4. COMMISSION DES EPHEMERIDES

PRÉSIDENT: D. H. Sadler.

MEMBRES: MM. R. Carrasco, Clemence, Cot, Eckert, Fayet, Fernandez de la Puente, Fricke, Gigizkij†, Gondolatsch, Hagihara, Kahrstedt, Kohl†, Kopff, D. K. Kulikov, Lahiri, Mme McBain-Sadler, MM. Planelles, Porter, Woolard, Zhongolovich.

SURVEY OF PROGRESS

Introduction

Most of the work of preparing Ephemerides is concentrated in the ephemeris offices, and will be found described in the reports from the Directors of the national ephemerides which are included as an Appendix to this report. No attempt is made either to give a complete bibliography of published papers or to describe theoretical work in detail. Emphasis is placed primarily on those matters affecting international co-operation or directly concerning the work of the Commission. The very comprehensive recommendations made at the General Assemblies of 1952 and 1955 are only now being carried into effect for the year 1960; since in the field of ephemerides frequent changes are undesirable, future changes will be based on long-term investigations which cannot yet have made substantial progress.

The national ephemerides

The *Astronomisch-Geodätisches Jahrbuch*, introduced for the year 1949, ceased publication after the edition for 1957. The *Berliner Astronomisches Jahrbuch*, introduced for the year 1776, will cease publication after the edition for 1959; while it is sad that such a long-established ephemeris should come to an end, its cessation must be regarded as an indication of increased international co-operation. By virtue of the saving of the costs of compilation and printing, the Astronomisches Rechen-Institut in Heidelberg has been able to take over the compilation and publication of the international volume *Apparent Places of Fundamental Stars*. Astronomers in Germany will use the unified British and American ephemeris, probably being provided with a German translation of the Introduction.

Other countries continue to publish essentially the same data (there are minor variations in content and in a few cases of authority also), within the framework of their own language and traditional format. There has recently been a new addition to the national ephemerides: *The Indian Ephemeris and Nautical Almanac*, prepared under the direction of N. C. Lahiri by the Nautical Almanac Section of the Regional Meteorological Centre, Alipore, Calcutta, and published for the first time for the year 1958. Although published in English, and therefore to a large extent duplicating the American and British publications, it serves a special purpose in relation to the complex Indian calendar.

Copy, in the form of reproducible material, for the unified American and British publication for 1960, is now complete; it will be reproduced by photo-lithography separately in each country. This material can be made available to other ephemeris offices at a small charge to cover the cost of preparation.

The title of the British national ephemeris will be changed to *The Astronomical Ephemeris* as from the first edition for 1960 of the unified ephemeris; the title of the American edition will remain unchanged as *The American Ephemeris* (and Nautical Almanac).

The bases of the ephemerides

It was agreed (Recommendation no. 5 of Commission 4 at the General Assembly at Rome in 1952) to base the ephemeris of Mars on the new general theory of the motion of Mars then being prepared by Clemence. Publication of this theory has been delayed (see report from G. M. Clemence in the Appendix) and consequently the ephemeris of Mars is currently being calculated from Newcomb's Tables, as amended by Ross's corrections, in continuation of the procedure up to 1959. The ephemeris of Mars in the first part of *The Astronomical Ephemeris* will, however, be based on the new theory as soon as practicable.

Numerical integration of the equations of motion of the Earth has indicated even more serious errors in Newcomb's tables of the Sun than were suspected. A new general theory, carried to a higher order and supported by modern computing techniques and facilities, is fast becoming a necessity.

From 1960 onwards the ephemerides of the four principal minor planets, Ceres, Pallas, Juno and Vesta are based on unpublished equatorial rectangular co-ordinates for equinox 1950·0 computed by numerical integration of the equations of motion by Dr Paul Herget.

As will be seen from the report from the Astronomisches Rechen-Institut in Heidelberg, the preparation of the revised fundamental catalogue FK 4 is well advanced; it will, however, be impracticable to base the apparent places for 1960 on FK 4; these will continue to be based on FK 3.

In other respects the ephemerides for 1960 and subsequent years are based precisely on the authorities and tables recommended by Commission 4 in 1952, with the minor amendments agreed in 1955.

Ephemeris time and the lunar ephemeris

The second of ephemeris time has been formally adopted as the fundamental unit of time by the Comité International des Poids et Mesures in the following terms (Resolution no. 1 of the session of 6 October 1956), *Procès-Verbaux des Séances*, Deuxième Série, tome XXV, p. 77, 1957:

En vertu des pouvoirs que lui a conférés la Dixième Conférence Générale des Poids et Mesures par sa Résolution No. 5, Le Comité International des Poids et Mesures, considérant

(i) que la Neuvième Assemblée Générale de l'Union Astronomique Internationale (Dublin, 1955) a émis un avis favorable au rattachement de la seconde à l'année tropique;

(ii) que, selon les décisions de la Huitième Assemblée Générale de l'Union Astronomique Internationale (Rome, 1952), la seconde de temps des éphémérides (T.E.) est la fraction:

$$\frac{12\,960\,276\,813}{408\,986\,496}\,10^{-9},$$

de l'année tropique pour 1900 janvier 0 à 12^{h} T.E.

