

## 4. COMMISSION DES EPHEMERIDES

### Report of Meeting, 16 August 1961

PRESIDENT: W. Fricke

SECRETARY: R. L. Duncombe

The meeting opened with an introductory report by the President. The Commission was informed of the following three items:

1. The "Consultative Committee for the Definition of the Second" met at the Bureau International des Poids et Mesures in Paris on 11 and 12 April 1961. Among the recommendations adopted by this Committee is the following of special interest to Commission 4:

"Le Comité Consultatif pour la Définition de la Seconde, considérant que la précision avec laquelle peut être déterminée la seconde des Ephémérides est inférieure à la précision que permettrait l'emploi d'étalons atomiques, recommande aux Laboratoires de pousser leurs recherches sur les étalons atomiques de fréquence assez activement pour qu'une nouvelle définition de l'unité de temps puisse être soumise à la Douzième Conférence Générale des Poids et Mesures."

The astronomers who are members of the "Consultative Committee" supported the recommendation. Therefore, there seems to be little doubt that a new definition of the unit of time will be introduced at the twelfth General Conference of Weights and Measures. No discussion is proposed on this item.

2. It has been noted with special satisfaction that in the *Japanese Ephemeris* for 1962 the ephemerides of the Sun, Moon and planets have been reproduced from the advanced proofs of the *Astronomical Ephemeris* which were provided by H.M. Nautical Almanac Office. This procedure is much welcomed by the Commission, since it is in complete conformity with its recommendation that multiple and independent calculation of basic astronomical data for the Ephemerides be avoided as far as possible.
3. G. M. Clemence is at present forming a new theory of the motion of the Earth. In view of the known deficiencies in the present theory the President proposes that Clemence's new theory be adopted as the basis of the published ephemerides as soon as possible after its completion.

A progress report on the formation of the new general theory of the motion of the Earth was given by G. M. Clemence. He stated that the first-order theory is now complete and that it is hoped to have the higher-order portion finished within a year. In view of this report recommendation no. 1 (given below) was unanimously adopted by the Commission.

In accordance with the newly adopted By-laws, the membership of Commission 4 has been enlarged. The nominations of W. Fricke for President, and G. M. Clemence for Vice-president, were submitted by the Executive Committee for the information of the Commission. On the recommendation of the Executive Committee, the Commission approved the following members of the Organizing Committee; Danjon, Fernandez de la Puente, Kovalevsky, D. K. Kulikov and Sadler.

On the determination of  $\Delta T$ , the difference between Universal Time and Ephemeris Time, Sadler commented as follows:

"There is now available a system of atomic time, denoted in principle by the abbreviation A.T., which is an essentially continuous measure of time based on an adopted value for the

frequency of the caesium oscillator. There are in fact two independent systems, denoted by A.T. and T.A.T., which are in good agreement. This measure of time, A.T., is linearly connected with Ephemeris Time, E.T., within the limitations of the possible physical difference between the nature of the astronomical and atomic time scales; over a period of several years the linear relationship is certainly adequate to within a few parts in  $10^{10}$ .

'The transmissions of A.T. directly provide the physicist with measures of frequency and of time-interval. By comparison with Universal Time (U.T.), observed by transits of stars to within a few milli-seconds, it also provides the geophysicist with a clear picture of the irregularities in the rotation of the Earth. E.T. is no longer a requirement for these purposes.

'Moreover, the constants in the linear relationship between E.T. and A.T. are to be determined from the observed values of E.T.; the precision of their determination increases with the number of observations of E.T. and with the length of the interval over which comparisons with A.T. are valid. At any one time, E.T. can now be derived from A.T. with a far higher precision than that with which it can be directly observed.

'If the difference between Universal Time (U.T.) and Atomic Time (A.T.) is denoted by  $\Delta A$ , in the sense  $A.T. = U.T. + \Delta A$ , then the difference  $\Delta T - \Delta A$  is a slowly-varying linear function of time; and  $\Delta T$  may be obtained from the observed values of  $\Delta A$  with far higher precision than it can be determined by a single night's observation of the Moon. Values of  $\Delta T$  so derived will almost certainly be adequate for the reduction of astronomical observations, for the calculation of local circumstances of eclipses, and for similar requirements; they will also form a surer basis for the extrapolation, over a few years, of the value of  $\Delta T$  used in the preparation of navigational ephemerides.

'There would thus appear to be no longer a requirement for the urgent availability of observed values of  $\Delta T$ . Moreover, if the only use for Ephemeris Time is astronomical, the precision required in its determination should be related to the precision with which it can be used. It is true that the highest precision is desirable to reduce the length of time required to determine whether there is a significant difference between the astronomical and atomic time scales; but other factors may impose a lower limit on this.

'The above considerations are relevant to the precise method of defining  $\Delta T$ , and the possible centralization of responsibility for issuing authoritative values of  $\Delta T$ . It is now clear that each individual investigator should be free to derive his own values from the observations; the important factors are that the methods of derivation and application should be consistent, and that the basis should be precisely stated.

'Ephemeris Time is the time-argument of the ephemerides of the Sun, Moon and planets, so that a precise knowledge of E.T. is in principle necessary for some space research; but other sources of uncertainty (for instance, the value of the astronomical unit) are likely to be more important.

