT. The last one has been operating using the second variant of ameliorated star positions, system "1978".

The local time scale UTC(TP) based on the cesium frequency standard is being regularly compared with time scales kept in Braunschweig, Hamburg, Potsdam, Berlin, Budapest, Uzhgorod, Bratislava, and Graz using the TV method calibrated by the clock transportation every year.

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G. FRANCE. LABORATOIRE PRIMAIRE DU TEMPS ET FREQUENCE, PARIS, (LPTF).

The French atomic time scale, TA(F), is a weighted average computed at LPTF from the data of about 15 commercial cesium clocks in the laboratory but also in other institutes in France. Daily time comparisons are made by TV method using automatic receivers developed at LPTF (precision < 100 ns). Since 1978, UTC is the official basis of legal time. It is implemented as UTC(OP) generated by one of the high performance LPTF cesium clock and kept within about ± 1 μs from UTC.

International time comparisons are made at LPTF by daily LORAN-C measurements (Norvegian and Mediteranean chains) and by occasional clock transportations (with Algeria, Canada, China, Czechoslovakia, USA, and USSR during the last 3 years). International time comparisons using the SYMPHONIE satellite are made regularly with NRC and PTB. The obtained precision is of the order of 1 ns. With the same goal, LPTF plans to participate to several experiments and systems in the next years, e.g. using the satellite OTS-2, SIRIO-2 (LASSO) and the GPS.

In 1980, frequencies of stabilized infrared CO_2 and He-Ne lasers have been measured at LPTF with a precision of about 10^{-10}. Work is now in progress to achieve about 10^{-12}.

Several laboratories located in the University and Centre National de la Recherche Scientifique (CNRS) are developing high performance frequency standards of various kinds (improved quartz devices (Besançon); superconducting cavity oscillators, H masers, ion storage devices, and optically pumped cesium beam (Orsey); several frequency stabilized lasers (Villetaneuse, Paris, Orsey). The Centre National d'Etudes Spatials (CNES) is also involved with time comparison by satellites. The laser station at the Centre d'Etudes et de Recherches Géodynamiques et Astronomiques (CERGA , Grasse) will participate to the LASSO experiment with an auxiliary time link with LPTF.

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H. D.R.GERMANY. ZENTRALINSTITUT FUR PHYSIK DER ERDE, POTSDAM, (ZIPE).

The local time scale UTC(ZIPE) is based on 1 HP cesium standard 5061A. UTC(ZIPE) is compared daily with UTC(ASMW) using TV method. UTC(ASMW) on his part is based on 3 atomic clocks (1 Ebauches B5000 and 2 Oscilloquarz 3200). TA(DDR) is computed using the data of the 4 cesium standards of both institutions.

For time comparisons among time scales kept in DHI, TP, PTB, PKNM, and AOS the TV method is used. Receptions of LORAN-C station Sylt and phase tracking of VLF transmitters are also carried out.

Astronomical observations for the determination of UT have been performed regularly with 1 Danjon astrolabe and 1 PZT. During 1980 a new industry made PZT (Carl Zeiss JENA) was installed, and the observations started in July 1980. Research was being continued for the improvement of observational instruments (27.031.655; 27.044.009). Investigations were carried out for the development of a photoelectric PZT (27.032.013; 27.032.014).

Results of time determination, synchronization, and time scale are published in every two months series bulletins (26.044.037; 27.044.024). It is planned to participate in the LASSO experiment for precise synchronizing standard clocks up to 1 ns.

I1. F.R.GERMANY. DEUTSCHES HYDROGRAPHISCHES INSTITUT, HAMBURG, (DHI).

Routine observations of UT0-UTC have been continued. Time signals have been transmitted daily at 0h and 12h through 3 radio stations on 4 frequencies (2 MF, 2 HF). The output of the master clock, a HP 5061A cesium standard, has been steered by means of a micro-stepper to keep UTC(BIH) minus UTC(DHI) within the limit of ± 2 μs. International and national time comparisons have been made regularly via LORAN-C and TV.

