31.TIME (L'HEURE)

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INTRODUCTION.

The scientific interest in Commission 31 topics and their applicability to new and practical fields is exponentially growing, pushing towards the recognition of new problems and subsequent research. In some cases as in Primary Standards the state of the art seems to be rather close to the actual and imagined needs. In other cases as in worldwide precise and accurate synchronization, we have to recognize that we still are far from the goals.

This report will try to briefly review the present situation in different "subjects to be considered by Commission 31, Time", as adopted in Grenoble 1976. It will also contain, as usually, a summary of the communications received from different institutions through members of the Commission, condensed as required by the limitation of space.

FUNDAMENTALS.

Actions derived from Resolution No. 2 by IAU Commissions 4 and 31 (1976) on the steering of TAI are described in the BIH report in these pages.

Steering of TAI has been implemented until now by discontinuities of $0,2 \times 10^{-13}$ in the frequency of the reference scale, but other more continuous methods are conceived. Some problems are to be solved in this direction, in the main: a) the improvement of the stability of the component clocks and b) the improvement of the precision and accuracy of links between laboratories and with the BIH. Solutions for a) can be found in the new designs of clocks, the introduction of methods for surveyance of the parameters of commercial clocks, the extension of the use of new primary standards functioning as clocks, the introduction of other well experimented quantum transitions (H-masers) etc..For b) the hope is put in the achievement of new long distance synchronization systems, with better coverage, precision, accuracy and accessibility than the actual ones.

The official extension to current activities of the use of the Coordinated Universal Time UTC is steadily progressing. Germany (D.R.) Germany (F.R.) Spain and URSS have officially adopted UTC as the basis of their legal time. In most cases the particular UTC_i scale that supports the definition in the country is mentioned in the laws.

INVESTIGATIONS ABOUT TIME SCALES.

Research on atomic scales were stimulated by the steering problem. Some practice in steering methods has been gained in this term by the laboratories envolved in TAI when intending to improve their own UTC(i) scales. Theoretical studies on calibration of the unitary interval of a scale and on the modelling and steering of TAI were made by Azoubib, Granveaud and Guinot with the occasion of the CCDS meeting, and by Becker in 1977.

Practical problems in the steering of TAI to be accounted for in the future are the influences of a) the systematic error in the realization of the SI second, b) the random error of the evaluations of primary standards, c) the fluctuations of the scales of reference, in particular EAL, d) the shortcomings of the used

links, at present Loran-C, and e) the number of calibrations per year.

TIME DETERMINATION.

Primary standards are operating or under development at Canada (NRC), Germany D.R. (ASMW), Germany F.R. (PTB), Great Britain (NPL), Japan (NRLM), (RRL), USA (NBS) and USRR (Gosstandart). Their proved or potential uncertainties (1 σ) are comprised between 3×10^{-13} and 1×10^{-14}.

Experience increased during the triennium in the functioning and operation of H-Masers, both in laboratory and field conditions. Efforts to transfer the well known performances of laboratory H-Masers to new generations of compacts instruments designed to field and space operation are now in progress in NASA and elsewhere. H-Maser underwent its space baptism in July 1976 (see "Relativity") and a first orbit-based H-Maser is planned to be launched on board the GPS-NTS3 Satellite by 1981. Since 1976, H-clocks are being introduced in the generation of the UTC National Scale of USRR.

Devices in the far infrared, infrared and visible regions show high promise. Techniques for the laser frequency stabilization are acompanied at present by deep research on superconductive cavity oscillators and on the new multipliers/mixers elements.

Cs standards are now profusely used. Methods have been proposed by G. Becker to maintain or increase the accuracy of commercial Cs standards by periodic adjustments. Cs and Rb are now compact, radiation-protected and fully reliable for their use in space.

Recent advances in quartz resonators design will bring new improvements in the characteristics of this basic element, mainly reducing its sensitivity to accelerations, temperature variations and probably the long-term aging. This will certainly benefit the quality of all atomic standards.

New techniques are being introduced in the field of the auxiliary equipment. In particular the "event timer" concept with its ability to date the arrival of single photons may aid in some fields such as laser ranging and laser-satellite synchronization projects.

While UT continues to be astronomically observed on a regular basis, new improvements or designs are introduced on the two main instruments, PZT and Astrolabe. New techniques for UT determination continue to be experimented in order to prove their precision, accuracy and other particular advantages. Work in Lunar Laser Ranging can be found in the Un. of Texas report. Radio-astronomy groups indicated their intention of making regular measurements; these include the USNO/NRL using the 35-km connected interferometer and later the Very Large Array. The VLBI groups plans to dedicate a 3-station network for regular service by 1980-81 and the JPL VLBI network to span Australia and Spain by 1979.

Comparative studies of all available techniques for UT determination have been made during the elapsed term in different occasions. Arising from the IAU Symposium No. 82 "Time and the Earth Rotation" held at Cadiz is the setting up of an IAU working group for this purpose and to make recommendations for new international programs on the Rotation of the Earth. As it was stated at this occasion, the definition of UT, as presently based on the sidereal rotation of the Earth is inadecuate in modern science and should be clarified in the future.

TIME DISSEMINATION AND SYNCHRONIZATION.