Décide: La seconde est la fraction

$$1/31\,556\,925{\cdot}974\,7,$$

de l'année tropique pour 1900 janvier 0 à 12^{h} de Temps des Ephémérides.

In Resolution no. 2 of the same meeting it was decided to set up a 'Comité Consultatif pour la Définition de la Seconde' whose function will be to advise the main Comité on future decisions concerning improvements in the standard of time. At a meeting of this Comité in June 1957, a sub-committee discussed the precision of the lunar ephemeris in relation to the determination of Ephemeris Time. The report of this sub-committee was adopted by the Comité in the following terms (English version):

The sub-committee considered the precision of the ephemeris of the Moon in relation to the practical determination of Ephemeris Time. It is estimated, with some uncertainty, that the present ephemeris is capable of giving an accuracy of 1 part in 10^{10} in the determination of the second of Ephemeris Time in five years, but not for either much shorter or much longer intervals. The sub-committee noted that the planetary terms in Brown's theory of the motion of the Moon had not been rigorously checked; and also that a complete revision of the theory would be a major undertaking. It concluded that a higher precision, over a longer interval, is desirable for comparison with physical determinations of frequency and suggests that the attention of Commission 4 of the International Astronomical Union be drawn to this conclusion, and the discussion on which it was based.

Commission 4 must undoubtedly take note of this conclusion, but it cannot usefully do more than express a hope that the improvement will eventually be undertaken, particularly in regard to the verification of the planetary terms in Brown's theory.

It is desirable that the annual mean values of ΔT, the correction to be applied to Universal Time to give Ephemeris Time, should be internationally agreed. At present definitive values of ΔT are obtained from discussions of the apparent motion of the Moon as derived from meridian observations, from lunar occultations and from the Moon-camera observations; and they must necessarily be several years in arrear. The U.S. Naval Observatory has undertaken the discussion of these observations, and the promulgation of definitive, provisional and extrapolated values of ΔT. The precise procedure, and time-table, for the circulation of these values to the offices of the national ephemerides could well be discussed at the meeting of the Commission in Moscow.

'Apparent Places of Fundamental Stars'

Preparations are well advanced at the Astronomisches Rechen-Institut in Heidelberg for the compilation, printing and early publication of the international volume of *Apparent Places of Fundamental Stars* (APFS) for 1960. Consideration has been given to the suggestion that the right ascensions of all 10-day stars with declinations less than 81° should be given to $0^{s}.001$, if necessary allowing errors of $0^{s}.002$ or $0^{s}.003$ for the extreme cases; and members of the Commission have given their approval by correspondence.

New satellites of the Earth

The recent acquisition by the Earth of man-made satellites raises the question of the responsibility of the Commission for the provision of suitable ephemerides. For satellites which at perigee are inside the Earth's atmosphere, and which are therefore subject to atmospheric drag and of relatively short life, the primary interest in their motions lies in the information they provide concerning the density of the Earth's atmosphere, and such investigations do not fall directly within the province of the Commission. Apart from the unpredictable perturbations introduced by atmospheric drag, the time-scale will generally be too short for ephemerides of high accuracy, necessarily based on analysis of observations, to be included in the national ephemerides.

However, a satellite with a sufficiently large perigee distance, and therefore of expected long life, will be of immense interest to fundamental astronomy; the Commission should undoubtedly recognize that this is a definite possibility and should be prepared to make recommendations as to how both approximate and precise ephemerides can be made available to astronomers. First of all the Commission should consider in very general terms the characteristics (for instance, the perigee distance, eccentricity, estimated life, visual magnitude, possibility of precise radio observations of position, etc.) of a satellite that would qualify it for inclusion in the province of the national ephemerides. It has already been suggested that it would be appropriate for the ephemeris office of the launching country to be responsible for the provision of ephemerides, and for their transmission on an agreed basis to the other ephemeris offices. For any particular satellite a precise ephemeris can only be prepared if the satellite's life is, at least, several years, and then only after a considerable period of observation; there will be ample time for detailed arrangements.

Although not of the same direct interest to fundamental astronomy, approximate ephemerides are required for both short-lived and long-lived satellites, to facilitate observation; these are required quickly and involve difficult problems of communication and publication. There exist special facilities for this during the period of the International Geophysical Year; but it is at least possible that the ephemeris offices could, with their specialized organizations, assist in translating orbital, or general ephemeris, data into the form of local predictions for the countries or areas that they serve. Any such arrangements, which would be of an informal nature between the ephemeris offices themselves, would have to be co-ordinated with other organizations making similar calculations and predictions.

