

## COMMISSION 31: TIME (L'HEURE)

### Report of Meetings

PRESIDENT: G. M. R. Winkler.

#### First Session, 21 August 1973

The session was opened by President G. M. R. Winkler.

##### IA

The first topic on the agenda was consideration of procedures to be used in maintaining an active membership list.

Markowitz and Smith both felt that the original wording was vague. The rescinding of membership should also extend to the consulting members to this Commission. The action of this Commission should be sent to all current members and failure to respond would automatically cause them to be dropped from the membership.

This matter will be resolved at the meeting on 29 August.

##### IB

The President next put forth the candidates for office:

*Proposal for Offices (1973–1976)*

President: H. Enslin.

Vice-President: A. Orte.

The candidates for the Organizing Committee will be put forth at the session of 27 August. The President informed the Commission that it was the wish of the General Secretary of the Union that the Organizing Committee consist of no more than 10 members and that individuals should serve no more than 2 consecutive terms. A consensus of many members indicated that continuity was important and therefore  $\frac{1}{2}$  or 5 new members should be placed on the Committee and should serve 2 terms and the 5 remaining members serve 1 term and thereafter the rotation would be established. Both Markowitz and Smith indicated they would offer to leave the Organizing Committee. A new list will be presented on 27 August.

The proposed President and Vice-President were approved by acclamation for transmittal to the Executive Committee.

##### IC. CONSULTANTS TO THE COMMISSION

The President stated the importance of Consultants to this Commission, especially from Standards Laboratories. It was noted in discussion that this list should fall under the same scrutiny as full membership.

The new Consultants put forward by the President were Barnes, J. A., Costain, C. C., Morgan, P., Muller, I. I., Penny, C. J. A. (Miss), and Steele, J. McA.

##### IIa. REVIEW OF DRAFT REPORT AND DOCUMENTS

Because of the draft reports not being readily available, the topic was deferred to a later session. Copies were made available by the President.

## IIb. PRIORITIES IN TIME

- (1) The BIH must receive more financial support.
- (2) Details of 1 second steps in UTC and DUT 1 dissemination should be resolved.
- (3) The questions regarding Ephemeris Time must be clarified.
- (4) The derivation of TAI should include more contributors as links with other time scales become available.
- (5) Close cooperation between the scientific and treaty organizations, CIPM, CCIR, IUGG, URSI, and IAU, must assure that the present evolution in worldwide standardization in the provision and use of precise time can continue in an orderly way.

These priorities will be voted on by the Commission on 29 August 1973. Remarks and additional items were requested by the President.

## IIIa. DRAFT RESOLUTIONS

The following draft resolutions were placed before the Commission. The result of this meeting concluded with the establishment of a drafting committee to revise draft resolutions to a form acceptable to all members. This committee consisted of Markowitz (Chairman), Becker, Enslin, Sinzi, and Wilkins.

Draft Resolution No. 1. Adoption of UTC as basis of standard time in all countries.

Draft Resolution No. 2. TAI decimal counting.

Draft Resolution No. 3. Modified Julian Date

Draft Resolution No. 5. Redefinition of ET with reference to TAI.

Draft Resolution No. 4 and No. 6. Maximum limit of TUI-UTC.

Draft Resolution No. 7. This resolution was deferred until after the joint meeting on UTC.

The remainder were individually discussed at later sessions.

## IVa. REPORT ON CCDS MATTERS BY W. MARKOWITZ

The CCDS met on 6 and 7 July 1972 to discuss the definition of an international atomic time scale for daily use. It was agreed that the problems involved should be studied by interested agencies, in particular, the IAU.

It was noted that the almost universal acceptance of UTC makes it a suitable basis for a time system for common use.

Agencies concerned with comparisons of atomic clocks were urged to send their results to the BIH, in the form which it may request.

The President passed out a paper 'Note on Ephemeris Time (ET), Relativity and the Problem of Uniform Time in Astronomy', by G. M. R. Winkler.

**Second Session, 24 August 1973**

Jointly with Commission 19 (see Commission 19 Report).

**Third Session, 24 August 1973**

Dr *Winkler* opened the session.

Reports by the directors of the BIH and BIPM were presented along with a report on the URSI meeting by Dr *Winkler*.