Actual need of accuracy in synchronization on a world-wide scale in now 10 ns, but will soon reach the 1 ns. level. Progress in time distribution and synchronization is to be found by space means which potentiality are in the 1 ns range. Sate-

llites of different applications continue to be used for this purpose, but navigation and communication satellites are most favorable for experiments. Some of them have been described using the satellites NOVA, INTELSAT, SYMPHONIE, ATS, RELAY, TELSTAR, GEOS, NTS and other.

Requirements in time distribution at all levels is also increasing and space-based services are now or will soon be possible with TRANSIT, GOES and GPS satellites, for which special receivers are now available.

Time played these years a primary role in most of the new space systems as GPS, and new and very interesting proposals for the near future exist as experiments with Space Shuttle, TDRSS satellites, and LASSO; all of them with one and two-ways methods capabilities.

The use of lasers and particular microwave frequency bands for pulse synchronization reduced propagation errors, thus the possibility to reach 10-50 ps level in time signals transference can be foreseen.

It is thought that the prioritary goal of the satellite time transfer should be the NBS-NRC-BIH-PTB linkage to make comparisons between the primary standards with a precision of $1x10^{-14}$ available.

Time and frequency comparisons are by-products of many of the VLBI observations with results comparable with those of Loran-C. Special experiments demonstrated accuracies within several 10 ns, and a weekly program is planned by JPL with Deep Space Network Stations to effect clock synchronization to 10 ns by 1979. The capacity of the VLBI method is claimed to be in the 1 ns range. Using a communication satellite to relay data, the correlation process can be speeded-up.

RELATIVITY.

Consequences of the Theory of Relativity, of paramount importance for the astronomer, continue to be a promising subject of experimentation for time specialist. The actual resolution of time measurements and the use of precise clocks on board of satellites permitted to add new well-established facts in the theory's support.

Comparisons of the primary standards in NBS (1,635 m altitude) with NRC standards demonstrated, within the accuracy error limits, the gravitational redshift. A more recent experiment by Iijima (see TAO report) closely agree with the theory.

The University of Maryland in conjuction with USNO, in a carefully conducted experiment using clocks on board of a radar-tracked aircraft checked the combined effects of both Special and General Relativity within a 98,7 per cent agreement with the theoretical prediction. The Smithsonian Astrophysical Observatory and the G.C. Marshall Space Flight Center of the NASA also succeeded in a joint experiment in which a rocket-probe embarking an H-Maser was launched to space at 10,000 km altitude. Combined relativity effects with important values ($4,5x10^{-10}$) appeared and have been measured in the orbiting clocks in the NTS-2 satellite.

Spacelab time experiments planned for the near future will include relativity tests.

COOPERATION WITH OTHER INTERNATIONAL ORGANIZATIONS.

W. Markowitz represented IAU in the 8th session of the Consultative Committee for the Definition of the Second (CCDS), held at Sèvres on April 1977. Consequences of this meeting are commented in these lines, mainly in the BIH report.

Besides Astronomy, in which the need of precise time is permanently growing, many other sciences are basing their progress in time and frequency measurements. To review the situation in connection with applied sciences the European Space Agency

(ESA) included a panel devoted to Time into its "Space, Oceanography, Navigation and Geodynamics Workshop", held at Schloss Elmau, Germany, 16-21 January 1978. The panel chaired by Prof. Leschiutta had the oportunity to discuss with specialists in different fields their actual needs and previsions for the next decade in the time domain.

IAU Symposium No. 82, "Time and the Earth's Rotation" organized by Commissions 19 and 31 met at San Fernando (Spain), 8-12 May, 1978, to discuss modern research in the field of the rotation of the Earth with particular emphasis on the role of new observational techniques in this work. Specific topics discussed were: time, polar motion, reference systems, conventional radio interferometry, very long baseline interferometry (VLBI), Doppler satellite,laser ranging, lunar laser ranging, and geophysical research concerning the Earth's rotation. It was attended by 87 astronomers and geophysicists.

H.M. Smith represented IAU at the International Radio Consultative Committee (CCIR), being a member of the Study Group nº 7 (Standard Frequencies and Time Signals).

REFERENCES

For brevity only major references documenting the subjects contained in the above report, are given. Complete references to the reports of the BIH, observatories and laboratories are to be furnished separately.

1) Proceedings of the 7th (8th and 9th) Annual Precise Time and Time Interval (PTTI) Planning Meeting 1975 (1976, 1977).

2) BIH Annual Reports 1975, 1976, 1977.

3) Comité Consultatif pour la Définition de la Seconde. 8e session - 1977. Bureau International des Poids et Mesures.

4) "Space, Oceanography, Navigation and Geodynamics". Proceedings of a European Workshop. ESA SP-137.

5) IAU Symposium No. 82 "Time and the Earth's Rotation". Edited by D.D. McCarthy and J.D. Pilkington. (in press.)

6) Documents on "Time and Frequency" from the International Union of Radio Science (URSI) XIX General Assembly, Helsinki 1978 (to be published).

7) Documents from the Study Group 7 of the International Radio Consultative Committee (CCIR) 1974-1978.

8) Documents from the XIV Plenary Assembly of the CCIR. 1978.

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

INTERNATIONAL ATOMIC TIME TAI AND COORDINATED UNIVERSAL TIME UTC.