Duplication of astronomical calculations

The rearrangement of the distribution of astronomical calculations between the ephemeris offices, as agreed at the last meeting (1955) of the Commission, has already started. As there proved to be no demand for apparent places of additional circumpolar stars, it has become unnecessary for the Instituto y Observatorio de Marina (San Fernando) to make calculations for the additional sixty-seven stars proposed.

A survey of the astronomical data, and the authorities on which they are based, in all published national ephemerides, 'annuaires', and almanacs reveals that there is still a considerable amount of independent calculation of basic data. It will, for instance, be noted that the calculations for the Japanese Ephemerides and Almanacs are almost entirely independent; otherwise the largest duplication arises in the case of apparent places of stars. These independent calculations lead inevitably to end-figure discrepancies. The Commission might take this opportunity of reminding the compilers of such almanacs that the basic data are generally available if required. The Astronomisches Rechen-Institut is proposing to advance the date of publication of *Apparent Places of Fundamental Stars*, so that apparent places of most stars will be more readily available for this purpose in future.

Navigational almanacs

The interest of the Commission in navigational almanacs lies primarily in ensuring that the basic astronomical data are available to the compilers in all countries, and this is largely achieved by the circulation of advanced proofs of the fundamental ephemerides in the first part of *The Astronomical Ephemeris*. But the almost universal use of the same principles of tabulation, with a large measure of similarity of presentation and, in a few cases, of identical material, cannot but be a source of satisfaction; it is clearly desirable that the practical navigational application of astronomy should be as efficient, and as universal, as possible.

The American and British almanacs for surface navigation have been completely unified as from the editions for 1958; they are printed from identical reproducible material but published separately in the two countries. As from 1960 they will have the common title of *The Nautical Almanac*. The arrangement is exactly parallel to that for *The Air Almanac*, which was introduced for the edition for 1953. No change has been made in the principles of tabulation, which now appear to be firmly established. Reproducible material is supplied to both Norway and Brazil as a basis for their navigational almanacs; and it can be supplied to other countries if desired.

As announced in the last Report, the French *Ephémérides Nautiques* has been revised as from the edition for 1958 to a form which is closely similar in principle to the American and British almanacs; and the French *Ephémérides Aéronautiques* has from 1955 been largely reproduced by photolithography from *The Air Almanac*.

Otherwise few changes in content or presentation have been made in almanacs designed for surface and air navigation.

The navigational applications of man-made satellites of the Earth are not being overlooked, though it may be many years before suitable objects are available.

MATTERS FOR DISCUSSION IN MOSCOW

The following matters and proposals need to be discussed at meetings of Commission 4, either alone or with other Commissions:

1. The conclusion of the Comité International des Poids et Mesures relating to the precision of the lunar ephemeris.

2. The procedures and time-table for the determination of internationally agreed values of ΔT, the correction to be applied to U.T. to give E.T., and for circulation of extrapolated, provisional and definitive values.

3. Report on the precision to which the right ascensions of stars will be given in APFS.

4. Report on the progress of FK4 and its planned introduction into APFS.
5. Report from G. M. Clemence on his discussions with Dr Atkinson regarding the value to be adopted for the semi-diameter of the Moon.
6. The arrangements to be made for the calculation and publication of ephemerides of those man-made satellites of the Earth considered to be of sufficient interest to fundamental astronomy.
7. The duplication of astronomical calculations.

D. H. SADLER
President of the Commission

APPENDIX

REPORTS OF THE DIRECTORS OF THE NATIONAL EPHEMERIDES

Instituto y Observatorio de Marina, San Fernando (Cádiz), Spain

The contribution to *Apparent Places of Fundamental Stars* of the apparent places of 396 10-day stars has been continued up to and including 1959. The *Almanaque Náutico, Almanaque Náutico para uso de los Navegantes* and *Almanaque Aeronáutico* have been published regularly, with only minor modifications.

F. FERNANDEZ DE LA PUENTE

Nautical Almanac Office, U.S. Naval Observatory, Washington, D.C., U.S.A.

The *American Ephemeris*, the *American Nautical Almanac*, and the unified *Air Almanac* have been published regularly without substantial change, the *American Nautical Almanac* being unified with the corresponding British publication as from 1958.

The apparent places of 162 10-day stars have been supplied annually for the volume *Apparent Places of Fundamental Stars* to the end of 1959. As from 1960, in accordance with decisions taken at the General Assembly of 1955, this Office will no longer supply these apparent places, having undertaken instead to calculate the ephemerides of the satellites of Saturn.

For the state of the work on long-range predictions of solar eclipses, see the report of Commission 13.

The work on the motions of the principal planets undertaken in 1947 jointly by the Yale University Observatory, The Watson Scientific Computing Laboratory, and this Office, has continued with the support of the Office of Naval Research. Since the preceding report, *Astr. Pap., Wash.*, vol. **15**, part III has appeared, containing precise co-ordinates of Venus at 4-day intervals from 1800 to 2000, by Paul Herget.

