

XVIth General Assembly

Grenoble, France

1976

XVIe Assemblée Générale

Grenoble, France

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Resolution No. 1

Proposed by IAU Commissions 4 (Ephemerides), 8 (Positional Astronomy) and 31 (Time)

Proposée par les Commissions 4 (Éphémérides), 8 (L'Astronomie Position) et 31 (L'Heure) de l'UAI

The International Astronomical Union endorses the recommendations given in the Joint Report of the Working Groups of Commission 4 on:

the IAU (1976) System of Astronomical Constants,
the new standard epoch and equinox,
the fundamental reference frame,
the procedures for the computation of apparent places
and the reduction of observations,
time scales for dynamical theories and ephemerides,
and other quantities for use in the preparation of ephemerides;

and recommends that they shall be used in the preparation of the fundamental catalogue FK5 and of the national and international ephemerides for the years 1984 onwards, and in all other relevant astronomical work.

L'Union Astronomique Internationale soutient les recommandations contenues dans le Rapport Commun des Groupes de Travail de la Commission 4 sur:

le Système des Constantes Astronomiques de l'UAI (1976),
le nouveau standard pour l'époque et pour l'équinoxe,
le système de référence fondamental,
les procédés de calcul des positions apparentes et de
réduction des observations,
les échelles de temps pour les théories dynamiques et les
éphémérides,
et les autres données nécessaires à la préparation des éphémérides;

et recommande de les utiliser pour la préparation du catalogue fondamental K5 et, à partir de l'année 1984, pour celle des éphémérides nationales et internationales, ainsi que pour tout autre travail astronomique impliquant ces éléments.

Resolution No. 2

Proposed by IAU Commission 5 (Documentation)

Proposée par la Commission 5 (Documentation)

The General Assembly of the International Astronomical Union *notes* with concern the large increases in prices of publications, which, together with the continuous expansion in scientific literature, makes accessibility of astronomical knowledge difficult to young astronomers and astronomers in the developing countries, and *recognizing* that the Executive Committee has already taken action, with success, to reduce the cost of publications,

requests

- (i) the Executive Committee to take whatever further action may be possible to ensure that IAU publications are made available at greatly reduced prices
- (ii) publishers of astronomical literature to make every effort towards the production of less expensive publications and to employ new ways of disseminating information.

L'Assemblée Générale de l'Union Astronomique Internationale s'inquiète de la forte augmentation du prix des publications qui, liée à l'expansion continue de la littérature scientifique, rend difficile aux jeunes astronomes et aux astronomes des pays en voie de développement l'accès à la connaissance astronomique, et reconnaissant que le Comité Exécutif a déjà pris, avec succès, des mesures en vue de réduire le coût des publications,

demande

- (i) au Comité Exécutif de continuer à veiller par tous les moyens possibles à ce que les publications de l'UAI soient disponibles à des prix fortement réduits,
- (ii) aux éditeurs d'ouvrages astronomiques de faire tous efforts pour produire des publications à un prix moins élevé et pour utiliser de nouveaux moyens de diffusion des informations.

Resolution No. 3

Proposed by IAU Commission 5 (Documentation)

Proposée par la Commission 5 (Documentation)

The General Assembly of the International Astronomical Union considers that Astronomy and Astrophysics Abstracts (AAA) fulfils excellently the specialized needs for an abstracting service in Astronomy and Astrophysics and recommends strongly that AAA continue to be produced by the Astronomisches Rechen-Institut, Heidelberg, Germany Federal Republic, under the auspices of the IAU.

L'Assemblée Générale de l'Union Astronomique Internationale considère que Astronomy and Astrophysics Abstracts (AAA) correspond parfaitement aux besoins spécifiques exigés par un service analytique en Astronomie et en Astrophysique et recommande vigoureusement que AAA continue à être préparé, sous les auspices de l'UAI, par l'Astronomisches Rechen-Institut, Heidelberg, République Fédérale l'Allemagne.

Resolution No. 4

Proposed by IAU Commissions 12 (Radiation and Structure of the Solar

Atmosphere), 14 (Fundamental Spectroscopic Data) and 29 (Stellar Spectra)

Proposée par les Commissions 12 (Radiation et Structure de l'Atmosphère Solaire),

14 (Donnée Spectroscopique fondamentales) et 29 (spectres stellaires) de l'UAI

The International Astronomical Union highly values the activities of the United States National Bureau of Standards in the compilation and critical evaluation of atomic and molecular data, and considers these activities essential for the advancement of astronomy.