The BIH continues to establish a time scale from the data of clocks only using the ALGOS algorithm (described in the Annual Reports for 1973 and 1974). This time scale is only used internally at the BIH and is denoted by EAL (Echelle Atomique Libre). Until 1977 January 1st, TAI is equivalent to EAL; after this date, TAI is derived from EAL by applying frequency corrections in order to keep the unitary interval of TAI in agreement with the second at sea level.

The clocks contributing to EAL, in January 1978, are about 100 commercial Cs clocks in more than 20 laboratories, and two laboratory Cs standards working quasi-continuously: NBS-4 and NRC CsV. These clocks are intercompared mostly by Loran-C, and also using the TV-method, with calibrations by clock transportation. There is no contribution of other types of clocks, in particular of H-masers, although it is possible and desirable.

The clock comparison systems, which are available on a current basis for long distances, are insufficient in precision (uncertainties of 0.1 μs), in accuracy (variation of delays by several 0.1 μs), and in coverage (restricted to parts of Europe and North America). They do not permit to make full use of the stability of the

colcks and of the accuracy of the frequency standards.

The IAU recommendation (1976) of introducing a TAI frequency step of -10×10^{-13} on 1977 January 1st, was implemented. Several laboratories took this opportunity to improve also the accuracy of the unitary intervals of their local atomic time scales.

The problem of the steering procedure, which consists in deriving TAI from EAL using a variable frequency correction based on the data of primary standards was considered by the 8th session of the CCDS. Some guidelines were issued and a CCDS working group was established in order to advise BIH on the level of confidence in the measurements with primary standards and the methods of steering. The W.G. met informally in January 1978 (Geneva), and had its first official meeting in August 1978 (Helsinki). In the meantime, a steering procedure was experimented, consisting in frequency steps of 0.2×10^{-13} at intervals not shorter than two months. This steering was necessitated by a significant decrease of the EAL frequency with respect to the primary standards of NBS, NRC and PTB. Such a steering conforms to the CCDS recommendation that the corrections are well within the noise of TAI. The steering extended from April to November 1977, with a cumulated correction of 0.8×10^{-13}; it was then discontinued, the TAI frequency lying between the $\pm 1\sigma$ limits of the uncertainties of the primary standards. This action was approved by the CCDS W.G., which however recommended caution in the use of data of primary standards on account to seasonal variations in the Loran-C delays. The cause of the variation of the TAI frequency is under study; an annual term seems to be superimposed to a general trend to EAL frequency decrease. It is known that the frequency of Cs clocks is temperature dependent; the BIH could be led to discard a priori the data of clocks which are not kept in good environemental conditions.

TAI and UTC are made available, at the submicrosecond accuracy: a) by monthly publication of corrections to the local independent atomic time scales (TAI-TA(i)) and to the local coordinated universal time (UTC-UTC(i)) in the Circular D. b) by corrections to contributing clocks, distributed to the participating laboratories.

The reported figures in Circular D were extended from the 100 ns digit to the 10 ns digit in order to avoid rounding errors. The TAI-TA(i) and UTC-UTC(i) are also given in the BIH Annual Reports, with sometimes minor improvements.

In 1976, the discrepancies between the BIH results based on the Loran-C, and the clock transportations reached 1 μs, mainly between the groups of laboratories in North America and of Europe. A readjustment of the BIH values of TAI-TA(i) and UTC-UTC(i) was made on 1977 January 1st. This type of correction is most inconvenient, but is presently unavoidable.

A BIH estimate of the duration of the TAI unitary interval is computed monthly, using an optimun filter. This estimate is subject to changes, when new data of primary standards are known. Improved values are published in the BIH Annual Report.

No particular problem arose in the implementation of the UTC system. Positive leaps seconds were introduced every year on the 1st of January. The DUT1 corrections were regulary issued.

OTHER ACTIVITIES.

In conjunction with the "Laboratoire Primaire du Temps et des Fréquences" (LPTF) of the Observatoire de Paris, the BIH participated to: a) clock transportations (in-Belgium, Brazil, Canada, Czechoslovakia, Germany D.R., Germany F.R., Holland, U.K.) b) clock synchronization experiments using the telecommunication satellite "Symphonie", between Germany (F.R.) and France (Dec. 1976), between Canada (NRC) and France (starting from June 1978), c) clock synchronization experiment organized by the Naval Research Laboratory (USA), using satellites NTS1 and NTS2 (May-Sep. 1978).

d) the proposal to the European Space Agency of a clock synchronization experiment, according to a project developped at French National Center of Space Research, by laser ranging to a geostationary satellite (LASSO project, 1977).

In conjunction, with the US Naval Observatory and the LPTF, the BIH participated to clock transportations and to the synchronization of the Mediterranean Loran-C chain.

Reports of Observatories and Laboratories

A. AUSTRALIA. DIVISION OF NATIONAL MAPPING, CANBERRA.

The Mount Stromlo PZT has been mechanically refurbished after a lengthy down time. During the period of refurbishment the opportunity was taken to computerise the Mount Stromlo data record at the "observable level". This program is now completed. Thus computer accessible plate data for all observations from plate 100 to 5000 are now available for analysis. It is hoped to use this record for recent historical extensions of UT1 as well as a basis for new and better work.

Work continued on the Lunar Laser Ranger with all possible speed. The first statiscal events were detected in June 1977 with sporadic events following at irregular intervals. Events are becoming more easily obtainable. It is hoped that the data will soon be augmenting the PZT data and contributing to the solution of UT1. Tests in conjunction with the Astronomy Department of the University of Texas under EROLD have confirmed all the procedures and communications networks.