A Doppler point positioning campaign using the NNSS satellites was carried out by the Institut für Angewandte Geodäsie (IfAG), Frankfurt, in November 1979 at a number of European time keeping institutions in order to obtain precise three-dimensional coordinates in a uniform reference system as required for one-way time transfer via satellites in the sub-microsecond domain. The uncertainties of the DHI coordinates as they have derived in the adjustment procedure, amount to about 0.3 m.

I2. F.R.GERMANY. PHYSIKALISCH-TECHNISCHES BUNDESANSTALT, BRAUNSCHWEIG, (PTB).

Since 1979 TA(PTB) is generated directly by the primary cesium time and frequency standard Cs1, which operates as a clock since mid-1978. UTC(PTB) is also produced by Cs1, it thus differs only by a constant time difference from TA(PTB).

Cs1 of the PTB now contributes directly to the formation of TAI (Becker, 1979). The main operational parameters are measured at regular intervals. the root mean square of the (1σ) uncertainties caused by the various corrections yields for Cs1 a relative uncertainty of 6.5×10^{-15} for frequencies averaged over 80 days (Becker, 1979). A cesium beam time standard allowing to adjust precisely the resonator position with respect to the atomic beam has been built. Phase gradient in resonators can thus be detected and their contribution to the uncertainty of primary standards evaluated. Three cesium beam time and frequency standards using quadrupole and hexapole deflection magnets are under construction.

At the end of summer time 1981 the coding of time information emitted by the transmitter DCF77 will be completed by a new zone-time coding, permitting to indicate that the broadcast time is UTC plus one or two hours (Becker et al, 1981).

The satellite SYMPHONIE is used for two-way time comparison between CRC (Ottawa, Canada), PB (Pleurmeur Bodou, France), and RAI (Raisting, F.R. Germany).

$$\Delta = \{T(CRC)-T(RAI)\} - \{T(PB)-T(RAI)\} - \{T(CRC)-T(PB)\}$$

which should be zero, indicates the uncertainty of these comparisons. From MJD= 44269 to 44351 the mean value of Δ was found to be -42 ns with a standard deviation of 8 ns. Starting with MJD=44353 a new measuring technique was introduced using in the receiver a crystal oscillator synchronized to a 1 MHz signal transmitted together with the second pulses (Costain et al, 1979). The crystal oscillator averages random fluctuations automatically. The superior quarity of time comparisons by SYMPHONIE satellite permits an assessment of the quarity of simultaneous time comparisons via LORAN-C.

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I3. F.R.GERMANY. DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT FUR LUFT- UND RAUMFAHRT, OBERPFAFFENHOFEN, (DFVLR).

Clock comparisons at a distance of 700 km between PTB-Braunschweig and the satellite ground station Raisting, were supported by clock transportations with aircraft. The residual uncertainty was smaller than ± 5 ns.

Preparation of the Space Shuttle experiment NAVEX was continued (Starker et al, 1979). The experiment was approved for the Shuttle mission D-1, which is planned for 1984. Aims of this experiment are one-way time dissemination, two-way clock comparison, and measurement of the relativistic effect of the on-board clocks.

Receiving of GPS time signals and investigation of relevant technical problems were performed with an experimental receiving equipment. GPS time transfer shall be compared with other methods during the next years.

In contact with European time institutes an experiment was prepared for time dissemination using TV-signals from European satellite OTS. In cooperation with PTB a receiving station was equipped at Oberpfaffenhofen.

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J1. ITALY. ROME ASTRONOMICAL OBSERVATORY AND ISPT, ROME.

The routine determination of UT, within the frame work of the BIH and IPMS, has been performed with an improved transit instrument equipped with automatic data acquisition. During the summer 1980 the station participated to the short campaign of project MERIT. Research on smoothing and data analysis is continuing.