'In this connection it must be emphasized that the time-argument of the ephemerides of artificial satellites, and thus the time-system which their motions define, cannot be precisely Ephemeris Time. The connection with E.T. can be directly determined only by observations of both the Sun and satellite over a long period of time. E.T. can be indirectly determined by observations of both the Moon and satellite over a shorter period of time; but the precision is then absolutely limited by the uncertainty in the connection between the motions of the Moon and the Sun. However, it is the comparison with the system of Atomic Time, and not with Ephemeris Time, that is of both practical and theoretical importance.'

Danjon commented that in order to derive Ephemeris Time it is necessary to determine the longitude of the Moon. For this purpose he advocated the formation of a central bureau, charged with the duty of determining Ephemeris Time.

Clemence pointed out that the only long-term determination of E.T. so far had been made by Brouwer, and since there is no generally accepted method for dealing with this problem, it seems inadvisable to have such a bureau. It was agreed that this was a problem for consideration by Commissions 17 and 31 also.

Aoki proposed a change in notation to distinguish the  $\Delta T$  and E.T., determined in practice by observations of the Moon, from the true  $\Delta T$  and E.T. defined by the motion of the Sun. Mikhailov pointed out that any such change should be submitted for the consideration of Commissions 17 and 31. A committee, on behalf of Commission 4, drew up recommendation no. 2 (given below) which was submitted to, and approved by, Commissions 17 and 31.

Fricke made a statement on the introduction of FK 4 into *Apparent Places of Fundamental Stars* (APFS). As announced in the Report of the Commission the 'Fourth Fundamental Catalogue' (FK 4) has been completed at Heidelberg. While the printing and publication of the catalogue will still take some time, the Astronomisches Rechen-Institut is already prepared to deliver on request positions and proper motions of FK 4 stars for 1950-0, on punched cards, to the ephemeris offices and to other users who urgently need the catalogue.

The first volume of APFS to contain printed values based on FK 4 will be that for 1964. The Astronomisches Rechen-Institut will publish the differences 'FK 4 - FK 3' for the year 1962, before the end of 1961. The differences can then directly be added to the apparent places in the volume APFS for the year 1962 to give apparent places on the system of FK4. The determination of Universal Time will therefore be based on the system of FK 4, commencing with 1962 January 1 (according to Resolution no. 59 of the tenth General Assembly).

In view of this report recommendation no. 3 (given below) was unanimously adopted by the Commission.

Danjon pointed out that the change from FK 3 to FK 4 introduces a discontinuity in the determination of Universal Time, and that since it is generally agreed that there is already available a much better value of the aberration constant ( $20''.51$ ) it is regrettable that it is too late now to introduce both changes at the same time. To emphasize the importance of this correction, he pointed out that the present aberration constant introduces an error of a few milliseconds in Universal Time as determined at Paris. He further stated that a new conference on astronomical constants to be held in 1963 would consider the adoption of the new value of the aberration constant.

In regard to the exchange of astronomical data in machine-readable form, Fricke pointed out that Commission 7 had appointed a committee to recommend exchange procedures. The chairman of this committee, W. J. Eckert, made the following statement.

'The committee would appreciate any guidance from Commission 4. The committee has concluded three alternatives:

1. Try to establish a central agency for the exchange of records.
2. Collect and publish information concerning the availability of records.
3. Treat machine-readable records the same as any other research facility and assume that exchanges will be arranged by individuals on their own initiative as at present.

The latter point of view is strengthened by the fact that in January the General Secretary of the Union circularized all Members with a request that anyone interested in making records available communicate with the Committee. No replies have yet come to the Chairman.'

It was proposed that any helpful suggestions by the members of the Commission be made directly to Eckert.

In regard to the compilation of a list of fundamental constants, it was pointed out that an historical list will be available in the *Explanatory Supplement to the Astronomical Ephemeris and to the American Ephemeris and Nautical Almanac*, and Fricke proposed that a modern list be compiled by the national ephemeris offices themselves.

Commission 4 unanimously approved the following proposed changes in the *Connaissance des Temps*, submitted by Kovalevsky.

Beginning with the volume for 1963; (a) the apparent places of stars that are currently published will be discontinued, and (b) the mean places, for the beginning of the tropical year, of all the stars in the Preliminary Supplement to the FK 4 will be included.

The *Draft Report*, as amended in the President's report, was approved unanimously.

#### RECOMMENDATIONS

1. It is recommended that, upon completion, Clemence's new theory of the motion of the Earth be adopted as the basis for the published national ephemerides.

Il est recommandé que, lorsque la nouvelle théorie du mouvement de la Terre par Clemence sera terminée, celle-ci soit adoptée comme base pour les publications des éphémérides nationales.

2. The provisional value of ephemeris time that is obtained by comparing the Moon's mean longitude, given by observations, referred to the equinox of FK 4, with the positions tabulated in the *Improved Lunar Ephemeris* be denoted by E.T. 0. The difference E.T. 0 - U.T. 2 is denoted by  $\Delta T_0$ .

La valeur provisoire du temps des éphémérides, obtenue en comparant la longitude moyenne de la Lune résultant d'observations rapportées à l'équinoxe du FK 4, avec les positions données par l'*Improved Lunar Ephemeris* est appelée T.E. 0. La différence T.E. 0 - T.U. 2 est appelée  $\Delta T_0$ .

3. It is recommended that mean and apparent places of fundamental stars published in national ephemerides shall be based on FK 4 as soon as this is technically possible.

Il est recommandé que les positions moyennes et apparentes des étoiles fondamentales qui sont publiées dans les éphémérides nationales, soient basées sur le FK 4 aussitôt que ce sera faisable.