Publication of the new general theory of the motion of Mars has been delayed, pending the explanation of some discrepancies between it and the results of a numerical step-by-step integration of the equations of motion. These discrepancies, amounting to $0\rlap{.}''05$ in the orbital longitude, are hardly of practical importance, but considerably exceed the limit of error aimed at in the general theory.

A numerical integration of the equations of motion of the Earth by Paul Herget from 1920 to 2000, when compared with the tables of the Sun of Newcomb and Leverrier, indicates errors in the tables of several sorts. In the tables of the longitude of the Sun there are errors of a quasi-periodic character, approaching $0\rlap{.}''15$, and the tabular secular change of the obliquity of the ecliptic is in error by about one per cent of its amount. These errors are presumably the result of Newcomb's and Leverrier's abridged treatment of the perturbations of the second order. Leverrier's tables of the latitude of the Sun are shown to be more accurate than Newcomb's, although both contain sensible errors.

Duncombe has finished his comprehensive discussion of all existing meridian observations of Venus, with the principal result that the motion of the node, long supposed to disagree with gravitational theory, is shown to agree with it. The discussion will be published in *Astr. Pap., Wash.*

The *Improved Lunar Ephemeris* 1952–1959, a joint supplement to the *American Ephemeris* and the (British) *Nautical Almanac*, contains in addition to its titular content, the nutation and aberration for the same years, a detailed article on the construction of the lunar ephemeris, by W. J. Eckert, Rebecca Jones, and H. K. Clark, an exhaustive comparison of the improved ephemeris with Brown's tables, by Edgar W. Woolard, an article on the subtabulation of the Moon's right ascension and declination, by A. E. Carter, and an article on the calculation of the nutation from the new series, by G. A. Wilkins.

G. M. CLEMENCE

Institute for Theoretical Astronomy, Leningrad, U.S.S.R.

L'Annuaire Astronomique de l'U.R.S.S. has been published annually; the volumes for the years 1958, 1959 and 1960 appeared in 1955, 1956 and 1957 respectively. The volume for 1960 was completely revised in accordance with the recommendations made at the eighth General Assembly in 1952. It was judged, however, that the predictions of eclipses in Ephemeris Time, i.e. without any extrapolated correction to pass to Universal Time, might also be of interest. The ephemerides of the Sun, Moon and Planets from 1960 are given in strict conformity with the first part of the *Astronomical Ephemeris* furnished in advance by the British Nautical Almanac Office.

The *Nautical Almanac* and the *Air Almanac* have been published regularly.

Other work has included:

The computation of the apparent places of 630 stars for the special time-service in accordance with the programme of the International Geophysical Year. The daily ephemerides, including the short-period terms of nutation, have been calculated for the periods in 1956, 1957, 1958 during which these stars transit the meridian when the Sun is below the horizon in the U.S.S.R.

The computation of tables giving the altitudes and azimuths of twenty-four stars in southern latitudes (mean equinox 1960·0).

The preparation of the star altitude curves for northern latitudes 80–90°.

The research on the group of astronomical constants connected with the Earth, mentioned in the preceding report, is in progress. Some results have been published [1, 2, 3].

Papers have been published on the application of the punched-card calculating machines to the computation of ephemerides [4, 5], and on the theory of eclipses [6, 7].

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M. F. SUBBOTIN

Astronomisches Rechen-Institut, Heidelberg, Germany

Fundamental catalogue

The first step in the revision of FK3, namely the derivation of individual corrections to positions and proper motions for all the fundamental stars, has been completed. The publication of the results was carried out in *Veröffentlichungen des Astronomischen Rechen-Instituts, Heidelberg*, no. 6 and no. 7. These publications contain the values $\Delta\alpha$ and $\Delta\delta$ for each year from 1956·5 until 1960·5. The corrections can be applied directly to the apparent places given in *Apparent Places of Fundamental Stars* (APFS). The derivation of the systematic corrections to the FK3, which will give the new FK4, is under way and expected to be completed soon. Observations, which are at present being preliminarily reduced with the individual corrections (FK3R), can be transformed to the new system of FK4 as soon as the systematic corrections are available.

Exchange of ephemerides

The exchange of ephemerides has been carried out for all data until the year 1959 (apparent places, ephemerides for circumpolar stars, data for the satellites of Saturn). As from 1960 the new system of distribution of data, which was agreed upon at Dublin, will be introduced.

On request of the Neuchâtel Observatory we have calculated apparent places for a list of PZT stars beginning with the year 1956. For the Paris Observatory apparent places have been calculated for the observation of stars with the prismatic Astrolabe.

Almanacs and APFS

The last issue of the *Astronomisch-Geodätisches Jahrbuch* is the volume for 1957. This almanac is being discontinued as well as the *Berliner Astronomisches Jahrbuch*, for which the volume for 1959 will be the last to be published. The decision to discontinue both almanacs was made to avoid duplication of work and printing.