Use of the NTS (Navigation Technology Satellites) for precise time transfer became a regular feature of our work. Deviations of the locally derived scale UTC (Australia) from UTC (USNO),MC) never exceded 1 μs. Unfortunately a number of operational difficulties prevented continuous trouble-free operation. Of significance in 1978 was a large multistation campaign to demonstrate the capabilities of the system. It included most of the major time laboratories.

Plans for future research: 1) A new PZT catalogue will become available and a reworking of the historical data set for Rotational Time will be set in motion. 2) Detailed intercomparisons of LLR and PZT data and of UT1 derived from LLR data should be possible. 3) The formal introduction of Southern Hemisphere clocks into the TAI system on a regular daily basis should become a reality.

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

Astronomical observations for the determination of UT has been performed with the Danjon astrolabe. The Doppler tracking station integrated into the IMATC Polar Monitoring Service and MEDOC experiment has continued operation. For the time scaling of the Doppler tracking network the satellite time marks are recorded during all passes.

The Brussels Time Service disposes of: a) 2 HP 5061 Cesium Standards, b) a visual Loran-C receiver and since 1976, a TV receiver is 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 accuracy is respectively 10, 0.22, 0.05 μs.

C. BRAZIL. OBSERVATORIO NACIONAL, RIO DE JANEIRO.

Routine observations of UTO have been made with two transist instruments and a Danjon Astrolabe installed during 1976 has started working on 1977.

For timekeeping, two HP Caesium standards (a 5061A standard tube and a 5061A high performance tube) and one TRACOR 304D Rubidium standard are used at Rio de Janeiro. A HP 5065A standard is at our installations at Brasília.

By clock transportation and line-10 TV method, we are comparing regularly our standards with Cs in other Brazilian establishments. These comparisons are being used to stablish the Brazilian Atomic Time Scales. Comparisons with UTC are made during occasional visits from USNO, USCG, BIH, ONBA and SAO. Efforts are being made to use the VLBI experiments between GRAAM at SP and Haystack at U.S.A. The first positive experience was made during 1978.

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

The NRC primary Cs standard CsV has been operated continuously since May 1975, and since Jan. 1, 1976 the NRC time scales have been derived directly from CsV.

Since the 1×10^{-12} change in TAI 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, CsVI, A,B,C, have been constructed. Their initial performance appears excellent, but evaluation will be completed only by late 1979.

Two-way time transfers between NRC and OP via Symphonie satellite are being made most days from July 1, 1978 to July 1, 1979. Similar transfers, using the Hermes satellite, are being made once a week between NRC and NBS, and NRC and USNO. The NRC-NBS results give approximately 1×10^{-14} accuracy in comparing frequencies of the UTC time scales and the frequencies of the primary standards.

E.CZECHOSLOVAKIA. PRAGUE.

The time UTC is being regularly determined at two stations with the circumzenithal, at one station with the visual transit instruments. The Ondřejov PZT has been operating with no interruption using the first variant of ameliorated star catalogue. Its observations have been included in the BIH system since 1975.

The local time scale UTC(TP) based on the cesium beam frequency standard is being regularly compared with time scales kept in Braunschweig, Hamburg, Postdam, Berlin, Budapest, Uzhgorod and Bratislava stations using the TV-method calibrated by the clock transportation in 1975, 1976, 1977 and 1978.

F. FRANCE. COMMISSION NATIONALE DE L'HEURE.

National time and frequency activities are coordinated by the Commission Nationale de l'Heure which is related to the Bureau National de Métrologie (BNM). The technical work relevant to this coordination is made at the Laboratoire Primaire du Temps et des Fréquences (LPTF) located at the Paris Observatory.

The French Atomic Time Scale, TA(F), is determined from an ensemble of about 15 commercial cesium beam clocks located in several institutes in Paris and elsewhere. Daily time comparisons are made by TV (passive method) to better than 100 ns for clocks located in remote laboratories.

A practical reference, especially for international time comparisons, is the time scale UT(OP) generated by one of the cesium clocks at LPTF; it is kept within $\pm$ 5 μs from UTC implemented by the BIH. Daily Loran-C measurements are made at LPTF for international comparisons.

Details on the French campaigns for time comparisons using satellites (Symphonie I, NTS1 and NTS2) can be found in the BIH, NRC and PTB reports. A time comparison method using clock transportation, flyover and laser pulses transmission has been developed by the Office National d'Etudes et de Recherches Aerospatiales (ONERA) between the Paris and San Fernando observatories yielding a time scale comparison within less than 20 ns; the resolution of the method and its potential accuracy are less than 1 ns.

A comparison method of distant stable frequency standards by means of the transmission of a beat note between the carrier of a TV broadcast signal and a frequency synthesized from the frequency standards has been developed at the Centre National d'Etudes des Télécommunications (CNET) and used to compare two hydrogen masers located 16 km apart.

Since May 1976, a commercial Cs standard allows the dissemination of a standard frequency through carrier-frequency stabilization of the Allouis broadcasting station (163,840 kHz) with an accuracy better than 10^{-11}.

Many organizations receive time signals and/or standard frequencies by lines directly from the LPTF. The dissemination of time by telephone is also made at LPTF.

