31. COMMISSION DE L'HEURE

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GENERAL

The preceding three years have seen considerable advances in the field of time determination. The activities of many time services have been greatly expanded, and new types of instruments have been introduced. The introduction of U.T. 2 has virtually freed Universal Time of periodic variations. Photographic observations of the Moon for the determination of Ephemeris Time were begun on a wide scale. The cesium standard of frequency is now being used to study variations in the speed of rotation of the Earth. Looking ahead, we see in the artificial satellites a possible new means of determining uniform time.

INSTRUMENTS

Photographic zenith tubes (P.Z.T.'s) are now in operation at Washington, Richmond, Ottawa, Neuchâtel, Herstmonceux, Tokyo, Mizusawa, Mount Stromlo, and Hamburg (Hydrographic Institute).

About fifteen Danjon astrolabes have been placed in service in connexion with the International Geophysical Year.

The application of photo-electric registration to the transit instrument has been continued in the U.S.S.R. and Japan.

On the basis of the reports of observatories which were submitted we may obtain some idea of the order of the *external* probable errors for one night for a time determination obtained by various methods. These are, approximately, as follows:

	ms
Transit instrument, impersonal micrometer	±18
Transit instrument, photo-electric registration	±12
P.Z.T. or Danjon astrolabe	± 4

The probable errors for individual instruments may vary from the values given, but they are considered to be representative. In obtaining the above values the Ottawa P.Z.T. was not considered. It is likely that the large probable error obtained with this instrument, despite several improvements recently made, is due to its unfavourable location, adjoining the main building of the observatory.

Two types of printing chronograph have come into use. The Belin prints directly to $0^s.001$, while the Omega prints to $0^s.01$ and gives the thousandth by interpolation. The latter instrument is smaller and simpler than the former.

The most accurate method of registering time signals is undoubtedly that which makes use of a cathode-ray oscilloscope to exhibit the leading edge of the signal. A number of observatories and laboratories have constructed comparison systems on this principle. Readings may be made to $0^s.00001$ for nearby transmitting stations. For distant stations variations in time of propagation do not permit such accuracy, but readings may generally be made to $0^s.0001$. When receiving signals on long waves, as from GBR and GBZ, the time of build-up of the signal is relatively long, several milliseconds, and it is particularly advantageous to see the signal on the oscilloscope.

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CLOCK AND ATOMIC STANDARDS

Quartz-crystal clocks have been introduced at practically all time services. The pendulum clock may be regarded as obsolete for timekeeping of the highest precision, except in connexion with some studies of gravity.

Atomic and molecular standards of frequency are being used to control standard frequency transmission and to study changes in the speed of rotation of the Earth. The cesium standard built by L. Essen and J. V. L. Parry at the National Physical Laboratory, Teddington, in 1955 has an apparent stability of 1 part in 10^{10} [1]. A cesium standard, called the Atomichron, is being built commercially in the United States. The stability appears to be about 3 parts in 10^{10}. The frequency of this standard is dependent upon the power of the radio-frequency field, but a study is being made in order to correct this. Atomichron serial no. 6 has been under study at the Naval Research Laboratory, Washington, since September 1956. A comparison of the standards at Teddington and Washington is being made through the U.S. Naval Observatory. Differences of the order of 1 part in 10^9 have been observed.

Ammonia standards have been built by K. Shimoda at Tokyo Observatory and at the Swiss Laboratory of Horological Research.

A joint study of the variation in speed of rotation of the Earth is being made by L. Essen and J. V. L. Parry at the National Physical Laboratory, and W. Markowitz and R. G. Hall at the U.S. Naval Observatory. Other studies are being made at Paris by N. Stoyko, at Neuchâtel, and at Tokyo.

Although the developments in the field of atomic standards are remarkable, discrepancies between various standards, even of the same type, exist. Clearly, much experimental work remains to be done.

VARIATION IN SPEED OF ROTATION OF THE EARTH

The seasonal variation during 1956 and 1957, that is, the sum of the terms of one year and 0·5 year period, has been practically the same as during the preceding five years. It is remarkable, indeed, how little change there is from year to year, especially if the seasonal variation is due to winds and tides. Practically the same seasonal variation is obtained from the use of the cesium standard as from the use of quartz clocks.

Analysis of the Washington and Richmond P.Z.T. observations by W. Markowitz has shown the existence of short-period terms of periods 27·6 days and 13·6 days [2]. These arise from deformation of the Earth's crust by tidal action of the Moon.

A joint study by the National Physical Laboratory, Teddington, and the U.S. Naval Observatory shows that since about September 1955 the period of rotation of the Earth has been increasing steadily by 5 parts in 10^9, or 0·43 ms per year.

U.T. 2

It was decided in September 1955 at Dublin that effective 1 January 1956 corrections for polar motion and for seasonal variation in speed of rotation of the Earth should be applied in deriving Universal Time. The Bureau International de l'Heure was given the responsibility of providing the required corrections.

Following an exchange of correspondence between A. Danjon and N. Stoyko of the B.I.H., and H. Spencer Jones and W. Markowitz, the outgoing and incoming presidents, respectively, of Commission 31, details of the new system were agreed upon. The necessary instructions and tables were issued by the B.I.H. by December 1955, in time for use by 1 January 1956.

