COMMISSION 31: TIME (L'HEURE)

Report of Meetings, 15, 16, 17, 18, and 20 August 1979

PRESIDENT: A. Orte

SECRETARIES: J. Benavente
D. D. McCarthy

General

Prior to Commission meetings, a short session of the Organizing Committee was held on August 14 afternoon, in which items and proposals to be submitted to the consideration by the Commission were revised.

Commission 31 meetings were arranged to allow members to attend most of the scientific sessions of Commissions 4 and 19.

30 members of Commission 31, 7 future members, 5 consultants, 3 future consultant members and 2 invited participants attended Commission 31 meetings.

15 August 1979

Following a joint meeting with Commission 19 (Rotation of the Earth) (See report of Commission 19.) an administrative meeting of Commission 31 was held. Members stood in silence to honor the memory of Z. M. Brkic, H. Dingle, E. Fichera, C. G. Lacombe, and N. Stoyko, deceased since the last meeting at Grenoble.

The members approved the nomination of S. Iijima as the new president and G. Hemmleb as vice-president. Organizing Committee members for 1979-1982 are D. J. Belotserkovskij, H. Enslin, H. F. Fliegel, B. Guinot (ex officio), D. D. McCarthy, A. Orte (past president), P. Pâquet, E. Proverbio, A. M. Sinzi, G. A. Wilkins. New members of the Commission are P.M. Afanaseva, C.C. Costain, V.A. Naumov, J.D.H. Pilkington, E. Smylie, G. Stanila, G. V. Starytsin, H. Yasuda, J. M. Chamberlain, I. Dominski, J. Gaignebet, H. Hellwig, W. G. Melbourne, P. Morgan, S. B. Pushkin. Consultants are C. O. Alley, J. A. Barnes, G. Becker, R. Lake, S. Leschiutta, P. Mourilhe-Silva, J. McA. Steele, J. Terrien, P. Giacomo, R. Kaarls, Y. Koga, J. Rutman, S. Starker. Representative to CCDS: Wm. Markowitz, to Directing Board of BIH: H. M. Smith and A. Orte, to CCIR: H. M. Smith, and to FAGS: H. Enslin.

B. Guinot presented the report of the Director of the Bureau International de l'Heure (BIH) in which he discussed BIH activities concerning atomic time and the problems arising from the need for an accurate scale unit for TAI. Since 1977, TAI has been established in two steps. A large number of clocks give a stable intermediate time scale through a stability algorithm. TAI is then derived from this time scale by frequency steering based on the data of primary frequency standards. Concerning the stability algorithm, he reported on the increasing number and quality of the contributing clocks. In addition to the data of about eighty industrially made cesium clocks and one Hydrogen maser, the BIH now receives the data of three laboratory cesium clocks (from NBS, NRC, and PTB). These laboratory standards are expected to have a much better long-term stability but raise problems in weighting which have not yet been solved. International time comparisons continue to limit both precision (to a few tenths of microsecond) and coverage (North America, Europe, and North Africa).

The BIH continues to operate the UTC system without any particular difficulty.

In the discussion Guinot emphasized the practical importance of the synchronization of national master clocks as well as systems such as Loran-C, OMEGA, and navigational satellites, with UTC. In addition to these current activities, the BIH participates in research concerning satellite comparisons including use of NTS-1, Symphonie, a proposal for Project LASSO, and study of the use of pulses of a high satellite in a differential mode for distance of a few hundred kilometers.

Wm. Markowitz presented a report on the 1977 Consultative Committee for the Definition of the Second (CCDS). An abstract of this report had been previously published in the IAU "Information Bulletin No. 38", p. 11. H. M. Smith reported on recent activities of International Radio Consultative Committee (CCIR) Study Group 7. IWP 7/1 which had formulated the present system of coordinated radio time signals, having satisfactorily completed its tasks, was formally dissolved. Mr. Smith had chaired this working party since its inception in 1968. The modifications proposed for the dissemination of coded information on DUT1 has been incorporated in Recommendation 460. CCIR concurred with CGPM in the use of the language-independent designations, TAI and UTC, and proposed in Recommendation 535 that the term UTC, should be used to designate time in all international communication activities. New working parties had been set up to advise on world-wide time dissemination by means of satellites (IWP 7/4) and on the accuracy and reliability of frequency standards and reference clocks (IWP 7/5). Further studies had been proposed on time transfer and dissemination. A glossary of terms had been prepared, and the list of standard frequency and time signal emissions (Report 267) had been revised.

The President brought to the consideration of the Commission the fact that some members have questioned the validity of Commission 31 inasmuch as the actual definition of time has little to do with astronomy, and that it is not possible for members to belong to more than three commissions. He proposed the following alternatives:

a) that Commission 31 remain as is;
b) that Commission 31 be modified
   b_1) by merging with another commission such as Commission 19 or 4,
   b_2) by any other decision.