Several laboratories in France are engaged in the development of frequency standards such as H-masers and ion devices (Laboratoire de l'Horloge Atomique); quartz crystal oscillators and ammonia standards (Laboratoire de Physique et Métrologie des Oscillateurs); frequency-stabilized lasers in at least four laboratories in the University; superconducting cavity oscillators (Institut d'Electronique Fondamentale). Within the program coordinated by BNM, frequency synthesis and measurement in the optical range (10^{12} Hz) are being performed at LPTF. Research on frequency stability characterization has been pursued at LPTF.

G. DEMOCRATIC REPUBLIC OF GERMANY. ZENTRALINSTITUT FUR PHYSIK DER ERDE. POSTDAM,(ZIPE).

Since 1 January 1978 an independent atomic time scale TA(DDR) is computed by the Amt für Standardisierung, Meßwesen und Warenprüfung (ASMW) and ZIPE from the data of the 3 caesium standards of these institutions. Comparisons are made in a daily basis by TV-method.

For time comparisons with time services DHI, TP and PKNM the TV-method is used. Receptions of Loran-C station Sylt and phase trackings of VLF transmitters are also made. Direct comparisons with UTC(OP) and UTC(SU) took place by means of travelling clocks.

The determination of UT0 has been continued with Astrolabe and PZT. By an accuracy analysis of PZT data the influences of various sources of error were examined and the efficiency of the instrument was estimated. For reduction of PZT observations a new star catalogue is used. All astronomical time determinations of the Potsdam Observatory from 1957.5 to 1973.0 were reduced to the homogeneous 1968 BIH system. A device was constructed and tested for the photoelectric registration of star transits with PZT.

H. FEDERAL REPUBLIC OF GERMANY. DEUTSCHES HYDROGRAPHISCHES INSTITUT. HAMBURG, (DHI).

Routine observations of UT0 have been continued with the PZT. Time-signals have been transmitted twice a day, on 4 frequencies (2 MF and 2 HF) in each case. UTC (DHI) has been produced by means of one of the 2 HP 5061A caesium standards at the DHI. In May 1978, an electronic microstepper, constructed at the DHI, was put into operation, which makes it possible to change the scale measure of UTC (DHI) in steps of 1×10^{-14}. Sidereal time has been obtained from the UTC-frequency by means of a frequency converter, the conversion ratio of which includes a frequency offset of -33×10^{-9}.

I. FEDERAL REPUBLIC OF GERMANY.PHYSIKALISH-TECHNISCHE BUNDESANSTALT.BRAUNSCHWEIG,PTB.

After improvements of the beam optics (reduction of the beam velocity to about 92 m/s) and resolving the problem of frequency shifting effects due to Majorana transitions a relative uncertainty of 8.10^{-14} has been attained at the primary time and frequency standard CS1 of the PTB. During 1977 the measurements revealed a considerable negative frequency drift of TAI. Since September 1978 the standard CS1 is in a nearly continuous operation in order to assist the BIH in steering TAI. Studies on the TAI steering problem, the pulling effect of the Rabi resonance and the uncertainty of Cs standards have been published.

Since the beginning of 1977 the time scale TA (PTB) is steered by the standard CS1 in applying appropriate corrections to the local free atomic time scale A(PTB). Before 1977 A(PTB) and TA(PTB) were identical.

A Franco-German satellite time comparison experiment using the communication satellite "Symphonie" has been performed at the end of 1977. A systematic uncertainty of 90 ns and a random uncertainty of a few ns has been attained. A digital phase tracking method for averaging the received carrier phase time of LF standard frequency and time signal transmitters has been developed. Studies have been made allowing to distinguish the ground wave and the sky wave of the mentioned LF emissions and to improve the stability of the received phase time.

J. ITALY. ASTRONOMICAL OBSERVATORY. ROME.

The routine determination of Universal Time was continued with a conventional transit instrument equipped with an automatic data acquisition system. Minor improvements have been done to the inclination setting. Research on smoothing and data analysis is continuing.

The UTC reference scale for the observations is furnished by the Istituto Superiore Poste e Telecomunicazioni (ISPT) by telephonic link. It is now derived from two Cs standards. Daily comparisons are performed with the IEN scale by TV-method, Loran-C and other VLF signals.

K. ITALY. ISTITUTO ELETTROTECNICO NAZIONALE. TURIN, (IEN).

The UTC(IEN) scale in the period 1975-1978 was based on 5 to 7 commercial cesium standards, but a minimum of four clocks were operating continuously. The time scale location is in process to being transferred from the old IEN building to the new facilities, located some kilometers apart.

The readings of the different IEN clocks are transferred to the BIH via measurement performed on the Loran-C stations operating on the Mediterranean. Some occasional portable clock trips were performed to the BIH in Paris and VNIIFTRI and URE in Moscow and Prague, respectively. The relevant results are to be found in the BIH bulletins. The divergence of the UTC(IEN) scale versus UTC, is of the order of 3-4 microseconds per year.

Work is in progress in order to construct a local atomic time scale.

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

Time and latitude observations have been made with the PZT. The revised PZT star catalog, α75, has been used since 1975, and the results of UT1 on TAI were recalculated basing on the α75 system back to 1956 on the consistent basis.

UTC(TAO) has been kept with four HP cesium clocks, two of them equipped with supertubes.