The notation adopted is as follows:

U.T. 0 is Universal Time as formerly computed;

U.T. 1 is U.T. 0 corrected for observed polar motion;

U.T. 2 is U.T. 0 corrected for observed polar motion and for extrapolated seasonal variation in speed of rotation of the Earth.

The B.I.H. issues corrections periodically for variation of longitude for each time station. Extrapolated corrections are given in Table C and interpolated corrections in Table B. It is the latter that are used in publishing final corrections of time signals.

The correction for seasonal variation is given in Table A for an entire year, in advance, by the B.I.H. No significant change in the seasonal variation has appeared in the last few years, and the same correction was adopted for 1956, 1957, and 1958. The formula used is

$$\Delta SV = 0^s.022 \sin 2\pi t - 0^s.017 \cos 2\pi t - 0^s.007 \sin 4\pi t + 0^s.006 \cos 4\pi t,$$

where t is the fraction of the year.

The polar motion is computed on a nearly current basis by the Rapid Latitude Service, which was set up in 1955 by Commission 19. Each week there is sent to the Central Bureau at Pino Torinese the variation of latitude results obtained during the preceding week with instruments such as the P.Z.T.'s at Washington, Richmond, and Ottawa, the Danjon astrolabe at Paris, and zenith telescopes at Belgrade, Carloforte, Mizusawa, Poltava, and Pulkovo. The polar motion is derived by the Central Bureau and sent to the B.I.H., which uses these data to compute the variation in longitude.

It should be noted that the final choice of the co-ordinates of the pole to be used in computing the variation in longitude rests with the B.I.H. Since results from the Central Bureau were not always received on time it has been necessary, on occasion, for the B.I.H. to compute the polar motion from variation of latitude results communicated directly to it. It is urged, in order to assure a continuity of service, that stations which can determine the variation of latitude rapidly send their results to both the Central Bureau and the B.I.H. The determination of the polar motion by the B.I.H. is discussed in detail by A. Stoyko and N. Stoyko [3].

The purposes of establishing U.T. 2 were to provide a system of relatively uniform time based on the mean speed of rotation of the Earth and to obtain homogeneity in the computation of Universal Time. Both of these objectives have been achieved during 1956 and 1957 with a large measure of success, thanks to the B.I.H. and the Central Bureau. In particular, the work of N. Stoyko has been of the greatest value in the operation of the new system.

TIME SIGNAL TRANSMISSIONS

The continuous, or nearly continuous, operation of stations which broadcast time pulses and standard frequency, such as WWV, WWHV, MSF, JJY, and HBN is of considerable value in many applications. The increase in the number of such stations and in the hours of transmission, however, has begun in some measure to defeat its own purpose; complaints are being made of interference.

Another difficulty that has arisen is due to the practice of some stations of attempting to keep the frequency constant in the absolute sense. Since the speed of rotation of the Earth is continually changing it is not possible for the seconds pulses, which are governed by the standard frequency, to remain on U.T. 2. Hence, the pulses are shifted in phase when necessary, 20 ms at a time by WWV and 50 ms by MSF. For some purposes these phase shifts are undesirable, especially as it is not known in advance when they will occur.

The practice for stations which broadcast only time signals, such as HBN and NSS, is not to shift the phase but to keep the frequency of the transmitting clock close to U.T. 2, that is, relatively but not absolutely constant.

THE SECOND

In 1955 the I.A.U. adopted a resolution defining the second in terms of the tropical year for 1900·0. In 1956 [5] the International Committee on Weights and Measures adopted in Paris a similar but not identical definition, which reads as follows: 'La seconde est la fraction

$$1/31\,556\,925,\,974\,7$$

de l'année tropique pour 1900 janvier 0 à 12 heures de temps des éphémérides'.

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The difference between the two definitions is small, but in order that there may be only one definition of the second it is proposed that the I.A.U. adopt the one given above.

A consultative Committee on the Definition of the Second was set up by the International Committee on Weights and Measures. This Committee met at Sèvres on 3 and 4 June 1957, under the presidency of A. Danjon. It recognized the advances made in the field of atomic standards and urged that additional standards be made and compared. The accuracy of the Improved Lunar Ephemeris, on which Ephemeris Time is based in practice, was discussed from the standpoint of providing a basis for uniform astronomical time.

ATOMIC TIME AND GRAVITATIONAL TIME

The practical construction of the cesium standard has focused attention on the question whether the atomic and gravitational time scales are the same or diverging. The test is to ascertain whether the frequency of cesium in terms of the second of Ephemeris Time changes secularly. A joint programme for this purpose has been started by the National Physical Laboratory and the U.S. Naval Observatory [4].

According to some theories the change in frequency that *might* occur, and the word might is emphasized, is about 2 parts in 10^{10} per year. The National Physical Laboratory standard is stable, presumably to 1 part in 10^{10}. Ephemeris Time can be determined, through use of several dual-rate Moon cameras, it is estimated, to 1 part in 10^9 in one year. Hence, it may take something like ten or twenty years to obtain even a preliminary answer.