J. D. Mulholland pointed out that it was necessary for him to resign from Commission 31 in order to retain his membership in three other commissions in which he is interested. In his opinion the present situation is that:

1) Commission 31, and no other, is now responsible for atomic time scales and dissemination of time.
2) Commission 19, and no other, is now responsible for polar motion.
3) Commission 4, and no other, is now responsible for dynamical time scales.
4) The only subject of interest to Commission 31 that remains is Universal Time. The controversy arises because all three commissions take jurisdiction, sometimes without consulting or even informing the others.

Since he feels that the responsibility for Universal Time logically resides with Commission 19, Mulholland proposed that Commission 31 renounce all responsibility for Universal Time and retain a purely consultative role as it does with dynamical time. Opinions were offered by G. Winkler and B. Guinot and it was agreed to defer any further discussion until the meeting of 18 August.

SCIENTIFIC PRESENTATIONS

G. Becker discussed the present and future of time and frequency metrology in which he reviewed the development of highly stable oscillators (excluding quartz oscillators). He spoke about experiments with super-conducting cavities in which very high Q factors (10^{11}) and small frequency instabilities (3×10^{-16}) have been achieved. Research on stored ion frequency standards has revealed the possibility of extremely high Q factors (10^{12} to 10^{14}) and small Doppler shifts. At different laboratories a reduction of the size of the Hydrogen maser, e.g. for space craft applications, has been achieved. The passive Hydrogen maser has turned out to be

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a promising device being less sensitive to frequency shifts due to detuning of the resonator. Not very much is known about the long-term instability of Hidrogen masers. Commercial Cesium beam standards of two producers are still very important for timekeeping. Due to the temperature dependence of the frequency (about 10^{-13} $^{o}K^{-1}$) a seasonal fluctuation of the frequency of TAI has been detected using the primary standards of NRC and PTB as references. NRC and PTB have operated their primary standards continuously (NRC since 1975, PTB since 1978) as "primary clocks". The uncertainty of the NRC standard is estimated to be 53 x 10^{-15}, and that of the PTB standard is estimated to be 7 x 10^{-15}. Each of these clocks is considerably more stable than TAI. A new method of considering the weighting of standards in the computation of TAI appears to be necessary. In discussion following this paper, G. Winkler suggested that temperature gradients within the laboratory can account for seasonal fluctuations observed in the standards.

H. Hellwig presented a paper on the present and the future of infra-red and visible radiation t/f metrology. He discussed the use of a laser stabilized by saturated absorption. At present time stabilities of 10^{-11} may be achieved.

C. C. Costain read a paper by A. G. Mungall entitled "Canadian Primary Cesium Standards, CsV, CsVIA, B, and C". The Canadian primary 2.1 meter cesium clock, NRC CsV was the first primary frequency standard designed to run continuously as a clock. It has operated in this manner since May, 1975, and both independent re-evaluations and international time comparisons made since then have demonstrated long-term stability and accuracy limits of the order of 5 x 10^{-14}. Three new, smaller, one-meter primary cesium clocks, CsVIA, B, and C have been constructed to similar specifications of accuracy and stability. In operation since late 1978, they currently serve as secondary standards. Their performance as primary clocks will be evaluated later in 1979.

B. Guinot discussed the steering of the frequency of TAI in steps of 0.2 x 10^{-13} at intervals not shorter than sixty days in such a way that the frequency of TAI does not depart by more than 1 x 10^{-13} from that of the primary frequency standards of NBS, NRC, and PTB. In the implementation of this steering, seasonal effects have been found with a peak-to-peak amplitude less than 1 x 10^{-13}. These do not seem to be entirely due to the time comparison methods. The general trend of a decreasing TAI frequency persists and was compensated by steering. The stability of TAI has been estimated to be 1 x 10^{-13} (for $\tau \approx 2$ months); and is limited by the links between laboratories. Guinot stressed the importance of links with higher resolution.

P. Giacomo presented the main conclusions that can be drawn from the last meeting of the Consultative Committee for the Definition of the Meter, CCDM (June 1979).

The variety and quality of stabilized lasers (optical frequency standards) is continuously increasing. Results have been presented concerning to Ar^+ lasers locked to iodine ($\lambda = 515$ nm), He-Ne locked to iodine ($\lambda = 633$ nm and $\lambda = 612$ nm) or to methane ($\lambda = 3.39$ µm), He-Xe locked to HCOOH ($\lambda = 3.51$ µm), and CO_2 lasers locked to SF_6 or to OsO_4 ($\lambda \approx 9$ to 10 µm).