Dr *A. M. Sinzi*, Director of the Japanese Hydrographic Office, was approved for membership in Commission 31.

## I. REPORT OF BIH DIRECTOR

Dr B. Guinot presented the Bureau International De L'Heure (BIH) report. A complete text with figures was handed out to the assembled participants. 'Report to Commission 19 and 31, 15th IAU General Assembly, Sydney, 21-30 August 1973'

On the subject of International Atomic Time (TAI) it was noted that the XIVth General Conference of Weights and Measures, formally recognized the BIH atomic time as TAI. Problems resulting from this rôle were noted with regard to (1) Uniformity and accuracy of TAI since it is the mean of the frequencies of a small group of commercial cesium standards. There are currently 7 contributing laboratories and the stability for 1 year is of the order of  $1 \times 10^{-13}$ . (2) Traveling clock service provided by the USNO made frequent checks of LORAN-C propagation delay. The 10-day averages of propagation delay showed a scattering of a few 0.1  $\mu$ s. The apparent propagation delay of the composite LORAN-C link between America and Europe has a periodic nature with an amplitude of 0.2  $\mu$ s over periods of 1 to 2 months. There appears a positive correlation between observatories/laboratories in North America. However, these fluctuations are of the order of magnitude of 0.2  $\mu$ s to 0.4  $\mu$ s and indicated the precision of LORAN-C reception.

With respect to implementation of Universal Coordinated Time (UTC) two facts were noted: (1) The step of 0.3  $\mu$ s, in coordinated time made on January 1, 1972, solved the problem of homogeneity of the time data between the laboratories and the BIH. (2) Announcement of a leap second is made at least 8 weeks in advance. Because of this the difference between UT1-UTC exceeded the tolerance of 0.7  $\mu$ s before 31 December, 1972 when the leap second was made. The Director of BIH requests more precise guidelines for future introduction of these jumps.

In regard to Time Signals, it was noted that time signals are emitted within  $\pm 0.2$  ms from UTC and this is much smaller than the CCIR tolerance and the propagation errors. The synchronization of the time signals has been practically achieved.

Matters relating to Universal Time and Coordinates of the Pole will be presented at a later session.

Dr Guinot reported that as a result of favorable action by the BIPM (Bureau International des Poids et Mesures) an assistant, responsible to work solely on TAI, will begin work on 1 September 1973. It was noted that increased responsibilities with respect to scientific research have resulted in significant increases in costs which need to be met. H. Smith strongly urged additional support and he and W. Markowitz will assist H. Enslin in providing a succinct resolution to the IAU finance committee requesting additional support because of increasing responsibilities to the astronomical community.

*Discussion:*

Dr Winkler presented additional facts regarding the calibrations and operation of the LORAN-C chain across the Atlantic. Also indicated was the fact that time synchronization across the Pacific is still a problem. Dr Morgan discussed the satellite link between the USNO and Australia. Dr Guinot also brought up in the course of the discussion a proposal to have guest workers from various laboratories around the world spend a residency period in Paris. This would essentially alleviate the manpower problem which Dr Guinot has, and also provide a broad dissemination of the problem in operation of the BIH. Additional discussion ensued as to the possible frequency adjustments and second jumps in the TAI Timekeeping System.

## II. REPORT OF BIPM DIRECTOR

Dr J. Terrien presented the report of the BIPM. The CGPM held its meeting in October, 1971, at which time a resolution was adopted which defined the basis of TAI. CIPM was asked to conclude the necessary arrangements with the BIH for implementation of the TAI.

The CCDS met in July, 1972 with Prof. Markowitz as the representative of the IAU. The fol-

lowing four actions were taken at this meeting. (1) Laboratories and observatories of cooperating countries were asked to give the BIH scientific support with more detailed information. (2) TAI should be adopted as a symbolic notation in every language for International Atomic Time. (3) That scales of time either be counted in decimals of a second or with normal designations of days, hours, minutes, and seconds. It was referred to the IAU for a recommendation. (4) Should the CCDS take official action to make civil time the same as UTC? This question was discussed and it was referred back for further studies with other appropriate international organizations.