The international volume APFS will be published by the Astronomisches Rechen-Institut as from 1960. In a conference at Heidelberg in December 1955 together with G. Fayet, Paris, and V. Planelles, San Fernando, it was agreed that the computations for the volume shall be carried out jointly by the offices at Paris, San Fernando and Heidelberg according to the following distribution scheme: all 10-day stars of FK3 at Heidelberg, all fifty-two circumpolar stars of FK3 at Paris, and those circumpolar stars which are in FK3 Supp. at San Fernando. Later an unexpected change of this distribution scheme had to be made, by cancelling the contribution of San Fernando. An inquiry circulated among a number of meridian observers resulted in the conclusion that no more than the fifty-two circumpolar stars already in FK3 are reasonably required for observation.

At present the calculation of apparent places for FK3 stars is being carried out at Heidelberg on an 'Electronic Calculating Punch' IBM type 626, and the copy for the volume APFS is being prepared on a new card-controlled typewriter (type 058) which was recently developed for this purpose by IBM-Germany.

W. FRICKE

Astronomisches Recheninstitut, Berlin, Germany

The calculations for the *Berliner Astronomisches Jahrbuch* have been done as usual up to the year 1959, mainly under the direction of O. Kohl, who died in April 1957. The edition for 1959 will be the last to be published. The Recheninstitut has now become a part of the Babelsberg Observatory.

A. KAHRSTEDT

Bureau des Longitudes, Paris, France

La date de publication de la *Connaissance des Temps* a pu être encore un peu avancée; le volume relatif à 1959 a paru en juin 1957.

Le volume pour 1960 présentera certaines modifications importantes: Adoption des formules de E. W. Woolard pour la nutation conformément aux décisions de l'U.A.I. (Rome, 1952); liste des parallaxes stellaires supérieures ou égales à $0\overset{''}{.}010$; table donnant l'angle horaire d'un astre à son lever ou à son coucher, permettant d'obtenir rapidement, pour le Soleil et les planètes, l'heure du lever et du coucher en un lieu donné.

Nous continuerons à publier le catalogue des positions moyennes pour les 1591 étoiles du FK3.

Les calculs concernant les positions apparentes des 52 circompolaires du FK3 seront, pour la première fois, en 1960 effectués en totalité par le Bureau des Longitudes.

La *Connaissance des Temps* publiera, comme par le passé, les données relatives aux quatre premiers satellites de Jupiter, mais, à partir de 1961, elle fournira, non seulement les quantités u_0, B, P, permettant de déterminer l'orbite de chaque satellite par rapport au système Jupiter-Terre, mais encore les quantités u_0', B', P' pour le système Jupiter-Soleil. D'autre part les configurations des satellites seront fournies sous forme de courbes indiquant l'élongation des satellites par rapport à Jupiter à un instant quelconque.

Depuis 1956, les *Ephémérides Nautiques* paraissent avec une présentation entièrement nouvelle. La partie essentielle de l'ouvrage se compose de feuilles quotidiennes fournissant, d'heure en heure, le temps sidéral, les coordonnées horaires du Soleil, de la Lune et des quatre planètes principales, ainsi que les heures des levers et couchers du Soleil et de la Lune et aussi les heures de commencement et de fin du crépuscule civil.

Le volume contient également d'autres renseignements utiles aux navigateurs: Phases de la Lune, équation du temps, planètes observables, positions d'étoiles, tables de la Polaire, tables d'interpolation, de conversion, tables de navigation.

Depuis 1955, les données des *Ephémérides Aéronautiques* sont pratiquement les mêmes que celles de *Air Almanac* anglais et américain, avec titres et explications en français.

Cependant les noms des 77 étoiles, dont la liste et les coordonnées figurent à la seconde page de la couverture, ont été donnés par les Services du Ministère de l'Air français.

La table de la page XLIII fournit, depuis 1956, les corrections pour l'altitude aux heures des levers et couchers du Soleil jusqu'à l'altitude de 21 000 mètres, au lieu de 18 000 en 1955.

Les *Ephémérides Aéronautiques* publient toujours le nomogramme pour le calcul rapide des levers et couchers du Soleil et de la Lune, de l'aube et du crépuscule civils, en fonction de la latitude et de la déclinaison de l'astre.

G. FAYET

H.M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux, England

The routine work of the Office has been continued without interruption. The *Nautical Almanac*, the *Abridged Nautical Almanac*, the unified *Air Almanac*, the *Star Almanac* and the international volume of *Apparent Places of Fundamental Stars* have all been published without substantial change of content.

As from the edition for 1958, the *Abridged Nautical Almanac* has been unified with the *American Nautical Almanac*; following the pattern of the unified *Air Almanac*, the two editions have been published separately in the United Kingdom and in the United States of America but have been printed from identical reproducible material. Although rearranged, no changes have been introduced in the principles of tabulation.

The occultation programme has also been continued without modification, including predictions for the occultations of radio sources by the Moon.

The whole of the copy for the third volume of *Planetary Co-ordinates for the Equinox* 1950·0, covering the years 1960–80, is now complete and ready for photolithographic reproduction. There has been included a comprehensive collection of both rigorous and approximate methods for the calculation of special perturbations; collected formulae and an illustrative numerical example are given for each method.