Clock comparison has been made via TV broadcast signals against clocks in ILOM, KGO (Kanozan Geodetic Observatory), NRLM, and RRL. Clock comparison by portable cesium clock (Cs3) was conducted once in 1977 and twice in 1978 against ILOM, KGO, NRLM, and RRL with the accuracy of $\pm$ 0.01 μs. Such trips of portable clock comparison will be continued regularly twice a year hereafter.

An experiment for the effect of environmental conditions, temperature, humidity, atmospheric pressure, and magnetic field, on the rate of cesium clock was conducted in 1977 by use of the vacuum chamber especially designed for this purpose, with respect to Cs3 as an example. The third attack to the experiment for the potential blue shift was tried in 1977 by carrying Cs3 between Mitaka (head office, 58 m above the mean sea level) and Norikura Corona Station (2864m) alternatively after each stay of about 1 week, and the amount of the blue shift corresponding to 94 $\pm$5% as

compared with the theoretically estimated value was detected after applying the corrections for the environmental conditions at the both sites.

M. JAPAN. INTERNATIONAL LATITUDE OBSERVATORY OF MIZUSAWA (ILOM).

Loran-C signals from Iwo-Jima master station have been received. VLF signals, NLK on 18.6 kHz, had been received until October 1977. Time comparison by network television broadcasts has been made against other related institutes in Japan.

The data of astronomical observations made at Mizusawa with the PZT No.1 from 1959 through 1975, and those with the Danjon astrolabe from 1966 through 1976 were recalculated, on a consistent basis, on TAI by use of the results of UTC(ILOM)-TAI obtained back to 1959.

Clock comparison between UTC(ILOM) and UTC(USNO, MC) was made by using the doppler satellite, TRANET 1970 30190, with the accuracy of $\pm$ 20 μs.

The fully automatic electronic astrolabe is under construction at the ILOM, and is expected to be in operation in 1980. The PZT No. 1 which had been used until May 1975 was moved to the University of Cagliari, Italy, for cooperative studies of the precise determination of the Earth's rotation and of other astrometric investigations.

N. JAPAN. JAPAN HYDROGRAPHIC DEPARTMENT (JHD).

For the purpose of the determination of 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:60 cm,f:15.6) especially designed for the occultation observation was installed at Sirahama Observatory in December, 1976.

Results on ET2-TAI, based on more than a thousand yearly occultations, for the epochs 1975.5, 1976.6 and 1977.5 were: 30.53, 30.58 and 30.52 s. respectively, with $\pm$ 0.04 s as m.e.. Forty per cent of the observations were photoelectrically made.

O. JAPAN. RADIO RESEARCH LABORATORIES (RRL)

A laboratory-type cesium beam standard is under construction, the design of which is based on beam optics using hexapole magnets, C-field by a solenoid coil, and Ramsey cavity of about 50 cm long. Observed intensity of Ramsey signal is proved satisfactory, and the further experiments are now proceeding. Two hydrogen masers of the improved model were constructed in 1976 for the purpose of clock operation. The continuous operation for 2 years has been achieved, and the frequency stability with automatic cavity tuning attains to about 1×10^{-14} at present.

UTC(RRL) has been kept by a system of working standards. An algorithm for the calculation of averaging time scales has been developed and is now under test.

New remote-controlled transmitting station for JJY and JG2AS (40 kHz) located about 60 km distant from the RRL has come into regular operation since the end of 1977.

Reception of VLF signals, NLK (18.6 kHz), the Loran-C signals from Iwo-Jima master station, and the Omega signals from 3 stations, Japan, North Dakota, and Hawaii have been continued. The international time comparison via navigation satellite will be commenced from the end of 1978.

On the analysis of data obtained by the two-way clock comparison experiment conducted in 1975 via ATS-1 satellite between Japan and the USA, the precision and accuracy of time comparison were proved to be 1 and 10 ns respectively, and a relativity effect due to the rotation of the Earth, Sagnac effect, was clearly confirmed.

P. JAPAN. NATIONAL RESEARCH LABORATORY OF METROLOGY, (NRLM).

The Cs frequency standard constructed in 1975, NRLM II, was modified by shortening the cavity separation down to about 1 m length to obtain the better uniformity of the C-field, and by increasing the C-field intensity up to 90 mOe to avoid the effect of neighboring lines. According to these modifications, the reproducibility of the frequency standard was improved to several parts in 10^{13} as measured against a HP cesium oscillator equipped with a super-tube.

Two HP cesium oscillators, No. 1 (regular tube) and No. 2 (supertube), have been used to keep UTC(NRLM). National time comparison of UTC(NRLM) has been continued regularly by TV. Stability of clock comparison via TV signals was analised on the data obtained between NRLM and RRL, and the following results was obtained, $\sigma_y(\tau) = 4 \times 10^{-13} \tau^{-1/2}$, where τ is the sampling time in days, and $5 \leq \tau \leq 20$.

Q. RUMANIA. CENTRAL INSTITUTE OF PHYSICS. BUCHAREST.

Time determinations with a Zeiss transit instrument is continuing and studies on the instrumental constants and the FK4 $\Delta\alpha$, $\Delta\delta$ corrections have been published. Rohde und Schwarz clocks are used for time-keeping but a Hydrogen-maser will be hopefully provided. Comparisons are made by VLF. The TV method is employed between Bucharest and Prague. As a result the long-term stability of clocks in both observatories is studied.