The UTC reference time scale is provided by the ISPT (Istituto Superiore Poste e Telecomunicazioni) by direct telephone link. It is now derived from 3 commercial cesium standards. Daily comparisons are made with IEN (Turin) scale by TV, and with LORAN-C. An HF transmitter (IAM) is also operated daily.

J2. ITALY. ASTRONOMICAL OBSERVATORY, CAGLIARI, (CAO).

The time service of the Cagliari Observatory is based on 2 commercial cesium standards and 2 quartz clocks. During the period 1978-81 the reference local time scale has been continuously compared by means of VLF and LORAN-C techniques. The UTC(CAO) scale was also compared via TV pulses with IEN (Turin) and ISPT (Rome). The accuracy of the UTC(CAO) scale versus UTC is about $1\text{-}3\times10^{-13}$.

Relativistic and non-relativistic effects (diurnal and annual) on physical time scales has been investigated.

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K1. JAPAN. TOKYO ASTRONOMICAL OBSERVATORY, (TAO).

Astronomical observations for time and latitude have been made regularly with the PZT, using the star system α_{75} and δ_{75} since the beginning of 1975. UTC(TAO) has been kept with the master clock selected out of 5 HP cesium clocks.

Time comparisons of UTC clocks have been carried out by a cesium portable clock of the TAO and via TV-signals against GSI (Geographical Survey Institute), ILOM,

KGO (Kanozan Geodetic Observatory), NRLM, and RRL in Japan. For international time comparisons, receptions of LORAN-C signals from Iwo-Jima master station and VLF signals NWC (22.3 kHz) have been continued. International time transfer via GPS satellites is now under preparation.

Delay time in LORAN-C receiving antenna and other corrections needed for the precise time comparison via LORAN-C signals were re-examined. By applying consistent corrections based on these results, systematic differences which have remained among institutions in Japan will be removed.

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K2. JAPAN. INTERNATIONAL LATITUDE OBSERVATORY OF MIZUSAWA, (ILOM).

Time and latitude observations have been made with the PZT No.2 and Danjon astrolabe. The fully automated electronic astrolabe is under adjustment. UTC(ILOM) has been maintained with a selected HP cesium clcok out of four.

LORAN-C signals from Iwo-Jima master station and Omega signals from Hawaii have been received for the clock comparison. Time comparison by TV has been made against clocks in NRLM, RRL, and TAO. Time comparison between UTC(ILOM) and UTC(RRL) was made by using the experimental broadcasting satellite (BSE) from November 1979 to June 1980. This experiment has proved the feasibility of time comparison via BSE with the accuracy of sub-microseconds.

Cooperative observation of the rotation of the Earth has been made by using PZT's on the ILS $39^{0}08'$N line between ILOM and SAIL (Stazione Astronomica Internationale di Latitudine Carloforte-Cagliari, Italy).

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K3. JAPAN. JAPAN HYDROGRAPHIC DEPARTMENT, (JHD).

For the purpose of determining ET, the occultation observations have been continued at the head office in Tokyo and three branch observatories in Sirahama, Simosato, and Kurasiki. A Cassegrain reflector (ϕ: 62 cm, f: 16.1) especially designed for the occultation observations was installed at Simosato Observatory in March, 1981.

Results on ET2-TAI, based on more than a thousand yearly occultation timings, for the epoch 1978.5, 1979.5, and 1980.5 were: 30.34, 30.56, and 30.50 s respectively, with the mean error of $\pm$0.04 s. Details are published in Data Report of Hydrographic Observations, Series of Astronomy and Geodesy and Japanese Ephemeris.

The services of the International Lunar Occultation Center were taken over to JHD from the Royal Greenwich Observatory on January 1, 1981.

K4. JAPAN. RADIO RESEARCH LABORATORIES, (RRL).

A laboratory type cesium beam standard using Ramsey cavity of 50 cm long was constructed, and experiments on Majorana effect were made (Kobayashi et al, 1978). In recent experiment on the hydrogen maser, a good performance with respect to oscillation power and line width has been obtained by utilizing the Majorana transition (Urabe et al, 1980).