ARTIFICIAL SATELLITES

Ephemeris Time is defined fundamentally by the motion of the Sun, but is obtained in practice from the motion of the Moon because of the more rapid orbital motion of the latter. The launching of an artificial satellite on 4 October 1957 in the U.S.S.R. means that another method of obtaining Ephemeris Time is, in theory at least, open to us. This would be the case if a satellite could be launched at a height such that non-gravitational forces would be negligible.

We may assume that the satellite can be used to determine time to one millisecond, and that an interval of one year can be determined to about 1 part in 10^{10} in terms of the time scale defined by the satellite. It should thus be theoretically feasible to test the possible divergence between atomic time and gravitational time more rapidly by using an artificial satellite instead of the Moon.

The question arises, however, is there any height at all at which the motion of the satellite will not be significantly affected by interstellar matter or electrical forces? It is upon the answer to this question that the use of artificial satellites in timekeeping depends.

INTERNATIONAL GEOPHYSICAL YEAR

Two programmes concerning time are part of the International Geophysical Year. Universal Time is being determined with about 15 Danjon astrolabes for the determination of astronomical longitude (latitude is also determined). Ephemeris Time is being determined with 20 dual-rate Moon cameras. As a result of the Moon programme it will be possible to obtain precise values of the frequencies of atomic and molecular standards in terms of the second of Ephemeris Time.

REVISION OF FK 3

The existence of systematic errors in FK 3 which increase with time has been known for some time, and a revision of FK 3 by A. Kopff and W. Fricke was begun. Since the revised catalog, FK 4, would not be published at the commencement of the International Geophysical Year a question arose as to what catalogue should be used in reducing International Geophysical Year observations.

The U.S.S.R. astronomers, A. Mikhailov, M. Zverev, N. Pavlov, and A. Nemiro, made a detailed study of this question. They pointed out that errors of the form $\Delta\alpha_\alpha$ have a serious effect on the determination of time (and longitude) at stations in high northern latitudes. They advocated using corrections in right ascensions, based on the differences (Puα1–FK 3) and (N 30–FK 3).

There is little doubt that the use of these corrections would improve time determination. There was a question, however, as to whether it was preferable to apply these corrections or to use a revision of FK 3, called FK 3R, during the International Geophysical Year, and revise the results when FK 4 became available. After an exchange of correspondence between those principally concerned it was considered advisable to use FK 3R and later FK 4. In case FK 4 should be adopted for time determination in place of FK 3 the effect of the change in system on different instruments will have to be considered.

A report on the revision of FK 3 by W. Fricke follows.

The revision of the FK 3 has been carried out in two different but not independent steps. The first is the derivation of individual corrections to α, δ and proper motions of the fundamental stars in the system of FK 3. For the corrections in right ascension 48 catalogues with new observations were used for stars in the northern sky down to $\delta = -30°$, and 41 catalogues for the corrections in declination. For the stars in the southern sky ($\delta < -30°$) the corresponding numbers are 13 and 15 catalogues. Thus, the results of the first step are revised positions and proper motions of the fundamental stars in the system of FK 3. (This intermediate catalogue obtained the title FK 3R.) This most laborious part on the way to the FK 4 has been completed before the beginning of the I.G.Y. and was published as *Veröffentlichungen des Astronomischen Rechen-Instituts*, Heidelberg, Nos. 6 and 7. In these two publications the individual corrections of the positions of the fundamental stars are given for 1956·5, 1957·5, ... 1960·5. It has been agreed at the international 'Conférence d'Astrométrie' at Brussels in 1955 to use these individual corrections for the AGK 3 programme. The same corrections should be used for preliminary reductions of observations during the I.G.Y.

The second step, namely the derivation of systematic corrections to FK 3, is being carried out at the Astronomisches Rechen-Institut at present and is planned to be completed during 1958; it will then be easy to obtain the results of observations (based on FK 3R) in the FK 4 system simply by applying the systematic corrections. These systematic corrections will be given by us as functions of α and δ.

REPORTS OF OBSERVATORIES AND LABORATORIES

In preparing this report it was necessary to condense considerably the numerous reports received. Details of many investigations had, unfortunately, to be omitted. I have suggested that authors of extended reports may wish to distribute such reports in advance of the General Assembly or at Moscow.

Belgrade

Observations for time have continued. Z. M. Brkić and L. Mitić have studied the influence of systematic effects on the determination of time.

Bucarest

During the International Geophysical Year it is planned to use a reversible Zeiss instrument and several quartz clocks in the determination of longitude.

Canberra (Mount Stromlo)

A P.Z.T. has recently been installed.

W. D. Heintz has analysed 20 000 observations for time made with a visual transit instrument to determine relative right ascensions of 856 fundamental stars.

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Geodetic Institute (Milan)

The time service is located at the Politecnico in Milan. C. Mazzon has made studies of quartz crystals and on methods of improving the reception and recording of time signals.

German Hydrographic Institute (Hamburg)

Time determinations are made with Askania Transit instruments. A P.Z.T., constructed by the Institute, was installed in September 1957.

Hamburg Observatory

J. v. d. Heide has analysed observations made for time to determine systematic errors in FK 3 of the form $\Delta\alpha_{\alpha}$. Significant errors were found, which are expected to be eliminated in FK 4.