R. SOUTH AFRICA. NATIONAL PHYSICAL RESEARCH LABORATORY. PRETORIA (NPRL).

The need for a more definitive method of comparison of TA(NPRL) with TAI decided NPRL in 1976 to initiate experiments to receive the signals emitted by the "Navstar GPS" navigational satellites. By 1977 December the system was able to receive the transmissions from NTS1 and NTS2 on 335 MHz and work was then begun on signal processing equipment to extract the timing information and to further extend the reception capabilities to 1580 MHz.

During March 1978 a cooperative experiment using the Commercial Communications Satellite Intelsat IV was conducted between the U.K. and R.S.A. by the NPL, Teddington, and NPRL. This experiment successfully demonstrated the precision attainable by satellite time transfer in the coordination of TA(NPRL) with TAI to an accuracy of ± 50 nanoseconds.

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

In April 1978, the Danjon Astrolabe completed its 10 year of continuous UT0 determination. An average of 220 Universal Time and latitude results is communicated every year to BIH and IPMS for UT0 and polar coordinates determination. Lunar occultations continued to be observed and analysed for ET.

Time-keeping equipment has been substantially improved during the triennium for better collaboration in TAI.

San Fernando was yearly included in USNO travelling clock trips for global synchronization. For national time and frequency occasional distributions, a mobile laboratory, mounting an atomic clock plus Loran-C and TV facilities is being developed. Between expeditions the equipment will be integrated in the main laboratory.

After the november 1977 fly-over experiment with ONERA and Paris Observatory (described in the French report), the Observatory is preparing to extend its capabilities to the field of laser sinchronization using satellites.

T. U.K. ROYAL GREENWICH OBSERVATORY, (RGO).

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

The atomic time scales TA(RGO) and UTC(RGO) have been formed throughout the

period by combining the readings of HP cesium clocks operating at RGO. Six clocks have been nominally available, three now equipped with "high performance" beam tubes. All the clocks have been continuously intercompared with resolutions of either 1ns or 10ns, but it has sometimes been deemed appropriate to form the time scales from the unweighted readings of only two clocks, with corrections applied for their estimated rates.

TA(RGO) which is an independent atomic time-scale, is a continuation of GA2 with a change of rate introduced at 1977 Jan. 1 to bring it into conformity with the new rate of TAI introduced on the same date; since then the rates of TA(RGO) and UTC(RGO) have been identical.

Measurements of Loran-C signals from Sylt, Ejde (two chains) and Estartit have been continued using four Austron 2000C receivers, one on loan from USNO; they have provided information used by the operating agencies to improve the effectiveness of the Loran system for position fixing and time dissemination.

Reception of signals from the Navigation Technology Satellites NTS-1 and NTS-2 has continued, using a receiver loaned by the US Naval Research Laboratory. The results have been used by NRL in the determination of the orbits of the satellites and are contributing towards the development of the NAVSTAR-GPS system for precise world-wide position determination and true comparison.

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

The U.S. National Aeronautics and Space Administration (NASA) has established an Intercomparison Project to measure a common set of intercontinental baselines by both Very Long Baseline Interferometry, and laser ranging to artificial satellites. The VLBI activity includes determination of the offsets in time and frequency of the clocks of the participating stations. The major purpose of the VLBI/Laser Intercomparison Project is to test the performance of new space systems, which exceeds all previous standards of comparison. Preliminary results from experiments conducted from February 24 thru 26, 1978, between Owens Valley, California, and Haystack, Massachusetts (3,900 km) indicate that clock offset was determined with a precision of 3.10^{-9} seconds, with potential accuracy of 3.10^{-10} seconds, if the systematic sources of error in the present system are identified and removed.

V. USA. THE UNIVERSITY OF TEXAS AT AUSTIN.

Activities were related to the various aspects of the determination of UT by the technique of lunar laser ranging (LLR). These activities have covered the entire extent of this technique, including observation, data identification and management, scientific analysis, and programatic coordination.

The LLR observing activity has continued essentially unabated at McDonald Observatory since the 1969 landing of Apollo 11. The quality of the data has continued to improve to the point where six centimeter ranges are now not unusual. The McDonald Observatory is the only facility that has demonstrated reliable observational capability. Consequently, technical consultation has been provided to several other observatories. The COSPAR-authorized observing campaign "Earth Rotation from Lunar Distances" (EROLD) envisions a network of five-seven regularly operating stations whose coordinated observations will be used to demonstrate the determination of Universal Time and the polar coordinates on a service bureau schedule. The stations presently intending to participate in EROLD are located in Australia, France, FRG, Japan, USA (Texas and Hawaii) and USSR. As Chairman of the EROLD Steering Committee, J.D. Mulholland is responsible for providing the coordination between the observatories and the BIH, which will serve as the centralized data processing center for EROLD. The beginning of the campaign has been delayed by the fact that several of the stations have encountered difficulties in attaining operational status. Nonetheless, recent developments indicate that EROLD may be underway by the end of 1978.

During this triennium, the raw observational data from McDonald Observatory, Hawaii, and Australia have all been processed at U.Tx., Austin. This activity consists of the statistical filtering of the photon detections to separate real lunar signals from noise. Over this period, approximately 1,000 observations have been confirmed from McDonald by this preprocessing.

