COMMISSION 31: TIME (L'HEURE)

Report of Meetings: 20, 21, 22, 26, and 27 November 1985

Acting PRESIDENT: D. D. McCarthy SECRETARY: H.F. Fliegel

20 November 1985

A Joint Discussion on Reference Frames was held including Commissions 4, 7, 8, 19, 20, 24, 31, 33, and 40, chaired by J. Hughes.

21 November 1985

REPORTS, AND ADMINISTRATIVE MATTERS:

Following a meeting of the Organizing Committee, an administrative meeting of Commission 31 was held. D. McCarthy announced that he was acting in place of Commission President G. Hemmleb, who has been ill.

The Report of the Commission President has been prepared by G. Hemmleb and was summarized by D. McCarthy; and has been published in "Highlights of Astronomy". The success of the MERIT campaign was noted, and members were reminded that the MERIT/COTES resolutions have been presented for possible approval to Commission 31. The IAU Symposium 109, sponsored by Commission 31, has been held, in which the need for the exact definition of entities which define astronomical time was identified as a special concern of Commission 31. The transfer of responsibility for International Atomic Time (TAI) from the Bureau International de l'Heure (BIH) to the Bureau International des Poids et Mesures (BIPM) was noted. There is a continuing need for astronomical observations of Universal time (UT) and Ephemeris Time (ET) from cooperating observatories. Thirty three laboratories including 140 clocks now contribute to the formation of TAI, and seasonal variation of commercial cesium clocks from primary cesium standards has been measured. Time synchronization experiments have been carried out using TV, LORAN-C, portable clocks, Very Long Baseline Interferometry (VLBI) and Global Positioning System (GPS) and other satellites. Accuracies have been reported in the 1 to 10 nanosecond range. GPS receivers have been deployed at the US National ureau of Standards (NBS), US Naval Observatory (USNO), BIH (at Paris Observatory),Physikalisch-Technische Bundesanstalt (PTB), Technische Universitat Graz (TUG), Tokyo Astronomical Observatory (TAO), and Australia.

B. Guinot presented the Report of the BIH. He noted that the number of clocks now used to form TAI is rapidly increasing, thanks to better methods of time transfer from remote laboratories (for example, GPS). That number is now 150, up from 140 at the time the Report of the Commission President was prepared (see above). As the first step in forming TAI, an intermediate time scale, Echelle Atomique Libre (EAL), is computed from the data of all available clocks. The stability of EAL has been 0.5 parts in 10 to the 14th for averaging times of 4 to 6 months. Then the duration of the scale unit of EAL is determined using the primary standards of the National Research Council of Canada (NRC), PTB, NBS, and the US Naval Research Laboratory (NRL). No steering has been necessary during 1984-1985. However, an annual variation has been discovered, traced to the clocks and not to the transmission methods or media, of approximately 1 microsecond amplitude over a year. The appropriate statistical treatment of the timing data is therefore still to be determined. Thirty nine laboratories now contribute to TAI, and 10 organizations form local independent scales of time, which are useful for intercomparison and statistical studies. More than half the contributing laboratories contribute to the BIH via GPS time transfers. The BIH has confirmed reports that 10 nanosecond accuracies are possible using GPS time transfer; but, because of imperfectly calibrated receiver delays, station location errors, software errors, and occasional inadequacies in local laboratory timing signals, the accuracy actually attained until now has been about 50 nanoseconds. The BIH now imposes a maximum value on the

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weight assigned to clocks, but is considering the possibility that very good clocks may be underrepresented by this procedure.

The Report to Commission 31 on the 10th Meeting of the Consultative Committee for the Definition of the Second (CCDS) had been prepared by W. Markowitz, and was read by D. McCarthy. The topic of chief interest to the IAU was the proposed transfer of responsibility for TAI from BIH to the BIPM. Other topics include atomic standards, time and frequency transfer, and relativity.

J. Pilkington's Report on the activities of CCIR Study Group 7 was read by H. Fliegel. The principal work consisted of updating previous reports dealing with dissemination of time and frequency, the assessment of frequency standards, and the formation of time scales. CCIR Report 439-3 is the working standard on time and relativity. The Recommendations Reports of the CCIR, Volume VII (1982), and the Conclusions of the Interim Meeting of Study Group 7 (CCIR Doc 7/77, 1984) are recommended for study to everyone in the field of time and frequency.