L'Union Astronomique Internationale tient en haute estime les activités du Bureau National des Standards (NBS) des Etats-Unis, consacrées à la compilation et à l'évaluation critique des données atomiques et moléculaires, et considère qu'elles sont essentielles aux progrès de l'Astronomie.

Resolution No. 5

Proposed by IAU Commissions 16 (Physical Study of Planets and Satellites) and 17 (The Moon)

Proposée par les Commissions 16 (Etude Physique des Planètes et des Satellites) et 17 (LA Lune) de l'UAI

The General Assembly of the International Astronomical Union noting the interest of several of its Commissions in the development of an International Solar System Programme, supports the COSPAR proposal for the establishment of a steering committee, including IAU representatives, to develop this programme.

L'Assemblée Générale de l'Union Astronomique Internationale prenant note de l'intérêt que plusieurs de ses Commissions portent au développement d'un Programme International du Système Solaire, appuie la proposition faite par le COSPAR de créer un comité directeur, comprenant des représentants de l'UAI, et chargé de développer ce programme.

Resolution No. 6

Proposed by IAU Commissions 19 (Rotation of the Earth) and 31 (Time)

Proposée par les Commissions 19 (Rotation de la Terre) et 31 (L'Heure) de l'UAI

The International Astronomical Union

recognizing

that the activities of the International Polar Motion Service and of the Bureau International de l'Heure are complementary, and that they both make essential contributions towards the determination and understanding of the motion of the pole, and

recognizing

that the new laser and radio techniques will make an important contribution to the study of polar motion but that it is at present too early to determine the form of a new service based on these techniques, and

noting

with satisfaction that the International Polar Motion Service multi-station derivation of polar motion has attained the precision needed to resolve long-standing problems,

recommends

that the International Polar Motion Service continue to operate in its present form, and that the Scientific Council of the International Polar Motion Service and the Directing Board of the Bureau International de l'Heure jointly keep under continuous review the possibility of the utilization of modern techniques on a permanent basis, and

urges

that the international and national agencies concerned continue their support of the Central Bureau of the International Polar Motion Service and of each co-operating observatory.

L'Union Astronomique Internationale

reconnaisant

que le Service International du Mouvement du Pôle et le Bureau International de l'Heure ont des activités complémentaires et que tous deux contribuent d'une façon essentielle à la détermination et à la compréhension du mouvement du pôle, et

reconnaisant

que les nouvelles techniques radio et laser apporteront une contribution importante à l'étude du mouvement du pôle, mais qu'il est encore trop tôt pour définir le profil d'un nouveau service fondé sur l'utilisation de ces techniques, et

notant

avec satisfaction que la détermination du mouvement du pôle issue des différentes stations du Service International du Mouvement du Pôle a atteint la précision exigée pour la solution de problèmes qui se posent depuis longtemps,

recommande

que le Service International du Mouvement du Pôle continue à fonctionner sous sa forme actuelle et que le Conseil Scientifique du Service International du Mouvement du Pôle et le Comité de Direction du Bureau International de l'Heure continuent à rechercher en commun les possibilités d'utilisation des techniques modernes sur une base permanente, et

insiste

auprès des organismes nationaux et internationaux concernés pour qu'ils maintiennent leur aide au Bureau Central du Service International du Mouvement du Pôle et à chacun des observatoires qui coopèrent avec ce service.

Resolution No. 7

Proposed by IAU Commissions 19 (Rotation of the Earth) and 31 (Time

Proposée par les Commissions 19 (Rotation de la Terre) et 31 (L'Heure) de l'UAI

The International Astronomical Union having reviewed the functions of the Bureau International de l'Heure, BIH, which were defined in the Transactions of the IAU, Vol. XIII A, 1967, taking account of subsequent developments which have resulted in the BIH being entrusted with additional responsibilities, it now

recommends

that the following terms of reference of the BIH be adopted:

The functions of the BIH shall be

- (a) to establish the scale of the International Atomic Time TAI, in accordance with the decisions of the 14th Conférence Générale des Poids et Mesures and in conjunction with the Bureau International des Poids et Mesures;
- (b) to establish, from all relevant data, and to publish the current values of the Universal Time and of the angular velocity of the Earth's rotation and, in addition, the operational coordinates of the pole used for this purpose;
- (c) to implement the system of the Coordinated Universal Time UTC by the distribution of all necessary information for the coordination of time signal emissions and the synchronization of clocks on the UTC scale;
- (d) to distribute information important for scientific users of time, and to supply on request the available data on the subject of time;
- (e) to perform scientific research as necessary for the improvement of the service.