CCDM met in June of 1973. Discussion were undertaken at this particular meeting with respect to the velocity of light and its value  $c = 299\,792\,458 \text{ m s}^{-1}$ . A conclusion was to keep this value regardless of the definition of the meter and the definition of the second.

### III. REPORT ON THE URSI MEETING IN WARSAW, POLAND

Dr *Winkler* presented the results of the URSI meeting. They were (1) the recommendation to adopt UTC, (2) recommendation for the definition of a meter, and (3) a resolution with respect to mutual interference of time signals. With respect to the latter, the time signals cannot be received in certain areas of the world. The various frequencies used in various countries and the principles under which they operate were briefly discussed with respect to CCIR, CHU in Canada, Russian Broadcasts and in the United States. The conclusion of this discussion seemed to be that the action of Commission 31 should be one of encouraging the CCIR to continue work in improvements in the dissemination of time signals.

*Cook* of the UK continued the discussion with respect to the definition of the meter and proposed that there needs to be a distinct view presented by the IAU.

#### Fourth Session, 25 August 1973

This session was opened by Dr Kovalevsky, President of Commission 4. It was a joint session of Commissions 31 and 4

This joint session had as its principal topic a discussion of 'UTC'.

*H. Smith* was asked to present the CCIR report. As the Chairman of the working party, it has been his responsibility to make sure that the UTC system has been implemented successfully. It is recognized that the UTC system is a compromise system. It also is a uniform system for meeting the general requirements for time. Questions were then posed: (1) Should any changes be made now in the UTC system? *H. Smith* recommended maintenance of status quo unless absolutely necessary. (2) Question of the leap second and the excess of departure above 0.7 s. He asked the question as to what might be preferred dates for change and stated that as far as he was aware, no serious inconvenience was to result from excess departures of the time limit. Referring to the draft resolution No. 6 by G. F. Sadler, having to do with the departure of UTC from UT1, he made the observation that if the earth continues to behave in its rate of rotation as past experience has shown, then perhaps two changes per year are inadequate. Possibly one solution is to allow a tolerance of 0.9 s. and also the possibility that the number of preferred dates go from say the current two to possibly four. Some combination of both or an adoption of one might be superior to the current resolution. Mr Smith indicated that there was a need for clear indication of the position of Commissions 31 and 4.

Dr *Barnes* stated that there were no complaints at the National Bureau of Standards with respect to the excess of 0.7 s. Dr *Mulholland* stated that the change of tolerance needs a resolution, but the number of dates does not. Dr *Iijima* proposed that the tolerance be set at 1.0 s. Dr *Winkler* indicated that a major difficulty would exist in the change required in the code format if the excess time deviation became larger than 0.95 s. *H. Schlegel* of the US said that the 0.7 s must be rigorously interpreted and any adjustment that should be made should be rigorously defined as hereto. Dr *Sinzi* indicated a study which they had conducted in Japan which concluded that the need for high accuracy in the sense of a one second tolerance seems not to have been demonstrated. Dr *Mulholland*

subsequently indicated that if 20% of the polled people in this study felt requirements on the value not to be less than 0.7, that these people should not be ignored.

At this time Dr *Winkler* presented the revised draft of resolution 1, to be found below. Resolution 1 was approved with two abstentions in the voting.

A discussion as to the name to be attached to UTC and TAI followed. Nine attendants favored a designation of international atomic time immediately; 14 indicated a desire to change the designation at a later date. With respect to universal time coordinated, 19 attendants indicated that it should be retained as the current designation of time. As a result, draft resolution 7 which contained a proposal for UTC to be changed to ICT (International Coordinated Time) submitted by Dr *Belocerkovskij* and supplemented by Drs. *A.* and *N. Stoyko* was defeated 16 against to 1 for, with no abstentions. Draft resolutions 4 and 6 dealt with the tolerance to be allowed with respect to the leap seconds. Dr *Morrison* of the Royal Greenwich Observatory presented a discussion on the rate of rotation of the earth and anticipated requirements both in leap seconds and in the number of dates. His conclusion was that if a recommendation were presented which allowed four unique dates and a tolerance limit of 0.9, that this modified resolution would satisfy requirements for many years. As a result of much discussion, draft resolutions 4 and 6 were referred to a drafting committee consisting of *Winkler*, *Guinot* and *Morrison* to be reworked and presented at the session on the 29th of August.