Draft Resolution 1 concerning the transfer of responsibility for TAI from the BIH to the BIPM was discussed, slightly amended, and passed unanimously (see below).

D. McCarthy reported that approval has been received for the proposed IAU Symposium 128, "Earth Rotation and Reference Frames", to be held in Washington DC, USA, 20 - 24 October 1986. The Academia Sinica proposes a Symposium on Time Frequency in Shanghai in 1987. It was suggested that 1987 might no longer be open, but members recommended that the IAU sponsor the Symposium for the earliest mutually agreeable date.

The members approved the following nominations for 1982-1985:

President: D. McCarthy Vice President: P. Paquet

Organizing Committee: S. Aoki, J. Benavente, N. Blinov, G. Hemmleb, J. Kovalevsky, Y. Miao, I. Mueller, J. Pilkington, E. Proverbio, B. Guinot, S. Ye.

Representatives: to CCDS, J. Benavente; to FAGS, J. Kovalevsky; to CCIR Study Group 7, J. Pilkington; to the CCDS Working Group on TAI, G. Winkler; to the BIH Directing Board, P. Paquet and G. Winkler.

The members approved without objection the proposed list of new members and consultants to the Commission.

22 November

ADMINISTRATIVE MATTERS:

D. McCarthy reported that the Draft Resolution approved in the Joint Discussion on Reference Frames included the recommendation to commit the task of the exact definition of TAI to a special working group. He therefore requested that Commission 31 Draft Resolution 2, concerning a definition of TAI, not be brought to a vote, but invited discussion on TAI. B. Guinot stated that there is a need to define the frame of reference of TAI. Although the reference frame of TAI has been defined as geocentric, in practice the unit of TAI has been the second as realized by clocks at mean sea level. Guinot believed that the definition of the TAI second given by the CCDS should be acceptable, but reported that some colleagues apparently object to the term "proper time" when applied to atomic clocks. In the ensuing discussion, it was reported that some astronomers object to the application of the term "coordinate time" to TAI. Commission members agreed to refer the issue to the forthcoming working group.

D. McCarthy requested that Draft Resolution 3, concerning the definition of the work of Commission 31, be withdrawn in favor of the Draft Resolution from the Joint Discussion

on Reference Frames (Resolution B2); and he invited discussion. There was general agreement that the members of Commission 31 would not object to an expansion of its role to include the definition and establishment of reference systems, nor to a change in the name of the Commission, if a consensus could be reached with other Commissions and the IAU leadership.

A joint meeting was held in the afternoon between Commissions 19 and 31 dealing with the MERIT/COTES Project (see Commission 19 Report).

26 November

There was a joint meeting uniting Commission 7,8,19, and 31.

SCIENTIFIC PRESENTATIONS:

B. Kolaczek, in a joint paper with W. Kosek, reviewed the search for periodic oscillations in polar coordinates with periods of 10 - 100 days. Quick look data taken by different techniques and reported in the MERIT Circulars were examined using Maximum Entropy Analysis and the Ormsby filter. Amplitudes ranged from several milliarcseconds for CSR - LAGEOS laser ranging, IRIS - VLBI and DMA - Doppler to 12 mas for BIH - Astronometry. Improved data sets showed only 2 mas amplitude for CSR - LAGEOS (84 L 01) and IRIS - VLBI (85 Feb. 01). Similar short period terms were detected in the equatorial components of the atmospheric excitation function chi 1, chi 2 of the European Centre for Medium Range Weather Forecasting (ECMRWF).

C. Kakuta presented results of collocations of geophysical observations at certain Earth Orientation Parameters (EOP) observing sites. Differences were formed between determinations of UT1 by two different observing techniques -- between the Connected Element Radio Interferometer (CERI, at Green Bank, West Virginia) and the USNO PZT at Washington; between VLBI Goldstone-Orroral and VLBI Goldstone-Madrid; between the International Latitude Station (ILS) at Mizusawa and the USNO PZT at Washington. The Mizusawa - Washington UT1 differences appear to correlate with mean sea level at Truk Island. An apparent displacement of Orroral westward appears to coincide with the 1982-1983 El Nino. Absolute gravity measurements made at the Esashi Earth Tides Station have been compared to Mizusawa UT1 residuals.