L'Union Astronomique Internationale ayant passé en revue les diverses fonctions du Bureau International de l'Heure, BIH, telles qu'elles sont définies dans les Transactions de l'UAI, Vol. XIII A, 1967, et prenant en considération l'accroissement de ces activités consécutif aux responsabilités supplémentaires confiées au BIH,

recommande

maintenant que soit adopté pour le BIH le texte de référence suivant:

Les fonctions du BIH sont

- (a) d'établir l'échelle du Temps Atomique International TAI, en accord avec les décisions de la 14ème Conférence Générale des Poids et Mesures et de concert avec le Bureau International des Poids et Mesures;
- (b) d'établir à partir de toutes les données pertinentes, et de publier, les valeurs courantes du Temps Universel et de la vitesse angulaire de la rotation de la Terre et, également, les coordonnées opérationnelles du pôle utilisées à cet effet;
- (c) de rendre effectif le système du Temps Universel Coordonné UTC en diffusant tous les renseignements nécessaires à la coordination des émissions des signaux horaires et à la synchronisation des pendules sur l'échelle UTC;
- (d) de diffuser les informations importantes pour les utilisateurs scientifiques du temps, et de fournir sur demande les données disponibles concernant le temps;
- (e) d'effectuer les recherches scientifiques nécessaires aux progrès du service.

Resolution No. 8

Proposed by IAU Commission 40 (Radio Astronomy)

Proposée par la Commission 40 (Radioastronomie) de l'UAI

The International Astronomical Union

recognizing

- (a) the value to mankind of the scientific results achieved by radio astronomy through the exploration of the universe;
- (b) the increasing use of the radio spectrum, especially by space and air-borne transmitters;

recommends

1. that designers of future ground, airborne and space-based transmitting services, ensure that the effects of in-band, adjacent-band and harmonic interference are below the harmful interference limits as specified in CCIR Report 224-3;
2. that efforts continue by the entire astronomical community to stress that the active users of the radio spectrum should adhere to these limits.

L'Union Astronomique Internationale

reconnaissant

- (a) que les résultats scientifiques de l'exploration de l'univers obtenus grâce à la radioastronomie sont importants pour l'humanité;
- (b) que le spectre radio est de plus en plus utilisé, principalement par des émetteurs localisés dans l'espace ou la haute atmosphère;

recommande

1. aux ingénieurs responsables de la conception des futurs services d'émission à partir du sol, de la haute atmosphère ou de l'espace, de veiller à ce que les effets de l'interférence dans les bandes allouées, les bandes adjacentes et les bandes harmoniques restent en-dessous des limites nuisibles d'interférence telles qu'elles sont spécifiées dans le Rapport CCIR 224-3;
2. à toute la communauté astronomique de continuer à insister fermement auprès des utilisateurs effectifs du spectre radio pour qu'ils respectent ces limites.

Resolution No. 9

Proposed by IAU Commission 50 (Identification and Protection of Existing and Potential Observatory Sites)

Proposée par la Commission 50 (Protection des Sites d'Observatoires Existants et Potentiels) de l'UAI

The International Astronomical Union notes with alarm the increasing levels of interference with astronomical observation resulting from artificial illumination of the night sky, radio emission, atmospheric pollution and the operation of aircraft above Observatory sites.

The IAU therefore urgently requests that the responsible civil authorities take action to preserve existing and planned observatories from such interference. To this end, the IAU undertakes to provide through Commission 50 information on acceptable levels of interference and possible means of control.

L'Union Astronomique Internationale s'inquiète vivement de l'augmentation des niveaux d'interférence avec les observations astronomiques, qui résulte de l'illumination artificielle du ciel nocturne, des émissions radio, de la pollution atmosphérique et du survol par les avions des sites d'observatoires.

En conséquence, l'UAI demande instamment aux autorités civiles responsables d'entreprendre une action urgente afin de préserver de telles interférences les observatoires existants ou en projet. Dans ce but, l'UAI se charge de fournir, par l'intermédiaire de la Commission 50, tous renseignements concernant les limites acceptables d'interférence et les moyens possibles de contrôle.

Resolution No. 10

Proposed by the Resolutions Committee

Proposée par le Comité des Résolutions

The General Assembly of the International Astronomical Union endorses the Resolutions adopted by its individual Commissions and recommends that astronomers give effect to these Resolutions.