The application of LLR in providing UT was thoroughly explored during the IAU/IUGG/COSPAR Symposium "Scientific Applications of Lunar Laser Ranging", held at U.Tx. Austin in June 1976. The proceedings include both analysis of real data and exhaustive simulation studies, which show that even very restricted combination of currently planned observations should be capable of providing UT1 determination within 100 ns. The delay in EROLD has prevented the full-scale testing of these conclusions. Nonetheless, several studies of UT0 from the McDonald data, which include determinations on up to 500 individual days over the last 7 years, show considerable promise for the future.

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

Routine observations of UTO-UTC have been made continuously with PZT 3 in Washington and PZT 2 in Richmond. A new system of PZT catalogs was developed and has been used since 1 Jan. 1978. Testing and further instrumental improvement of PZT 7 (65 cm) is being continued. Work has begun on a new PZT (20 cm diameter) for use in a cooperative effort with the National Geodetic Survey at the International Latitude Survey site in Ukiah, CA PZT 6 has been installed in Richmond. Further improvements are required for this instrument. PZT plates obtained in Richmond are now measured automatically using a microdensitometer located at the station in Richmond.

Observations with Danjon astrolabes at Washington and Richmond continued. Past observations with the astrolabes have been reduced and placed on magnetic tape for analysis. Internal smoothing corrections for the Washington astrolabe have been determined and applied to the observations since 1 July 1978.

An autoregressive, integrated, moving average (ARIMA) algorithm has been developed and implemented in the construction of the atomic time scales. A computer is used to steer the master clock of reference system 1 and 2 via a microstepper and an ARIMA extrapolation control procedure. Formation of time scales for remote monitoring sites has been implemented.

Television line-10 triggers of television stations WTTG in Washington and KTTV in Los Angeles as well as Maryland Center for Public Broadcast stations have been synchronized to USNO. Monitoring of Transit satellite system timing along with that of the NTS-1 and NTS-2 satellites was begun. Plans have been formulated for monitoring and timing of the GPS satellites. Portable clock trips continue to be performed regularly to many observatories. The results are published in Time Service Announcements, Series 4. Experiments have been performed in time transfer using VLBI techniques. The USNO also cooperated in a relativity experiment conducted by the University of Maryland.

Monthly observations of UT1 were initiated in December 1977 using the radio interferometer at Green Bank, West Virginia. Daily observations with this instrument have been used since October, 1978 for the determination of UT1 and polar coordinates.

X. USSR.

Les déterminations astronomiques du temps se sont effectuées aux 11 services à l'aide des instruments photoélectriques de passage (10), des instruments visuels de passage (2), des astrolabes à prisme Danjon (3) et d'un tube zénithal photographique (1).

Le traitement des observations sur les instruments de passage s'est effectué

dans le système du Catalogue général des services horaires de l'URSS (KCB) avec l'utilisation de nouveaux valeurs des mouvements propres. Les ascensions droites apparentes des 807 étoiles du KCB ont été calculées d'une manière centralisée pour chaque jour.

Le Temps Universel a été calculé par le traitement en commun des résultats des observations astronomiques des 11 services horaires de l'URSS et des 10 services horaires de R.S.T., R.P.P., R.S.R., R.P.M., R.D.A. et R.S.F.Y., participant au travail du Service d'Etat de temps et de fréquence (ГСВЧ) de l'URSS. A partir de 1975 on utilise une nouvelle méthode probabiliste-statistique de calcul qui donne l'information plus détaillée sur les changements de la vitesse de la rotation de la Terre et qui permet d'efectuer les calculs avec une périodicité hebdomadaire.

On a effectué des travaux sur l'automatisation du processus des observations, sur l'enregistrement des résultats des observations et de leur traitement (Riga, Moscou), sur l'automatisation du rassemblement des données météorologiques (Irkoutsk) sur l'automatisation du traitement en commun des résultats des observations (Mendéléevo), sur l'amélioration de la précision de la détermination du retard de l'appareillage photoélectrique (Nicolajev). On a effectué des recherches théoriques et des études expérimentaux sur la valeur et la reduction des influences réfractives, (Riga, Irkoutsk), sur les influences du milieu ambiant (Nicolajev). Le prof. N.N. Pavlov (Poulkovo) a proposé un perfectionnement de la méthode photoélectrique de l'enregistrement des passages d'etoiles commode pour l'application sur les grands instruments d'observatoire.

Le programme des observations sur les astrolabes á prisme a été mis au point pour la détermination indépedante du temps et de la latitude (Irkoutsk). On a effectué des travaux sur le calcul des trois nouveaux catalogues photoélectriques des ascensions droites des etoiles (Poulkovo). On a étudié les irrégularités de marée de la rotation de la Terre sur les observations astronomiques pour la période de 1951 à 1975 (Moscou).

Les échelles nationales du temps TA(SU) et UTC(SU) de l'URSS ont été basées sur l'étalon primaire d'état de temps et de fréquence dans lequel entrent le repère métrologique á césium, les repères de frequence a hydrogène et les garde-temps à césium et à hydrogène. Les échelles locales du temps coordonné des services horaires ont été basées sur les horloges quantiques ou sur les horloges à quartz.

Les comparaisons des échelles de temps entre elles et avec le BIH se sont effectuées par différentes voies: des canaux de télévision et météoriques, signaux dans les gammes des ondes longues et très longues et transports de l'horloge quantique.

A. ORTE

President of the Commission

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