#### Fifth Session, 27 August 1973

The session was opened by *G. Winkler*, President. The president proposed a slate for the new Organizing Committee. This slate, which took the new requirements for composition and tenure of the Organizing Committee into account, was approved unanimously.

Dr *Guinot* presented comments on 'Advances in Timekeeping at the BIH'. Dr *J. Barnes*, NBS, reported on the status of the 'Primary Frequency Standards'. After complete evaluation and account of the individual frequency standard biases, it appears that the three standards at PTB, NRC, and NBS are within about  $2 \times 10^{-13}$ . TAI appears to be high in frequency by about  $1 \times 10^{-12}$ .

Dr *Morgan* gave a report on timekeeping in Australia. Clocks at various establishments are now intercompared by TV with a composite scale computed by the Mt. Stromlo (Dept. of National Mapping) Time Service. Australia is tied to the rest of the world by portable clocks (with USNO) and also recently by satellite (Doppler tracking of TRANSIT satellites). Experiments with Timation satellite established a link to the USNO with a scatter from day to day of about 0.2  $\mu$ s.

*R. Keating* reported on the relativity experiments with clocks which he conducted together with *J. Hafele*. The discussion centered on the question of claimed accuracy of, and confidence in, the experimental results (internal precision  $\pm 10$  ns, estimated external accuracy  $\pm 30$  ns). The difficulty of estimating disturbing factors as for instance the Earth's magnetic field, temperature shocks, physical motion, etc., was discussed. A repetition of such experiments has been suggested by several.

Dr *Becker* reported that an analysis of TAI and its contributors in reference to his laboratory primary frequency standard clearly shows tendencies of time scales to decrease their frequency. TAI decreased by  $1.4 \times 10^{-13}$  per year. This is suggested as typical for the commercial frequency standards used. The USNO time scale proved to have the best long term stability, whereas PTB was best for 100 day intervals.

#### Sixth Session, 29 August 1973

*G. Winkler*, President, opened the session. The question of membership retention of inactive members was resolved with a recommendation to the President to take the necessary steps to reduce the membership periodically to include only active members and consultants. Consultation with the Organizing Committee is advisable in doubtful cases.

After much discussion the resolutions and "Priorities" given below were adopted in final form.

**Resolutions**

## RESOLUTION NO. 1 BY COMMISSIONS 4 AND 31

*(Adopted 25 August 1973)**Considering:*

- (a) that a single worldwide coordinated clock time scale based upon the SI second is desirable,
- (b) that the Coordinated Universal Time system (UTC) makes the International Atomic Time (TAI), which is based on the SI second, generally available, and
- (c) that the UTC system provides mean solar time directly to a precision that is needed for navigation and surveying,

*Recommend:*

the adoption of the UTC system as the basis for the dissemination of standard time (heure normale) in all countries.

## RESOLUTION NO. 2 BY COMMISSIONS 4 AND 31

*(Adopted 29 August 1973)**Considering:*

- (a) that TAI equalled UT2 (nominally) when UT2 was 1958 January 1<sup>d</sup>, 0<sup>h</sup> 0<sup>m</sup> 0<sup>s</sup>,
- (b) the necessity of maintaining all conventional calendrical and time designations,
- (c) the desirability of bringing into accordance ET and TAI, which differ by about 32s;

*Recommend:*

- (1) that a change be introduced in the TAI as soon as practicable so that TAI (new) equals TAI (old) plus 32 seconds precisely,
- (2) that DTA (DAT) be defined by TAI minus UTC, where DTA is an integral number of seconds,
- (3) that the CCDS be invited to take the necessary action.

*Explanation:*

- (1) TAI is not affected by leap seconds but UTC is.
- (2) The value of DTA is determined and announced by the BIH.
- (3) UTC is the basis of standard time, the time in common (civil) use, as disseminated by radio time signals.

## RESOLUTION NO. 3 BY COMMISSIONS 4 AND 31

*(Adopted 29 August 1973)*

This was adopted by the General Assembly specifically because of its wide importance (Resolution No. 4).