Dr. M. K. V. Bappu
Chairman, Resolutions Committee

L'Assemblée Générale de l'Union Astronomique Internationale cautionne les Résolutions adoptées individuellement par chacune de ses Commissions et recommande aux astronomes de mettre ces Résolutions en application.

Commission 4 (Ephemerides/Ephémérides)

Recommendations

The Chairman drew the attention of the meeting to the following recommendation on the Physical Ephemeris of Mars.

"Considering that recent new determinations of the rotational elements of Mars indicate the need for a revision of the elements currently adopted in the physical ephemeris of Mars, and that a new approach to the definition of the origin of areographic longitudes appears useful (G. de Vaucouleurs, M. E. Davies and F. M. Sturms, Jr., J. Geophys. Res. 78, 4395, 1973), Commission 4 and 16 recommend

- (1) that the tie between the new and current physical ephemeris of Mars be firmly established by appropriate comparisons between ground-based and Mariner coordinate systems, and
- (2) that new elements and a new definition of the origin of the areographic longitudes consistent with the results of (1) above and the definitions adopted previously (IAU Trans XVB, 1973, 107) be incorporated in the physical ephemeris of Mars as soon as deemed practicable in the judgement of the cognizant Directors of the National Ephemerides Offices."

The Chairman said that the present resolution was to re-emphasize the need for this work.

The resolution was approved by the meeting.

The Chairman then introduced the following recommendation concerning cartographic coordinates and rotational elements of the planets and satellites.

"Noting that

- (a) confusion exists regarding the present rotational elements of some of the planets
- (b) extensive amounts of new data from radar observations and by direct imaging from spacecraft have made cartography of the surfaces of the Moon, Mercury, Venus and Mars a reality
- (c) there will be an extension of these techniques to the mapping of larger satellites of Jupiter and Saturn in the near future

assert that

to avoid a proliferation of inconsistent cartographic and rotational systems, there is a need to define the rotational elements of the planets and satellites on a systematic basis and to relate the new cartographic coordinates rigorously to the rotational elements

and therefore recommend that

Commission 4 (Ephemerides) and Commission 16 (Physical Study of Planets and Satellites) establish a Joint Working Group to study the cartographic coordinates and rotational elements of the planets and satellites and to report recommendations thereon at the next general assembly of the IAU."

II. RESOLUTION

We request that the following draft resolution be submitted to the Joint Meeting of IAU Commissions 4, 8 and 31 with the view of its being adopted at the Sixteenth General Assembly of the IAU. "The IAU endorses the recommendations given in the Joint Report of the Working Groups of Commission 4 on:

- the IAU (1976) System of Astronomical Constants,
- the new standard epoch and equinox,
- the fundamental reference frame,
- the procedures for the computation of apparent places and the reduction of observations,
- time scales for dynamical theories and ephemerides,
- and other quantities for use in the preparation of ephemerides;

and recommends that they shall be used in the preparation of the fundamental catalogue FK5 and of the national and international ephemerides for the years 1984 onwards, and in all other relevant astronomical work.

III. RECOMMENDATIONS TO IAU GENERAL ASSEMBLY, 1976

RECOMMENDATION 1: IAU (1976) SYSTEM OF ASTRONOMICAL CONSTANTS

It is recommended that the following list of constants shall be adopted as the "IAU (1976) System of Astronomical Constants".

Units

The units metre (m), kilogram (kg) and second(s) are the units of length, mass and time in the International System of Units (SI). The astronomical unit of time is a time interval of one day (D) of 86400 seconds. An interval of 36525 days is one Julian century. The astronomical unit of mass is the mass of the Sun (S). The astronomical unit of length is that length (A) for which the Gaussian gravitational constant (\underline{k}) takes the value 0.017 202 098 95 when the units of measurement are the astronomical units of length, mass and time. The dimensions of \underline{k}^2 are those of the constant of gravitation (\underline{G}), i.e., $L^3M^{-1}T^{-2}$. The term "unit distance" is also used for the length A.