Laboratoire National de Radio-electricité (Paris)

Experimental transmissions of standard frequency and time signals have been started on station FFH. A quartz clock using transistors has been constructed. The cathode-ray tube is used to monitor time signals. A cesium standard, an Atomichron, is to be placed in service shortly.

Madrid

The operation of the time service has been improved by the installation of two quartz clocks and two modern chronographs, supplied by Belin.

Mizusawa (International Latitude Station)

Observations are made with the P.Z.T. in a joint programme with the U.S. Naval Observatory, for time as well as latitude. About half the stars used at Mizusawa are common to those at Washington, which furnished the mean places for the common stars. The mean places of the others were determined at Mizusawa with respect to the common stars. The accuracy for a night is estimated at ± 10 ms, standard deviation.

National Bureau of Standards (Boulder)

The laboratory at Boulder has built a cesium standard and an ammonia standard (MASER), and has obtained an Atomichron. These are used to stabilize the standard frequency transmissions of WWV at Beltsville, Maryland, and of WWVH at Hawaii. Transmissions of standard frequency on a carrier of low frequency, 60 kc/sec, were begun at Boulder.

National Physical Laboratory

The cesium standard constructed in 1955 is used to calibrate the standard frequency transmissions of station MSF. In conjunction with the U.S. Naval Observatory comparisons of frequency are made to determine the frequency of cesium in terms of the second of Ephemeris Time. A new cesium standard is under construction by Essen and Parry, which is expected to have a precision of a few parts in 10^{11}.

Neuchâtel

Observations for time are made with the P.Z.T., Danjon astrolabe, and meridian circle, and the results are intercompared. The frequency of an ammonia standard (MASER) of the Swiss Laboratory of Horological Research is being determined in terms of U.T. 2. Standard frequency transmissions are emitted by station HBN. Although the ammonia standard is used to stabilize the frequency from day to day the frequency emitted is on the system U.T. 2.

A new catalogue of P.Z.T. positions was prepared. It is based on AGK 2, but is corrected internally from the P.Z.T. observations themselves. The mean error for one star is $0\overset{''}{.}12$ (time or latitude) and $0\overset{''}{.}06$ for one group. In units of time these values are $0\overset{s}{.}012$ and $0\overset{s}{.}006$ respectively.

Ottawa

A new catalogue of P.Z.T. stars has been formed, based on P.Z.T. observations made since 1954. The connexion to FK 3 is based on meridian circle observations made in 1950–53.

P.Z.T. improvements include installation of an external shutter, a gold-plated dish for the mercury pool, and a photo-electric timing device. Mean errors are $0^s.019$ for one star and $0^s.011$ for the night.

Continuous broadcasts of time are made by station CHU on frequencies 3330, 7335, and 14670 kc/s.

Prague

The time service of the Czechoslovak Academy of Science was reorganized in accordance with resolutions adopted by the I.A.U. at Dublin. Observations are made with a visual transit instrument and, during the International Geophysical Year, an astrolabe of Nušl-Frič. Three other stations will use similar astrolabes in Czechoslovakia during the International Geophysical Year to determine time and latitude. Signals are monitored with an electronic chronograph. Special time signals are emitted towards Japan for the purpose of studying transmission times. These are received at Tokyo with a stability of 0·1 ms.

Poznań University Observatory

Observations are made at Poznań and at Borowiec, about 13 km to the south-east, using transit instruments. Photo-electric registration is being installed at Poznań. Quartz clocks are used at both stations.

Rio de Janeiro

Three quartz clocks and a Cintel decimal counter were installed. L. I. Gama is studying local effects on time determination.

Royal Greenwich Observatory, Herstmonceux

The Time Department was moved from Greenwich and Abinger, and is now operating at Herstmonceux. The last observations were made at Greenwich on 23 April 1957, and 1 November 1955 at Abinger. Observations with a transit instrument were made at Herstmonceux from 23 April to 16 October 1957. The P.Z.T. was installed at Herstmonceux in 1955, and regular observations commenced on 23 November 1955. The currently adopted star places are, relatively, those given by the P.Z.T., but the zero has been tied to the average of the FK 3 stars between $+40°$ and $+60°$ as observed with the Airy transit circle at Greenwich from 1949 to 1951.

U.T. 2 was observed to have a significant residual variation which is considered to be associated with the observations rather than the clocks.

San Fernando

Beginning May 1956 results of time determinations have been sent to the B.I.H. Equipment used in time determination includes two transit instruments, a meridian circle, and two quartz clocks.

Service Central Hydrographique (Paris)

Studies have been made of methods of time determination for use in the field or at an observatory. A. Gougenheim has developed a method for the determination of position called 'des droites d'azimut'.

Sternberg (Moscow)

Attention has been given to improving the time service as regards equipment, and organizing the work at the site of the new observatory on the Lenin Hills. In connexion with the International Geophysical Year the activities have been increased. Two transit instruments are used, one of which is having photo-electric registration added.