The full, but little used, title of the *Nautical Almanac*, dating from its introduction for the year 1767, is *The Nautical Almanac and Astronomical Ephemeris*; as from the edition for 1960 it will be retitled *The Astronomical Ephemeris*. The almanac designed specially for surface navigation, at present titled *The Abridged Nautical Almanac*, will as from the edition for 1960 be retitled *The Nautical Almanac*. This is a long overdue recognition of the fact that the two purposes of the original almanac are now met by two quite distinct almanacs; both are direct continuations of the original and it is appropriate that each should bear the relevant part of the original title. The title of the *American Nautical*

Almanac will also be changed so that the unified almanacs for surface navigation will have the common title of *The Nautical Almanac*.

The Astronomical Ephemeris for 1960 will be completely unified with *The American Ephemeris*; the two almanacs will be printed from identical reproducible material, but will continue to be published separately in the two countries. An *Explanatory Supplement* is being prepared jointly with the U.S. Nautical Almanac Office; but this will be printed and published in the United Kingdom only.

Advance proofs of the first parts of the *Astronomical Ephemeris* for the years 1960 and 1961, redesigned in accordance with the Recommendations made at the eighth General Assembly in 1952, have been circulated to the offices of the national ephemerides and to other agencies concerned with the preparation of navigational and other almanacs.

D. H. SADLER

Tokyo Astronomical Observatory, Mitaka, near Tokyo, and Hydrographic Office, Tokyo, Japan

Five papers have been published in: *Tokyo Astr. Bull.*, second series, No. 76, 1955 and No. 91, 1957; and in *Tokyo Astr. Obs. Rep.*, vol. **11**, no. 2, 1955, no. 3, 1956 and no. 4, 1956. The first two relate to the reduction of occultation observations in Japan. The other three relate respectively to the amendment of Brown's lunar tables, to lunar eclipses and to the prediction of the transit of Mercury of 1957 May 5–6 by Bessel's method.

The following work has been done in the Japanese Hydrographic Office (Chief of Astronomical Section: Y. Tukamoto).

Compilation and publications: *Japanese Ephemeris* for the years 1957–59; *Nautical Almanac* for the years 1956–58; *Abridged Nautical Almanac* for the years 1956–58; *Astronomical Navigation Tables* (republication); *Abridged Astronomical Navigation Tables*, vol. **3** and vol. **5** (republication); *Altitude and Azimuth Almanac* (in Prince Harald) for the years 1956–58.

Ephemerides computations: Sun: Ecliptic, equatorial rectangular and equatorial co-ordinates and associated quantities for the years 1960–63. Moon: Ecliptic and equatorial co-ordinates and associated quantities for the years 1959–60. Planets: Heliocentric co-ordinates of Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune, geocentric ecliptic and equatorial co-ordinates of these planets, and associated quantities for the years 1958–61.

Besselian and independent day numbers for the years 1960–64. Stars: Apparent places of 790 10-day and ten circumpolar stars, and associated quantities for the years 1958–60.

Eclipses and occultations: Elements, circumstances, predictions and associated quantities for the years 1957–60.

Y. HAGIHARA

Report of the Joint Meeting of Commissions 4, 7, 17, 20 *and* 31. 16 August 1958

PRESIDENT: D. H. Sadler.

SECRETARY: W. Fricke.

The Programme was divided into two parts, namely on the use of A, the Moon, and B, artificial satellites of the Earth, in fundamental astronomy and in the determination of Ephemeris Time.

A. THE MOON

1. G. M. Clemence reported on the procedures and time-tables for the determination of internationally agreed values of ΔT, the correction to be applied to Universal Time to give Ephemeris Time, and for the circulation of extrapolated, provisional and definite values. Some of the national ephemerides, including the *American Ephemeris*, will publish values of ΔT, to three degrees of precision: $0^s.01$, $0^s.1$ and $1^s.0$. It is hoped that

these will meet the needs of most users, but the U.S. Naval Observatory is ready to supply to any observatory, on request, the best values known at the moment in advance of publication. No single observatory should be considered as the official authoritative source of ΔT; observatories should be free to work out and to publish their own values, and the service of the U.S. Naval Observatory is merely an accommodation to those astronomers who wish to make use of it.

2. W. Markowitz reported on the accuracy of observations of the Moon and the resulting precision of determination of Ephemeris Time. Three statements can be made, namely:

(*a*) The value of E.T. obtained from an observed position of the Moon with respect to the stars depends on the systems to which the Moon and stars are referred. It was decided to compute E.T. as follows: the position of the Moon as a function of E.T. is taken from the *Improved Lunar Ephemeris 1952–1959*, as tabulated therein; the positions of the stars are referred to the improved Newcomb equinox of N 30 and FK 4, which are considered equivalent.