## RESOLUTION NO. 4 BY COMMISSIONS 4 AND 31

*(Adopted 29 August 1973)**Considering:*

- (a) that present procedures governing the insertion of leap seconds have been variously interpreted and,
- (b) that if the present trend of the rotation of the earth continues, it will become impossible to maintain UTC within the present limits by the insertion of leap seconds on two preferred dates only and,
- (c) that it is important for many users to have UT1 minus UTC remain within a *fixed* limit;

*Recommend:*

- (1) that the *maximum limit* of UT1 minus UTC be set at  $\pm 0.950$  seconds,
- (2) that the maximum deviation of UT1 from UTC plus DUT1 be  $\pm 0.100$  s,
- (3) that, when necessary, leap seconds may be introduced at the end of any month, but that first preference be given to the end of June and December, and second preference be given to the end of March and September.

## RESOLUTION NO. 5 BY COMMISSIONS 4, 14, 31 AND 40

This was adopted by the General Assembly specifically (Resolution No. 6).

**Applications of Time – Priorities**

There is still a very large number of users who need UT1 and who depend on the time signals entirely. There is also a considerable group of users who need UT1 with greatest precision (Satellite Geodesy, deep space tracking). There is a growing number of observatories who need to point their telescope to within 1' or 2' (for optical retroreflector satellite tracking, Pulsar studies, etc.). They are very concerned about DUT1.

The need for precise clock time has increased even more dramatically. Pulsar time of arrival observations can be done with microsecond precision. Lunar optical ranging measures travel times with  $10^{-10}$  s resolution. Indeed there is no doubt that in a large number of scientific observations the superior accuracy of time measurements, compared to any other quantity, will become useful.

In view of these ever growing applications, not only in pure science, the following priorities in our work can be recommended:

- (1) The BIH must receive more support, financial and otherwise.
- (2) Details of the 1 second steps in UTC and of the DUT1 dissemination should be resolved.
- (3) The questions regarding Ephemeris Time must be clarified.
- (4) The derivation of TAI should include more contributors as links with other time scales become available.
- (5) Close cooperation between the scientific and treaty organizations, CIPM, CCIR, IUGG, URSI and IAU, must assure that the present evolution in worldwide standardization in the provision and use of precise time can continue in an orderly way.

**Special Session, 29 August 1973**

## APPLICATIONS OF PRECISE TIME IN ASTRONOMY

This session was organized and chaired by the Vice President, H. Enslin.

*G. Winkler* gave a report on present capabilities of various electronic systems to disseminate time. Loran-C in its area of groundwave coverage is the most useful system which offers a precision of better than a microsecond. Television is being used increasingly as a local and intermediate distance link. Satellites, looking very promising, have not yet been used for routine operations. They are still experimental.

*L. V. Morrison* reviewed a comparison of ET2 with AT over the period 1955.5 to 1972.0. It was found that the value of the tidal deceleration in mean longitude of the Moon should be corrected by  $-10'' T^2$ . The speaker recommended redefinition of ET with reference to TAI.

*J. D. Mulholland* presented a paper on 'The Use of Precise Clock Time in Laser Ranging' At a level of  $\pm 15$  cm range uncertainty as now achieved at McDonald Observatory, the availability of precise epoch and frequency are crucial to the observing strategy, and also to data recognition and applications.

*K. I. Kellermann* spoke about 'Very Long Baseline Radio Interferometry' Starting-synchronization of the clocks at the two stations is generally obtained from Loran-C. Final synchronization of

about  $0.1 \mu\text{s}$  as often required can be achieved after the observation by comparing the tape records with different time delays until maximum correlation is found.

*R. Wielebinski* gave an account of 'Applications of Precise Time in Pulsar Research'. Time of arrival observations can be done now with sub-microsecond precision. This precision over periods of months constitutes the most demanding requirement for a uniform clock time including the necessary reductions to a coordinate time. The "corrections" involved are critical for the reduction of observations (see Hunt, G. C.: 1971, *Monthly Notices Roy. Astron. Soc.* **153**, 119).

*H. F. Fliegel* gave a review on the utilization of time in deep space tracking. In order to obtain accurate orbit determinations, tracking station clocks must be synchronized with each other, and their relationship to UT1, TAI, and ET must be known precisely. Use of the BIH rapid service for UT1 and the pole coordinates has greatly improved the precision of tracking.