Tashkent

As a result of the International Geophysical Year work on time determination has increased, using visual transit instruments. H. P. Shakirova has studied systematic errors affecting clock corrections and B. V. Yasevitch has determined the longitude of the International Latitude Station known as Ulugbeka.

Tokyo

Since the beginning of 1956 the Tokyo time formally adopted as U.T. 2 has been referred exclusively to observations made with the P.Z.T. Simultaneously with these observations additional observations for the International Geophysical Year are made with a transit instrument equipped with a photo-electric device. The accuracies for a single night are ± 5 ms for the P.Z.T. and ± 11 ms for the transit instrument.

Time is kept by nine quartz crystal clocks. Inter-comparisons are made with the aid of an electronic decimal counter and a beat counter. Time signals are registered with the decimal counter and, photographically, with the oscilloscope.

Three kinds of time signals are emitted from Tokyo: mean time by JJC, standard frequency by JJY, and special time signals by JAG 3, JAU 4, etc. The latter signals are part of an extensive series of signals sent out at Tokyo and elsewhere for the purpose of determining the travel time of radio signals.

U.T. 2, as determined at the Tokyo Observatory, is being compared with the Stark-Zeeman Ammonia Absorption standard of K. Shimoda at Tokyo University. The frequency of ammonia on U.T. 2 increased gradually during 1956, but has been decreasing since the spring of 1957.

S. Iijima has made studies of systematic effects of time determined with the P.Z.T. and of the travel time of radio signals between Europe and Tokyo.

Uccle

Observations for time are made at Uccle with three transit instruments, Bamberg-Askania. Three quartz crystal clocks were installed.

The Belgian government has established a time station in the Belgian Congo, in the region of Lwiro. It will commence the emission of time signals in 1958.

Union Observatory

Time signals and standard frequency are broadcast from radio station ZUO. It is planned to install a P.Z.T. In the meantime, signals are sent by setting the clocks with reference to time signals from WWV.

U.S. Naval Observatory

Observations for time were made with P.Z.T. no. 3 at Washington, D.C., and with no. 2 at Richmond, Florida. The Washington P.Z.T. was moved a short distance, from its temporary to its permanent housing, on 13 April 1956.

The three Essen-ring crystal oscillators, which have run continuously since being installed in 1954 and 1955, serve as primary standards. Two quartz clocks built by the Naval Research Laboratory (N.R.L.) are used for monitoring and comparison purposes. These include a cathode ray and decade delay monitoring system.

Beginning about January 1956 time signals from naval radio stations NSS, NPG, etc., have been emitted from clocks located at the stations. These clocks are not shifted in phase. The rates are controlled by direction from the U.S. Naval Observatory.

The dual-rate Moon camera is used for the determination of Ephemeris Time.

A joint programme is being carried out by the National Physical Laboratory and the U.S. Naval Observatory to obtain the frequency of cesium in terms of the second of Ephemeris Time.

During the International Geophysical Year a Moon camera and Danjon astrolabe will be operated at Washington and, in conjunction with the U.S. Naval Observatory, at San Diego by San Diego State College, and at Hawaii by the U.S. Coast and Geodetic Survey.

Computations involving the P.Z.T., the Moon programme, and the astrolabe have been programmed for the I.B.M.-650, under the direction of R. Glenn Hall.

U.S.S.R.

The time service of the U.S.S.R. is based on the collaborative work of twelve universities and scientific institutions. These are: Institute of Physical and Radio Technical Measurements (Moscow), Sternberg Observatory (Moscow), Institute of Geodesy, Air-survey and Cartography (Moscow), Pulkovo Observatory, Mendeleyev Institute of Metrology (Leningrad), Institute of Physical and Radio Technical Measurements (Irkutsk), Tashkent Observatory, Nikolayev Observatory, Kharkov Observatory, Irkutsk University, Leningrad University, and Riga University. The work is co-ordinated at the first of these.

Astronomical observations are made at all twelve time services. Signals are monitored at eight stations, and transmitted at three. Eighteen transit instruments are in use, made in the U.S.S.R. or by Zeiss, Bamberg, Askania, etc. Six of these have photo-electric registration. The mean value of the mean square error is ± 23 ms for the visual, with impersonal micrometer, and $\pm$ 20 ms for the photo-electric. Stroboscopic chronoscopes, electronic counters and cathode-ray tubes are used for registering time signals. Time is computed from the data of the Russian time services and also those of the Chinese People's Republic, the German Democratic Republic, and Czechoslovakia.

A catalogue of precise right ascensions was compiled by P. M. Afanasyeva.

At Pulkovo, V. M. Vasilyev studied thermal effects in relation to time determination. N. Pavlov studied means of ventilating the pavilion in order to eliminate refraction effects.

Warsaw

Observations are made at Jozefoslaw, 15 km from Warsaw, by the Institute of Geodetic Astronomy, using a Zeiss transit instrument. The station is connected by wire with the clock station of the Polish National Bureau of Standards. Time determinations are to be made at the latter station, also, with a Bouty instrument.

RAPPORT DU DIRECTEUR DU BUREAU INTERNATIONAL DE L'HEURE POUR LA PÉRIODE 1954–57

La période de 1954–57 a continué de marquer un progrès de l'activité du B.I.H. par rapport à la période précédente. Le nombre des réceptions de signaux horaires a augmenté de 15% en moyenne et celui des observations astronomiques de 66%.