Stabilities usually attain 1 x 10^{-11} to 1 x 10^{-13} for sampling times of 1 s (Allan variance). Although short term stability and frequency repeatability of these lasers are generally well known, we have but very little information on their reproducibility, which seems to be better than the 1 x 10^{-11} level.

"Direct" frequency measurements attain the $\lambda = 1.15$ um level (f = 260 THz) and, by frequency doubling, the visible (λ = 576 nm, f = 520 THz) is reached.

Two new wavelengths of absorption lines of iodine, used as references; $\lambda = 514\ 673\ 467$ fm (Ar^+ laser) and $\lambda = 611\ 970\ 771$ fm (He-Ne) laser are recommended

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by the CCDM as secondary standards, their relative uncertainty being 2×10^{-9}.

All recent measurements of frequency or wavelength confirm the value already recommended for the velocity of the light ($c = 299\ 792\ 458\ ms^{-1}$). It is under consideration for adoption in 1983 a new definition of the meter based on the distance covered by a plane electromagnetic wave in 1/299 792 458 of a second. Such a definition should implicitly establish the velocity of the light. Before it can be adopted it will be necessary to consider the problems which could arise when putting it into use. Access to the new definition would be possible only in a few well equipped laboratories. Therefore, to extend the benefits of this new definition of the meter to more modest laboratories it will be necessary to recommend values for wavelengths of some secondary standards and to give a reasonable estimate of their uncertainty. It will also be necessary to advise on the means that are available, to these laboratories, for checking their own implementation of such secondary standards; for example, the way to compare frequencies from different standards in the visible.

16 August 1979

A joint meeting with Commissions 4, 7, 8, 19, and 24 was held for the presentation of the report of the Working Group on Nutation and the Progress Report on the Preparation of FK 5. (See the report of Commission 4.)

17 August 1979

C. O. Alley reviewed the relativistic effects in timekeeping and reported on experiments whose results agree with the general theory of relativity to within ± 2 %.

S. Starker reported on a proposed experiment using the Space Shuttle. After presenting a short review of a package of experiments in the fields of communications and navigation, one of the experiments, "Clock Synchronization and One-Way Ranging", was described in detail. The goals of this experiment are: investigation of the behavior of atomic clocks in a low orbit, time dissemination, orbit determination, and ground station position determination with one-way time signals, and comparison of on-board and ground-based clocks by a two-way method. It was emphasized that, in low orbits, the relativistic effect of velocity prevails over the effect of gravity, and that this experiment therefore provides a good opportunity to measure the velocity effect with high accuracy. In the ensuing discussion, it was stressed that although the relativistic velocity effect is well known from particle radiation measurements, the proposed experiment would deal with macroscopic, man-made clocks as objects of observation, and that the accuracy would be much higher than in the case of particle radiation provided that no unexpected disturbing influence appears.

J. Rutman discussed two-way time transfer via Symphonie satellite between NRC and LPTF. B. Guinot mentioned and Rutman stressed that this campaign was part of a more general program begun with the active participation of PTB and including the Symphonie connection PTB-LPTF. This work is intended to test the possibility of long-term operational methods of time transfer by satellite. Instrumental delays remain as the primary problem, and Rutman asserted that a precision of ± 5 ns can be achieved for individual transfers.

P. Nuspl reported on progress with the CENSAR (Centralized Synchronization and Ranging) experiment. Using the HERMES satellite the tracking precision is about ± 1 ns, prediction error is ± 10 ns, and the bit timing can be synchronized to ± 2 ns.

S. Iijima concisely reviewed the situation in the Far East concerning time comparisons. He noted that 24 commercial Cesium clocks, two Hydrogen masers, and

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three laboratory standards belonging to seven institutions in the Far East are not able to provide regular contributions to the formation of TAI because of the lack of adequate links. Since January, 1976 intercomparisons between laboratories and Loran-C have been performed, including a linkage to USNO via portable clock and NTS 1 satellite, but the precision has been limited by defects in ionospheric modelling. He stressed the need for closer cooperation with western laboratories and offered Resolution No. 1 for consideration. Discussion was postponed for the final administrative session. S. Ye compared the situation described by Iijima to the similar situation in China, and further stressed the importance of having better and more permanent links in this area.

S. Leschiutta presented a paper on the future of world-wide synchronization. In his talk he stressed the need for 3-5 cm accuracy for geodesy which, in turn, requires new methods of synchronization such as VLBI, laser, and advanced navigational satellites.

W. J. Klepczynski discussed high precision clock comparisons by means of VLBI measurements. In his talk he stated that VLBI provides one of the most accurate time transfer systems currently operational. After an initial effort to install a self-calibration system at the two terminals taking part in the experiment is made, accuracies of $\pm$ 1 ns are feasible on a regular basis with only modest effort. It seems that a precision of $\pm$ 0.1 ns should be obtainable on a regular basis within the next few years. Two factors which affect this latter goal are:

a) ability to calibrate antenna systems to this precision, and
b) ability to model adequately the tropospheric water vapor.