(*b*) Taking into account observations made by all methods—that is, dual-rate camera, meridian transits, and occultations—and using the atomic clock as interpolating device, E.T. can be given with a probable error of $\pm 0^s\!.1$.

(*c*) As a result of the determination of the frequency of the caesium atomic standard made jointly by the National Physical Laboratory, Teddington, and the U.S. Naval Observatory, Washington, it is possible to provide the second of E.T. with an absolute probable error of ± 2 parts in 10^9. The caesium standard provides a higher relative precision, about ± 1 part in 10^{10}.

L. Essen commented that physicists require an accuracy of Ephemeris Time of 1 in 10^{10}; this accuracy can be given by atomic frequency standards, and these measurements can be related to Ephemeris Time.

3. W. J. Eckert reported on his recent work on the lunar theory. The purpose of this work is to obtain the harmonic series for the co-ordinates of the Moon by numerical methods and with higher precision than that of Brown. Numerical values of the parameters and mean motions of the perigee and node were substituted into Brown's expressions for the rectangular co-ordinates to obtain initial series which were then substituted into the differential equations of motion. The residuals for each term in the equations provide equations of condition for the determination of corrections to the adopted values of the coefficients and motions. The solution of the 'main problem' is being done in two approximations: the first with 10-figure precision on the IBM 650 and the second with higher precision on the IBM 704. The equations of condition for the first approximation are now being solved. This solution will be followed by work on the planetary perturbations. The work is described in the report on the 'Conference on Celestial Mechanics' held in New York in March 1958 (*Astr. J.* **63**, 415, 1958).

B. ARTIFICIAL SATELLITES

1. G. M. Clemence spoke on necessary conditions of orbit, lifetime and observability. He explained that it is absolutely necessary for the above-mentioned purposes that the effect of the Earth's atmosphere on the satellite be negligible for periods of about one year. The precise height required to meet this condition is not known, but probably a perigee height of 1000 km would be adequate. It is also desirable that the period be long enough and the satellite bright enough so that it can be observed with simple photographic techniques. Probably a nearly circular orbit at a distance of 6000–10,000 km would be good. His own estimate was that with such a satellite Ephemeris Time could be determined in 7 months with the same precision as is obtained by observing the Moon for 5 years. He added that, until the frequency of caesium is precisely known, this statement must be regarded as applying to a possible difference between the gravitational and atomic time scales, rather than to Ephemeris Time itself; and he thanked H. J. Abraham for drawing his attention to this fact.

Comments: W. Markowitz drew attention to the paragraph on 'Artificial Satellites' in the Report of Commission 31 (page 491) and remarked that the motion of an artificial satellite might also be affected by electrical forces which would have to be investigated.

2. D. Brouwer reported on the practicability of determining an orbit of adequate precision. A striking feature of the problem is its close similarity to the 'main problem' of the lunar theory, so that any method, which has proved to be effective in the lunar theory, may also be used for this problem. All the difficulties of the problem are caused by the fact that the mean argument of perigee, g, has a slow motion. The motion is negative for inclinations less than about 63°5 and positive for inclinations greater than this value, and in the vicinity of this critical inclination it may actually be zero. In this case the developments become illusory; a solution of perfect form, characteristic of that of the main problem of the lunar theory, cannot be obtained. From a practical point of view this objection may not be serious, since a useful solution for an adequate interval of time can probably be obtained by expansion in powers of time which will appear in the coefficients. The same objection applies to all the other methods that have been used in the lunar theory, with the exception of Delaunay's method. After Delaunay transformations the Hamiltonian is of the form

$$C_0+C_2\cos 2g+C_4\cos 4g+\ldots,$$

in which the coefficients C_0, C_2, $C_4\ldots$ depend only on the variables L, G, H. The system of equations is thus reduced to one of only one degree of freedom, and this may be solved completely without mathematical difficulties. Thus the Delaunay method, perhaps with some modification, offers the possibility of creating a perfect literal solution for the problem of the motion of an artificial satellite. Practical considerations require that the eccentricity of the orbit be reasonably small, in order to avoid having too numerous terms in the developments.

D. Brouwer has completed preliminary studies on the theory without introducing atmospheric resistance and other complications into the problem; these can be considered separately at a later stage. He will make a start on the project in the fall of this year. A detailed report on this subject was presented by him at the 'Conference on Celestial Mechanics' to appear in the *Astronomical Journal* (**63**, 433, 1958).

3. D. Brouwer also spoke on the precision required of observations of artificial satellites for use in fundamental astronomy. The motion of the node in the plane of the equator, relative to a fundamental star system, is of considerable interest; for this only the orientation of the orbit is required. The motion of the argument of the perigee is also of interest, but this is more dependent upon precisely timed observations. Also, for orbits with small eccentricities the position of the perigee is indeterminate. Both motions depend on the quantities designated by J and K in the expansion of the potential of the Earth. J and K cannot be well separated from observations of the motions of the node and perigee of a single satellite. The best result is obtained if different satellites at different distances from the centre of the Earth are observed. The longer the lifetime of a satellite, the more accurate the values that may be obtained for the motions of node and perigee, and for the derived values of J and K.