Le Bulletin a paru régulièrement. Il a donné les heures demi-définitives de toutes les émissions reçues au B.I.H. Il a publié, de plus, les heures définitives pour les années 1954, 1955 et 1956.

Le calcul de l'heure définitive a demandé, en moyenne, l'exploitation de 550 réceptions journalières. L'heure définitive est publiée pour 230 émissions journalières en moyenne et, de plus, les corrections journalières sont données pour 30 observatoires, ce qui exige un travail considérable.

A partir du 1er Janvier 1956 les heures définitives et demi-définitives sont publiées en Temps Universel uniforme provisoire (T.U. 2). Ce temps est corrigé de l'influence du déplacement du pôle et de l'irrégularité saisonnière de la rotation de la Terre.

Ces corrections sont calculées par le B.I.H. d'après la décision de l'Assemblée Générale de l'U.A.I. à Dublin en 1955. Les coordonnées du pôle instantané sont calculées dans le système S.I.R. en utilisant les résultats des observations de latitude de dix observatoires. Les corrections dues à l'irrégularité saisonnière de la rotation de la Terre sont extrapolées en utilisant les résultats des meilleures horloges à quartz par rapport à l'heure définitive.

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Les observations astronomiques ont été faites régulièrement en utilisant deux astrolabes à prisme impersonnels de M. A. Danjon (petit modèle, modèle O.P.L.) et deux lunettes de passage (Gautier no. 381, Bouty).

Pendant la période écoulée on a étudié au B.I.H. la précision des garde-temps (pendules et horloges à quartz), des observations astronomiques et des services horaires, la propagation des ondes radio-électriques, les erreurs expérimentales, les tremblements de terre, le déplacement du pôle, la nouvelle définition du temps (temps uniforme) et l'irrégularité de la rotation de la Terre en utilisant un étalon atomique de fréquence à caesium.

PROPOSALS

A. Danjon proposes that the following resolution be considered:

Que la fréquence des étalons de fréquence atomiques ou moléculaires soit rattachée, au moins provisoirement, et le plus tôt possible, au Temps des Ephémérides afin d'éviter la consécration par l'usage d'une autre échelle de temps.

W. Markowitz proposes that the I.A.U. adopt a definition of the second which is identical with that adopted by the International Committee of Weights and Measures in 1956 (see text under Second).

AGENDA

The following topics have been placed on the Agenda for discussion at Moscow:

(1) Report of the Director of the B.I.H.
(2) Determination of U.T. 2 and its employment.
(3) Revision of FK 3; introduction of FK 4.
(4) Time signal transmissions.
(5) Ephemeris time, atomic time, and the second.
(6) International Geophysical Year.
(7) Instruments; astrolabe, P.Z.T., photo-electric registration.
(8) Use of artificial satellite in time determination.

W. MARKOWITZ
President of the Commission

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APPENDIX

The following two additions to the *Draft Report* were received:

Milan (Brera Observatory)

During the International Geophysical Year time observations near the zenith are made with the Askania Transit Instrument and with the Bamberg Transit Instrument.

Zi Ka Wei

Observations for time are made with a Danjon astrolabe, a transit with photo-electric device, and two transits with impersonal micrometer. The accuracies for a single night are ± 6 ms for the astrolabe and ± 15 ms for the transit instrument. Time is kept by seven quartz crystal clocks. Time signals are registered and clocks are compared with the oscilloscope. Time signals are emitted from Shanghai by stations BPV and XSG.

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Report of Meetings. 14, 16 and 19 August 1958

PRESIDENT: W. Markowitz.

SECRETARIES: N. Stoyko, M. Thomson.

First Meeting. 14 August

The session was opened by the President, who made several introductory remarks.

In order to conserve time the President had requested that the reports for the sessions should be mimeographed and distributed in advance. He requested that this practice should be continued for any additional reports to be given during the meeting. In this way it would be possible to proceed with the discussions of reports without taking time to have them read and translated in detail.

All participants of the General Assembly were invited to take part in the discussion of Commission 31. Only members of Commission 31, however, would be expected to participate in the voting of that Commission.

The *Draft Report* was approved with minor corrections, and other items of the agenda were then taken up.

The President invited attention to the resolutions that would be acted upon. A resolution committee was appointed, and those interested were invited to discuss the resolutions with members of the committee in advance of their being discussed formally at the sessions.

The report of the Director of B.I.H. was approved.

The President announced that he had received the financial report of the Director of B.I.H. and that it was in order.

The President stated that the time system U.T. 2 has proved to be very useful since its adoption in January 1956. The success of the new system was due largely to the work of Dr Stoyko in preparing and distributing promptly corrections for seasonal variation and for variation of longitude. It was noted that the same formula for seasonal variation was adopted by the B.I.H. for use during 1956, 1957, and 1958.

Attention was invited to the fact that Commission 19 had under consideration a proposal by Prof. Cecchini to change the position of the mean pole. A change in the position would affect the corrections for variation in longitude. It was considered that the mean pole used by the B.I.H. for time-keeping purposes need not be the same as that used by the Central Bureau of the International Latitude Service for obtaining the definitive variation in latitude.