An algorithm for calculating a mean atomic time scale, TA(RRL), based on working atomic standards was developed and has been put into use since 1978 (CCIR, Doc.

7/106-E, 1981).

Reception of LORAN-C signals from Iwo-Jima master station and Omega signals from two stations, Japan and Hawaii, have been continued. The international time comparison via NTS-1 was made for about one year beginning in October 1978, between USNO and RRL (Saburi et al, 1979). Experiments on frequency and time dissemination were made from 1978 to 1980 using the satellite BSE (Saburi et al, 1979). The accuracy of several parts in 10^{10} and 10 μs were obtained in the frequency and time dissemination respectively. Besides, accuracy of sub-microsecond was obtained in the time comparison via TV synchronization pulse from BSE between ILOM and RRL, about 400 km apart with each other.

System development of Japan-US joint experiment of VLBI, beginning in 1983, has begun since 1979. Projected accuracy of the base measuremnet is a few cm using X- and S-band frequencies.

REFERENCES

1) Kobayashi,M. et al, 1978, IEEE Trans., TM-27, 4.
2) Urabe,S. et al, 1980, IEEE Trans., IM-29, 4.
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K5. JAPAN. NATIONAL RESEARCH LABORATORY OF METROLOGY, (NRLM).

The accuracy of the cesium beam frequency standard, NRLM-II, was evaluated as 5×10^{-13}, and its frequency was estimated as few parts in 10^{13} higher than that of TAI. A digital signal processing system has been equipped to reduce the major error caused by the modulation and demodulation of the resonance signal.

Three HP cesium clocks have been used to keep UTC(NRLM). The NRLM moved at the beginning of 1980 to the new site in Tsukuba Science City, about 60 km apart from the old one in Tokyo. Reception of the LORAN-C signals from Iwo-Jima master station and the mailing of the data to BIH have been made regularly since then.

International time comparison between UTC(NRLM) and UTC(USNO) was made by using NTS-1 satellite with the precision of ±1 μs for about one year until September 1979.

L. RUMANIA. ASTRONOMICAL OBSERVATORY, BUCAREST.

A l'Observatoire de Bucarest on détermine le UT0 à partir des observations méridiennes (lunette Zeiss réversible, 1000-100 mm) et ensuite le UTC. Les résultats sont communiqués à BIH, IPMS, Moscou, Shaanxi, et Prague.

M. SOUTH AFRICA. NATIONAL PHYSICAL RESEARCH LABORATORY, PRETORIA, (NPRL).

Difficulties encountered in the reception of the GPS satellite signals have made it necessary to relocate the reception equipment to the CSIR satellite tracking facility at Hartebeesthoek. In preparation for this move a precision time transfer system between the satellite tracking facility and the Time Standard Laboratory in Pretoria via TV signals has been developed (Lake, 1981). This system will enable the tracking station timing system to be calibrated in terms of TA(NPRL) to a precision of 10 ns or better, and will be used subsequently as a link in the comparison of the GPS clocks with TA(NPRL).

REFERENCES

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N. SPAIN. INSTITUTO Y OBSERVATORIO DE MARINA, SAN FERNANDO, CADIZ, (IOM).

Series of observations with the Danjon astrolabe for UT0 and polar coordinates determination have been continued since 1968 without discontinuity. Results were regularly sent to BIH and IPMS.

A loaned Doppler equipment was installed at the Observatory during the MERIT

short campaign in 1980. Results stimulated the introduction of this technique at the OMSF, and an Observatory Doppler set was ordered by 1981.

Time keeping at San Fernando is actually based on the operation of 6 cesium clocks. Experiments are in progress to improve their environmental operating conditions. A substantial gain, both in the weights of the clocks and in the long term stability of the UTC local scale, has been achieved in last 3 years, the divergence of the scale versus UTC remaining practically compensated.