L. Morrison summarized the astronomical observations of secular non-tidal variations. For the period from 700 BCE to 500 CE, about 40 Babylonian records of the time of lunar eclipses are available, and about 12 Chinese observations of total or near solar eclipses, of which 6 are valuable, plus one Babylonian record. For the period from 500 to 1600 CE, a number of untimed solar eclipses are available, and about 30 timed solar and lunar eclipses. From 1620 CE forward, records of 37000 lunar occultations are available, plus eclipse data. When all the data are assembled, no one parobolic curve can be fitted to all the data, as one might expect if the variation in UT were entirely from lunar tidal deceleration of Earth rotation. A two acceleration model has been used, with values of 2.4 msec/day/century prior to 1000 CE, and 1.4 msec/day/century thereafter.

27 November

SCIENTIFIC PRESENTATIONS:

S. Leschiutta made a brief introduction to the subject of time transfer and synchronization, reviewing the history of increases in accuracy which followed the introduction of each new method: HF, VLF, LORAN-C, and space techniques.

S. Starker's abstract was read in absentia by D. McCarthy. An experiment was performed on NASA Space Shuttle mission D-1, in which a cesium and rubidium clock on the shuttle were compared to several cesium techniques. After a few initial difficulties, 74 hours of useful data were obtained. The predicted Einstein relativistic effect agreed with the data to better than 1%.

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W. Klepczynski surveyed the latest developments in timekeeping at the US Naval Observatory. It was noted that the accuracy of timekeeping has, on the average, improved by a factor of 10 every 10 years, until it has attained 1 nanosecond. Beginning in 1983, the USNO introduced H-masers into its master clock system. Two active Smithsonian Astrophysical Observatory (SAO) VLG 11B active masers are used at the USNO at present. One maser is employed as master, the other as slave; and the two can be switched. Frequency residuals between the two masers for one day averaging times are typically 0.5 parts in 10 to the 15th. The output from the two masers is fed into a microstepper, and the microstepper output is adjusted to track USNO UTC. At present, the draft of the master maser with respect to UTC(USNO) is about 2 parts in 10 to the 15th. Over a four week period, the master hydrogen maser showed a drift of about 1 nanosecond relative to UTC. An experiment using GPS single channel receivers (STI 502) between USNO and TAO provided good statistics on the accuracy of the common view technique. The r.m.s. residual for two hours of observation, 6 second data points, was 22 nanoseconds.

H. Fliegel reviewed the current status of the Global Positioning System (GPS) satellite constellation. Navstars 3,4,6,8,9,10, and 11 are currently operational. The ground tracks of Navstars 4,8, and 9 are more closely spaced than they will be in the final GPS configuration, in order to provide good coverage over the test facility at Yuma, Arizona; therefore they are also well placed for experiments over India, central Asia, and Japan. There are currently no US restrictions on export of GPS receivers designed for Clear Access (C/A) use. Satellite ephemerides are to be made generally available by the US National Geodetic Survey (NGS). H. Fliegel has agreed to act as coordinator for non-US users who need information or contacts using GPS.

R. Kaarls' contribution was presented in absentia by S. Leschiutta. A number of experiments were made by five European laboratories between 1980 and 1983 using direct TV satellites. The precision was about 10 nanoseconds after a few seconds operation; after the fact, biases of about 200 nanoseconds were measured between this TV method and GPS.

S. Leschiutta presented the results of several time transfer experiments between Italy and China using the Italian SIRIO-1 satellite. Using 3-meter antennas and MITREX equipment, two way ranging employing pseudo-random code and a spread spectrum technique, 200 picosecond resolution was obtained; and the uncertainty was estimated to be about 150 nanoseconds.

H. Fliegel reminded all users of LORAN-C that the US Coast Guard is scheduled to phase out all its non-US chains in favor of GPS by 1992, unless special arrangements are made to transfer operations to other, interested nations. S. Leschiutta commented that new LORAN-C chains have recently been put into operation in Scandinavia and in Saudi Arabia; the LORAN-C technique will no doubt continue to be used in Europe and in Asia.