Professor Danjon reported on seasonal variation as obtained with the prismatic astrolabe. An analysis for the various terms has not yet been made, but the variation appears to be different from that which has been obtained recently at various observatories. Professor Danjon said he would report on this further at the symposium on the Rotation of the Earth.

A summary of Dr Fricke's report to Commission 4 concerning the introduction of FK 4 as the fundamental star catalogue was read. Dr Fricke thought that the FK 4 system could be introduced in the *Apparent Places of Fundamental Stars* (*A.P.F.S.*) about 1963, but that individual corrections to change from FK 3 to FK 4 would be available about 1960. The question thus arose as to whether FK 4 should be introduced into time-keeping as soon as the corrections became available, or later when *A.P.F.S.* was printed with the FK 4 positions. Professor Danjon thought that it was better to wait until the *A.P.F.S.* was based on FK 4 in order to avoid possible confusion. Dr Levallois, Secretary Adjoint of the International Association of Geodesy, said that speaking for geodesists, they preferred to wait until the *A.P.F.S.* was on FK 4 so that no corrections would be needed. However, reports by U.S.S.R. astronomers had shown that FK 3 was now causing large systematic errors in time-keeping, and that a change to FK 4 was desired as soon as possible. Dr Clemence suggested that corrected volumes of *A.P.F.S.*, in which the corrections FK 4 minus FK 3 were written under each star, could be provided to any one using *A.P.F.S.* for this purpose.

The President remarked on the fact that time signals were now controlled both by astronomers and by physicists, who use them for slightly different purposes. It is desirable to maintain a close agreement between all signal transmissions. Dr Decaux discussed the difficulties arising from the fact that a large number of standard frequency transmissions were broadcast on the same carrier frequency. He urged that steps be taken to reduce the interference.

The President pointed out the difficulties which ensue because of the abrupt changes in phase of the transmitting clocks; the U.S. Naval radio stations make no abrupt changes, but WWV makes changes of 0·020 sec on certain Wednesdays at 1900 U.T. He pointed out the desirability of eliminating or reducing such changes.

It had been urged at the ninth General Assembly that the atomic standards should be referred to Ephemeris Time as soon as possible. The President reported that an initial determination of the frequency of caesium in terms of Ephemeris Time had now been made. This work was carried out jointly by the National Physical Laboratory, Teddington, and the U.S. Naval Observatory, Washington. The results were published in two papers [1, 2]. The frequency obtained is 9 192 631 770 cycles per second. The President stressed that this was only the first determination and that other determinations would be made in the future, at the U.S. Naval Observatory and elsewhere.

The manner in which the second of time becomes available was described in a report by W. Markowitz, 'The Second of Ephemeris Time'. In essence, a time system denoted A. 1 is formed, which is based on the running of caesium clocks. The system could be readily changed when an improved value of the frequency of caesium is obtained.

Dr Essen announced that it was planned to report the frequencies of transmissions of MSF with respect to the assumed value of 9 192 631 770 cycles per second.

Professor Danjon presented a report concerning the progress of the Longitude and Latitude Program of the International Geophysical Year (I.G.Y.). He was asked whether he thought it advisable to continue the program past the nominal termination date of 31 December 1958. It had been recommended that the work of the I.G.Y. should continue for another year although under a different name. Professor Danjon stated that it would be desirable to continue the observations beyond the I.G.Y. and that the Paris Observatory was willing to continue to act as a data center for the Longitude and Latitude Program. However, he thought that there would not be sufficient funds available for operation of all temporary stations which participated in this program. Dr Markowitz stated that the U.S. Naval Observatory, for its part, would be glad to continue with the reduction of Moon plates taken beyond the termination of the present I.G.Y. program.

Second Meeting. 16 August

A joint meeting was held by Commissions 4, 7, 17, 20, and 31 to discuss problems relating to Ephemeris Time and the use of artificial satellites in astronomy. A report of this meeting is included in the report of Commission 4.

A symposium on 'The Rotation of the Earth and Atomic Standards' was held on 18 August 1958, at which Prof. A. A. Mikhailov presided.

Third Meeting. 19 August

Results obtained with Danjon astrolabe and P.Z.T. had been given in the symposium on the Rotation of the Earth. The President noted that there was a discrepancy in the precision of time determination obtained by photo-electric methods, as given in various reports. He called upon Professor Pavlov to describe the work at Pulkovo. Professor Pavlov explained that, in part, results of low precision were due to the fact that the transit instrument was at fault. With the newer instruments which have been placed in operation at Pulkovo high precision was obtained.

Variations in the speed of rotation of the Earth had been discussed at the symposium. An additional report by Dr M. Miyadi and Dr K. Shimoda was read. Through use of an ammonia frequency standard, combined with the observations for time of the Tokyo Observatory, it was found that the variations in speed of rotation were similar to those found by the National Physical Laboratory, by the U.S. Naval Observatory and by Dr Stoyko.