San Fernando was yearly included in USNO flying clock trips for global synchronization. For national time and frequency distribution, a mobile laboratory has been implemented, including a cesium standard, LORAN-C receiver, and measuring facilities. Four calibration and synchronization trips have been made during last two years with satisfactory results, and daily links via LORAN-C with distant Spanish laboratories began to be established, these including a master clock in the INTA/NASA station at Robledo de Chavela.

Works are under way to participate in the LASSO experiment. The laser station at San Fernando will hopefully participate in the so-called "Commissioning exercise" operating in the two-way mode after the ESA launching of SIRIO-2 by February 1982.

O1. UK. ROYAL GREENWICH OBSERVATORY, (RGO).

Observations of UT0 have been made regularly with the Herstmonceux PZT and have been communicated regularly to the BIH.

The independent atomic time scale TA(RGO) has been formed throughout the period by combining the readings of HP cesium clocks operating at RGO. Up to 7 clocks have been nominally available. All the clocks have been continuously intercompared with resolutions of 1 ns or 10 ns and with daily measurement of higher precision, but it has sometimes been deemed appropriate to form the time scale from the unweighted readings of only 2 clocks, with corrections applied for their estimated rates. Since 1977 January 1 the rates of UTC(RGO) and TA(RGO) have been identical, but this relationship will not necessarily persist indefinitely.

Measurement of LORAN-C signals from Sylt, Ejde (two chains) and Estartit have been continued using 4 Austron 2000C receivers, one on loan from USNO; the results have provided the main link between the clocks and time scale of RGO and those of other establishments, and have also been used by the operating agencies to improve the effectiveness of LORAN-C system for position fixing and time dissemination.

Satellite laser ranging equipment now being developed at RGO and University of Hull is expected to be in operation at Herstmonceux by late 1982.

O2. UK. NATIONAL PHYSICAL LABORATORY, (NPL).

Work has continued on the 1-m interaction length primary cesium frequency standard, NPL III. Recent improvement to the excitation system have reduced the noise level to -80 dB in a 10 Hz bandwidth, at 100 Hz from carrier. The velocity spectrum in the beam will now be determined.

In the near future an improved (cryogenic) pumping system will be installed which will facilitate the cavity reversal procedure and thus enable more rapid evaluation of the standard.

P1. USA. U.S. NAVAL OBSERVATORY, (USNO).

Routine observations of UT0-UTC have been made continuously with PZT 3 in Washington, D.C., and PZT 2 in Richmond, Florida. PZT 6, a visual 20-cm instrument, was operated in Richmond and PZT 7, a visual 65-cm instrument, was operated in Washington during this period. Observations with the Danjon astrolabe at Washington

and Richmond have been suspended.

Routine observations have been made continuously during this period with the 35-km Connected Element Interferometer (CEI) at Green Bank, West Virginia. The observational results indicate an internal precision between 0.4 and 1.2 ms for a UTO-UTC normal point based on three days of observations.

Regular predictions of UT1-UTC, based on an algorithm which treats observations made with new observational techniques and classical methods, were inaugurated and published in Time Service Announcement, Series 7.

The USNO participated in the preliminary MERIT campaign, providing regularly updated predictions of the Earth's orientation and acting as an analysis center for the CET technique.

A high-precision laser time transfer link has been installed between USNO and Goddard Space Flight Center in preparation for the LASSO experiment under contract with Professor Alley's group at the University of Maryland.

A PTTI Automated Data Service (ADS) was made operational and is collecting and reducing PTTI data on a routine daily basis and making these data available on commercial and military dial-up telephone systems. The service provides information on: LORAN-C, TV, Omega, TRANSIT and GPS data, preliminary values of UTC(USNO MEAN) minus UTC(USNO MC), predictions of Earth rotation parameters, and a variety of other data.

A GPS time transfer receiver was acquired, evaluated, and placed into routine operational service during this period. Results of USNO monitoring are available in USNO Time Service Announcement Series 4 and in real-time through the PTTI ADS.