4. Sir Harold Jeffreys reported on the information obtainable from artificial satellites in respect of the higher harmonics or anomalies in the Earth's gravitational field. The Earth's gravitational potential at external points can be put in the form

$$U=\frac{fM}{a}\left\{\frac{a}{r}+J\frac{a^3}{r^3}\left(\tfrac{1}{3}-\sin^2\phi'\right)+D\frac{a^5}{r^5}\left(\sin^4\phi'-\tfrac{6}{7}\sin^2\phi'+\tfrac{3}{35}\right)\right\}$$
$$+\Sigma\Sigma A_{ns}S_{ns}/r^{n-1},$$

where ϕ' is the geocentric latitude. S_{ns} are spherical harmonics $P_n^s(\cos s\lambda,\ \sin s\lambda)$.

The most detailed information about the coefficients J and A_{ns} comes from measures of gravity, but in fact remains very incomplete. J is well known, but not so well as we should like. Four other harmonics with $n=2$ and $n=3$ are significantly determined, but might easily be wrong by half their amounts. A conventional value of D is used in geodesy; it is chosen so that the ocean surface would be part of an exact ellipsoid of revolution.

So far as artificial satellites are concerned J and D will contribute to the motions of the node and perigee and may give useful additional information. Terms with n odd and $s=0$ (especially P_3^0) will give a small disturbance of mean latitude. According to O'Keefe and Batchelor the effect of the term $P_2^2 \cos 2\lambda$ is of the order of $5''$ as seen from the Earth's centre. On the whole larger n and s will give shorter periods, so it seems that useful information will not be obtained from artificial satellites unless the position at known time can be measured to less than 150 m. If an extra term in P_4 is present in the figure it can be represented by a term $-a\kappa \sin^2 2\phi$ in the radius and by redefining a and the ellipticity. The contribution to D is $\frac{4}{3}\kappa$ and that to the coefficient of $\sin^2 2\phi$ in gravity is $3g_0\kappa$. According to Bullard the hydrostatic theory leads to $\kappa=68\times 10^{-8}$, and D would be increased from 0·0000107 to 0·0000116. King-Hele and Cornford, from discussions of the motion of the nodes of Sputnik II, would require either a reduction of J from 0·001637 ± 0·000004 (standard error) to 0·001626 or an increase of D to 45×10^{-6}. Either of these would be further evidence against the hydrostatic theory. The change in D would make the coefficient of $\sin^2 2\phi$ in gravity about 78 milligals, and this would be obvious on inspection. Sir Harold thinks that the suggested D is impossible. The value of J would correspond to ellipticity 1/298·3. According to O'Keefe the motion of the node of satellite Vanguard has been discussed by Jacchia and gives 1/(298·3 ± 0·1).

5. J. A. O'Keefe reported on the precision of observations required for the purpose of geodesy and navigation. The precision must be of the same order as that required on the surface of the Earth.

(*a*) For the determination of the geodetic position of certain oceanic islands the precision should be better than 300 metres.

(*b*) For the improvement of the values of the relative positions of the continents, with a view to the improvement of the general figure of the Earth, a precision of the order of 50 m is necessary in order to yield a significant improvement over the values already available.

(*c*) For navigational purposes, an accuracy of about 1 nautical mile, or 2 km, is generally considered desirable. It is important to realize that not only must the observations be of this accuracy; the orbit must also be. As to the precision required in the motion of the satellite, it is certain that satellites which are heavily disturbed by the Earth's atmosphere are almost useless for geodetic or navigational purposes. This is especially true if the satellite is non-spherical, so that the drag varies in an irregular manner with time. It is probable that a perigee altitude of at least 500 km is necessary for a useful geodetic or navigational satellite.

6. E. Buchar reported on his determination of the Earth's oblateness from the motion of the nodal line of Sputnik II (1957β). The daily motion $d\Omega/dt$ of the nodal line as determined on the basis of visual observations performed during 4 months in Czechoslovakia gives

$$\frac{d\Omega}{dt} = -2^\circ\!.88220 \pm 0^\circ\!.00376 - (0^\circ\!.004444 \pm 0^\circ\!.000080)(t-t_0)$$
$$- (0^\circ\!.00001962 \pm 0^\circ\!.00000270)(t-t_0)^2,$$
$$t_0 = 1958 \text{ January } 22.0 \text{ U.T.}$$

The mean error of one node's position is $\pm 0^\circ\!.18$. By using the orbital elements deduced by D. G. King-Hele and several other values published in circulars of the Smithsonian Astrophysical Observatory, Cambridge (Mass.), the following results for K and α (Earth's oblateness) have been obtained:

$$K = 0{\cdot}0010852 \pm 0{\cdot}0000013; \quad 1/\alpha = 297{\cdot}90 \pm 0{\cdot}18.$$