Artificial satellites were next discussed briefly. This subject had been discussed at the joint meeting with the other Commissions (4, 7, 17, 20, and 31) on 18 August. Dr Atkinson pointed out that it would be desirable to have satellites launched in both east to west and west to east orbits so as to study the effect of atmospheric drag.

The resolutions were then taken up for discussion. Professor Danjon raised a question concerning the proposal of Clemence and Sadler for the definition of Ephemeris Time, as to whether the definition should be based on the geometric mean longitude or the apparent mean longitude of the Sun at the given epoch. This is discussed further in the report of the meeting of Commission 4.

On the subject of determination of the frequency of atomic standards in terms of Ephemeris Time, Professor Danjon expressed a desire that determinations of Ephemeris Time should be centralized.

The question of when to introduce FK 4 in time-keeping gave rise to considerable discussion; there were good reasons for adopting either side of the question. It was decided by vote that FK 4 should be introduced as soon as corrections became available. The following resolutions and recommendations were adopted.

RESOLUTIONS

Ephemeris Time (E.T.), or Temps des Ephémérides (T.E.), is reckoned from the instant, near the beginning of the calendar year A.D. 1900, when the geometric mean longitude of the Sun was $279^\circ\ 41'\ 48''.04$, at which instant the measure of Ephemeris Time was 1900 January $0^d\ 12^h$ precisely. The fundamental unit of Ephemeris Time is the second as defined by the Comité International des Poids et Mesures (*Procès-Verbaux des Séances*, deuxième série, Tome xxv, p. 77), namely

'la fraction 1/31 556 925, 974 7 de l'année tropique pour 1900 Janvier 0 à 12 heures de temps des éphémérides'. (Resolution no. 2.)

The determination of Universal Time shall be based on the system FK 4 commencing with the first of the year following publication of corrections to individual mean positions of fundamental stars which transform FK 3 positions into those of FK 4. (Resolution no. 59.)

RECOMMENDATIONS

I. The Commission expresses the wish that an organization shall centralize the observations of the Moon to assure the reductions and regular publications of ΔT.

I. La Commission exprime le vœu qu'un organisme centralise les observations de la lune, en assure la réduction, et publie régulièrement les valeurs de ΔT.

II. The number of stations which transmit standard frequencies and time signals has increased to the point at which the interference produced limits the usefulness of the transmissions.

(1) Commission 31 recommends that the stations which transmit standard frequencies and time signals shall adopt such measures as may be feasible to make possible the reception of distant stations and their identification.

(2) Commission 31 recommends that methods of controlling clocks which emit time signals be adopted which either eliminate abrupt changes in the clock setting entirely or reduce the necessity for such changes.

(3) Commission 31 notes with satisfaction that the first determination of the frequency of caesium with respect to Ephemeris Time has been made. It recommends that additional determinations of caesium, and of other atomic and molecular standards, be made as soon as possible.

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II. L'augmentation du nombre des stations d'émission de fréquences étalon et de signaux horaires a atteint un point tel que les brouillages produits nuisent à l'efficacité des émissions.

(1) La Commission 31 recommande que les stations d'émission de fréquences étalon et de signaux horaires prennent, autant que possible, les mesures nécessaires pour rendre possible la réception des stations lointaines et leur identification.

(2) La Commission 31 recommande qu'on adopte des méthodes de contrôle des pendules émetteuses de signaux horaires, dans le but soit d'éliminer les changements brusques de mise à l'heure, soit de réduire la nécessité de tels changements.

(3) La Commission 31 constate avec satisfaction que la première détermination de la fréquence du césium a été effectuée. Elle recommande que des déterminations supplémentaires du césium et des autres étalons atomiques et moléculaires soient effectuées le plus tôt possible.

ANNEX

The definition of Ephemeris Time is contained in Resolution no. 2. Since it may not be evident how Ephemeris Time is determined in practice, however, the following notes are added:

(1) The independent variable in the theory of the motion of the Sun is Ephemeris Time (E.T.). Hence, E.T. may be obtained by interpolating the ephemeris of the Sun as tabulated in the national ephemerides to the observed position of the Sun.

(2) The theory of the Sun, upon which the ephemeris is based, involves (in particular) two constants, which correspond to the value of E.T. at the fundamental epoch and to the rate at which the mean longitude of the Sun increases in a unit of time. In the past these constants were determined from astronomical observations made in terms of Universal Time (U.T.). In the future, however, these constants will be fixed numbers which define the measure of E.T., and which have no relation to U.T.

(3) If the solar ephemeris should be revised in the future, these constants must not be altered.

(4) The amendments to the lunar ephemeris which have been previously adopted have had the effect of bringing the lunar ephemeris into agreement with the solar ephemeris, and the lunar ephemeris may be used to determine E.T. In practice, E.T. is determined by interpolating the ephemeris of the Moon as tabulated in *Improved Lunar Ephemeris*, 1952–9, and in the national ephemerides from 1960, to the observed position of the Moon.

(5) *Nomenclature*. The fundamental unit of time adopted by the Comité International des Poids et Mesures in 1956 is the second, without any qualifying adjective. In cases where ambiguity is possible the term 'second of Ephemeris Time' may be used when referring to the second adopted in 1956, and the 'second of Universal Time' may be used when referring to the second as defined previous to 1956.

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