About 20 domestic and 8 foreign portable clock trips are performed annually to many observatories to support the national and international efforts to calibrate time transfer systems. Time transfer information received from more than 20 terminals of the Defence Satellite Communication System are routinely processed and published in Time Service Announcement Series 16. These data are used to calibrate some LORAN-C chains.

About 60 clocks are monitored through the IBM 1800 Data Acquisition System; approximately 22 of these cesium standards from the USNO time scale. Typically the difference between the steered UTC(USNO MC) and UTC(USNO) is less than 50 ns. Clock comparison data were transmitted regularly to the BIH.

P2. USA. JET PROPULSION LABORATORY, PASADENA, CALIFORNIA, (JPL).

As part of the TEMPO program the epoch and rate offset between the clocks at Australia (DSS 43) and Spain (DSS 63) and the clock in California (DSS 14) operated by the Deep Space Network (DSN) were measured. The nominal clock offset accuracy is 10 ns, but until instrumental delay calibrations are available, the true clock offset accuracy will be on the order of 50 ns. The clocks are usually hydrogen masers, and the clock in California is tied to the NBS time reference in Boulder, Colorado.

P3. USA. NATIONAL BUREAU OF STANDARDS, BOULDER, COLORADO, (NBS).

The NBS primary standard of frequency, NBS-6, has operated intermittently for the last several years. The intention is to perform a complete evaluation of all pertinent parameters on a nearly yearly basis.

The primary means of comparing frequencies (nationally and internationally) is via LORAN-C and portable clocks; however, comparisons via the GPS with the USNO

have been started. The precision of time measurement is a few ns, and consistency of frequency measurements is a few parts in 10^{15} for averages of two weeks.

Improvements in the NBS Time Scale are in progress. New time measurement equipment has been developed which shows stabilities of a few picoseconds.

Q. USSR.

Les déterminations astronomiques du temps se sont effectuées aux 11 services de l'heure (à partir du mai 1979 aux 12 services de l'heure) à l'aide des instruments photoélectriques de passage (12), des instruments visuels de passage (2), des astrolabes à prisme Danjon (2), et des tubes zénithals photographiques (2).

Les résultats des déterminations astronomiques du temps sont communiqués chaque semaine par télex au BIH et mensuellement par la poste à l'IPMS. Pendant la période d'essai du programme MERIT aux observations ont participé 18 instruments à l'aide desquels on a effectué près de 1500 déterminations du temps par les méthodes classiques.

Le temps universel a été calculé au Centre Principal Métrologique (ГМЦ) du Service d'Etat de Temps et de Fréquence (ГСВЧ) de l'URSS par le traitement en commun des résultats des observations astronomiques de tous les services de l'heure de l'URSS et des 11 services de l'heure de RST, RPP, RDA, RSR, RPB, RPM, et RSFY, participant au travail de ГСВЧ de l'URSS.

On a effectué les travaux sur le perfectionnement des amplificateurs photoélectriques pour l'enregistrement des passages des étoires.

On a effectué les travaux sur l'observation et le calcul des catalogues des ascensions droites des étoires.

Les échelles nationale du temps atomique et du temps coordonné ont été basées sur l'étalon primaire d'Etat de temps et de fréquence dans lequel entrent le repère métrologique à césium, les gardiens à hydrogène des dimensions des unités de temps et de fréquence, les horloges-gardiens à césium, à hydrogène et à rubidium des échelles du temps. Les échelles du temps coordonné des services de l'heure ont été basées sur les horloges quantiques ou sur les horloges à quartz. Les comparaisons des échelles du temps des services de l'heure entre elles, avec l'étalon d'Etat et avec l'échelle du BIH se sont effectuées par l'intermédiaire de différentes voies de transmission: des canaux de télévision et météoriques et à l'aide de la réception des signaux dans les gammes des ondes longues et des ondes très longues et aussi à l'aide du transport de l'horloge quantique.

S. Iijima

President of the Commission

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