Jean Gaignebet reported that the LASSO package has been integrated into another metrology satellite, but will probably not be launched before early 1987, and will not be visible from the US. However, San Fernando in Spain, Grasse in France, and Wettzell in Germany are prepared to transfer time using LASSO.

There was a joint meeting with Commission 19 and 31 described in the report of Commission 19.

RESOLUTION C1 : Astronomical Constants
COMMISSIONS 4, 7, 8, 19, & 31

RECOGNIZING the importance of ensuring that the IAU system of astronomical constants is rigorously defined and is well suited to current applications,
INVITES the President of IAU Commission 4,7,8,19, and 31 to form a working group to serve in collaboration with the appropriate special study group of the International Association of Geodesy which will

1. review current determinations of astronomical and geodetic constants,
2. provide for informational purposes the current best estimates of the values, accuracies and sources of these constants,
3. propose appropriate changes in the relevant definitions and values of the constants of the IAU system.
4. urge all authors to specify completely the values and accuracies, as well as the sources, of the constants used in their work, and
5. submit a preliminary report in 1987.

RESOLUTION C2: Reference Systems
COMMISSION 4, 7, 8, 19, 20, 24, 31, 33, & 40

RECOGNIZING

1. the existence of inconsistent reference systems based upon different theories and modes of observations,
2. the significant improvement in the accuracy of observations using new techniques, and
3. the importance of a space-fixed reference system, independent of the mode of observation, for use in astronomy and geodesy and satisfying the requirements of relativistic theories,

INVITES the Presidents of interested IAU Commissions (for example, 4, 7, 8, 19, 20, 24, 31, 33 and 40) to form an IAU Working Group, with appropriate sub-groups devoted to specialized topics, under the overall chairmanship of the Chairman of the Joint Discussion on Reference Frames, which will report to the XXth General Assembly in 1988 with recommendations for

1. the definition of the Conventional Terrestrial and Conventional Celestial Reference Systems,
2. ways of specifying practical realizations of these systems,
3. methods of determining the relationships between these realizations, and
4. a revision of the definitions of dynamical and atomic time to ensure their consistency with appropriate relativistic theories, and

INVITES the President of the International Association of Geodesy to appoint a representative to the Working Group for appropriate coordination on matters relevant to Geodesy.

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THE INTERNATIONAL ASTRONOMICAL UNION

RECOGNIZING the highly significant improvements in the determination of the orientation of the Earth in space as a consequence of the MERIT/COTES* programmes of observation and analysis, and

RECOGNIZING the importance for scientific research and operational purposes of regular Earth-orientation monitoring and of the establishment and maintenance of a new Conventional Terrestrial Reference Frame,

THANKS all the organizations and individuals who have contributed to the developments and implementation of the MERIT and COTES programmes and the the operations of the International Polar Motion Service and the Bureau International de l' Heure, and

ENDORSES the final report and recommendations of the MERIT and COTES Joint Working Groups, and

DECIDES

1. to establish in consultation with IUGG a new International Earth Rotation Service within the Federation of Astronomical and Geophysical Services (FAGS) for monitoring Earth-rotation and for the maintenance of the Conventional Terrestrial Reference System; the new service is to replace both the IPMS and the BIH as from 1988 January 1;
2. to extend the MERIT/COTES programmes of observation, analysis, intercomparison and distribution of results until the new service is in operation;
3. to recommend that an optical astrometric network be maintained for the rapid determination of UT1 for so long as this is recognized to be useful;
4. to set up a Provisional Directing Board to submit recommendations on the terms of reference, structure and composition of the new service, and to serve as the steering committee for the extended MERIT/COTES programmes; and

INVITES National Committees for Astronomy and for Geodesy and Geophysics to submit proposals for the hosting of individual components of the new service by national organizations and observatories; and

URGES the participants in Project MERIT to continue to determine high-precision data on Earth rotation and reference systems and to make the results available to the BIH until the new service is in operation.

***MERIT** = A programme of international collaboration to monitor Earth-rotation and intercompare the techniques of observation and analysis.

***COTES** = A programme of international collaboration to establish and maintain a new conventional terrestrial reference system.

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