G. Winkler discussed time dissemination capability with the Global Positioning System (GPS). A timing precision of $\pm$ 0.1 μs is expected, and the 24 satellites in high orbits will provide continuous coverage. He expressed the thought that GPS would, in the future, become the standard method for intercomparing clocks such as Loran-C is today. The cost of the first receiver is \$150 000 but subsequent models may be as cheap as \$50 000. He asked those who are interested in purchasing a receiver to contact him possibly to lower the price through a large order. He noted that even with a limited number of satellites, a good coverage could be obtained and he cited as a reference, Navigation, Vol. 25, No. 2, 1978.

18 August 1979

SCIENTIFIC PRESENTATIONS

J. Gaignebet presented a paper on the LASSO experiment, a project for the synchronization of clocks by using laser ranging to a geostationary satellite. The package will be mounted on the meteorological satellite, SIRIO-2, to be launched during 1981. He briefly described the technical concept of LASSO and emphasized the operational requirement for an accuracy of some hundreds of picoseconds in contrast to the normal requirement for a few nanoseconds accuracy. This leads to the need for a very stringent collaboration among all elements of the link. Event timers are therefore required at the ground stations. Although a two-way system is conceived in order to measure the propagation delay, provisions are possible to allow smaller stations to access the system at the price of a reduced accuracy. Gaignebet announced that ESA would send, in the near future, an Announcement of Opportunity to all potential participants.

J. Rutman presented a general review of the world situation in national timekeeping which was followed by brief comments on their national organizations by G. Becker for the Federal Republic of Germany, J. McA. Steele for the United Kingdom, C. C. Costain for Canada, S. Leschiutta for Italy, P. Pâquet for Belgium, and G. Winkler for the United States.

A. M. Sinzi presented his results for the determination of ET-TAI from occultation observations made at four stations in Japan over a period of fifteen years. Over nine thousand individual observations of stars to the ninth magnitude were used in this study. He showed that ET-TAI may be represented by the expression, ET-TAI = $(30^{s}.74 \pm 0^{s}.04$ m.e.$) - (0^{s}.016 \pm 0^{s}.007$ m.e.) (year - 1970).

ADMINISTRATIVE SESSION

The President, A. Orte, opened the session by presenting for discussion a draft of a recommendation by S. Iijima. After some debate, Resolution No. 1 was passed unanimously. A second discussion of the future of Commission 31 followed. Comments by J. Hers were presented expressing the view that he could not visualize an IAU without a commission on time since time is a basic building block of astronomy, no matter what the particular interests of Commission 31 might be at any given time. It was debated whether Commission 31 should merge with another commission or modify its terms of reference that were adopted at the Grenoble IAU meeting. By vote it was decided that Commission 31 would remain in its present form as defined by the Grenoble terms of reference.

20 August 1979

A joint meeting was held with Commissions 4 and 19 to discuss the redefinition of Universal Time and the nomenclature of Dynamical Time. (See the report of Commission 4.)

Resolution No. 1

1. The International Astronomical Union

Considering

a) that International Atomic Time, TAI, is established by the BIH on the basis of data provided by several laboratories operating independent clocks and frequency standards, and
b) that data from other laboratories needed to improve TAI cannot be used by reason of the inadequacy of existing international links,

Recommends

a) that laboratories concerned with time and frequency in the Far-East and Asia, Africa, Australia, and South America establish international links with high accuracy, and
b) that support be given by national and international bodies to these laboratories for the use of high precision techniques such as Loran-C, flying clocks, artificial Earth satellites, and VLBI.

1. L'Union Astronomique Internationale

Considérant

a) que le temps Atomique International, TAI, est établi par le BIH d'après les données fournies par plusieurs laboratoires où fonctionnent des horloges et étalons de fréquence indépendants et
b) que des données d'autres laboratoires, nécessaires pour améliorer le TAI, ne peuvent pas être utilisées car les liaisons horaires internationales existantes ne conviennent pas,

Recommande

a) que les laboratoires qui s'occupent du temps et des fréquences en Extrême Orient et Asie, en Afrique, en Australie et en Amérique du Sud établissent des liaisons horaires internationales de grande exactitude et
b) qu'une aide leur soit apportée par les organismes nationaux et internationaux pour qu'ils puissent utiliser des techniques de grande précision, telles que celles qui impliquent l'usage du LORAN-C, des horloges transportables, des satellites artificiels de la terre et de l'interférométrie à très longue base.

Other resolutions discussed and approved by the members of the Commission are included in the reports of Commissions 4 and 19 in this volume.