Defining constants

1. Gaussian gravitational constant $\underline{k} = 0.017\ 202\ 098\ 95$

Primary constants

2. Speed of light $\underline{c} = 299\ 792\ 458\ \text{m s}^{-1}$
3. Light-time for unit distance $\tau_A = 499.004\ 782\ \text{s}$
4. Equatorial radius for Earth $\underline{a}_E = 6\ 378\ 140\ \text{m}$
5. Dynamical form-factor for Earth $\frac{J_2}{J_2^e} = 0.001\ 082\ 63$
6. Geocentric gravitational constant $\frac{GM_E}{G} = 3.986\ 005 \times 10^{14}\ \text{m}^3\ \text{s}^{-2}$
7. Constant of gravitation $\underline{G} = 6.672 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$
8. Ratio of mass of Moon to that of Earth $\mu = 0.012\ 300\ 02$
9. General precession in longitude, per Julian century, at standard epoch 2000 $\underline{p} = 5\ 029''\ 096\ 6$
10. Obliquity of the ecliptic, at standard epoch 2000 $\epsilon = 23^\circ 26' 21''\ 448$
11. Constant of nutation, at standard epoch 2000 $\underline{N} = 9''\ 2109$

Derived constants

12. Unit Distance $\frac{c}{\tau} A = \frac{A}{\pi_o} = 1.495\ 978\ 70 \times 10^{11} \text{ m}$
13. Solar parallax $\arcsin(\frac{a_e}{A}) = \frac{A}{\pi_o} = 8'' 794\ 148$
14. Constant of aberration, for standard epoch 2000 $\kappa = 20'' 495\ 52$
15. Flattening factor for the Earth $f = 0.003\ 352\ 81 = 1/298.257$
16. Heliocentric gravitational constant $\frac{A^3 k^2}{D^2} = \underline{GS} = 1.327\ 124\ 38 \times 10^{20} \text{ m}^3 \text{ s}^{-2}$
17. Ratio of mass of Sun to that of Earth $(\underline{GS})/(\underline{GE}) = \underline{S/E} = 332\ 946.0$
18. Ratio of mass of Sun to that of Earth+Moon $(\underline{S/E})/(1+\mu) = 328\ 900.5$
19. Mass of the Sun $(\underline{GS})/\underline{G} = \underline{S} = 1.989\ 1 \times 10^{30} \text{ kg}$

System of planetary masses

20. Ratios of mass of Sun to those of the planets and their satellites

Mercury	6 023 600	Jupiter	1 047.355
Venus	408 523.5	Saturn	3 498.5
Earth+Moon	328 900.5	Uranus	22 869
Mars	3 098 710	Neptune	19 314
		Pluto	3 000 000

RECOMMENDATION 2: THE NEW STANDARD EPOCH AND EQUINOX

It is recommended that:

- (a) the new standard epoch (designated J2000.0) shall be 2000 January 1st, which is JD 2 451 545.0, and the new standard equinox shall correspond to this instant;
- (b) the unit of time for use in the fundamental formulae for precession shall be the Julian century of 36525 days; and
- (c) the epochs for the beginning of year shall differ from the standard epoch by multiples of the Julian year of 365.25 days.

RECOMMENDATION 3: THE FUNDAMENTAL REFERENCE FRAME

It is recommended that:

- (a) the fundamental reference frame defined by the positions and centennial variations in the FK5 shall correspond as closely as possible to the dynamical reference frame;
- (b) a correction to the zero point of right ascensions of the FK4 (equinox correction) and a correction to the motion of the equinox of the FK4 shall be derived from relevant modern observations;
- (c) the expression for Greenwich mean sidereal time at 0^hUT shall be amended by the same equinox correction and motion as adopted for the FK5 in order to avoid a discontinuity in UT.

RECOMMENDATION 4: THE PROCEDURES FOR THE COMPUTATION OF APPARENT PLACES AND THE REDUCTION OF OBSERVATIONS

It is recommended that:

- (a) stellar aberration shall be computed from the total velocity of the Earth referred to the barycentre of the Solar System, and mean places shall not contain E-terms;
- (b) the tabular nutation shall include the forced periodic terms listed by Woolard for the axis of figure in place of those given for the instantaneous axis of rotation, and the two calibrations performed by him shall be revised accordingly, taking account of the change in the adopted precession;
- (c) reductions to apparent place should be computed rigorously and directly, without the intermediary of the mean place for the beginning of year, whenever high-precision is required.

RECOMMENDATION 5: TIME-SCALES FOR DYNAMICAL THEORIES AND EPHEMERIDES

It is recommended that:

(a) at the instant 1977 January 01^d00^h00^m00^sTAI, the value of the new time-scale for apparent geocentric ephemerides be 1977 January 1.000 372 5 exactly;

(b) the unit of this time-scale be a day of 86400 SI seconds at mean sea level;

(c) the time-scales for equations of motion referred to the barycentre of the solar system be such that there be only periodic variations between these time-scales and that for the apparent geocentric ephemerides; and

(d) no time-step be introduced in International Atomic Time.

RECOMMENDATION 6: OTHER QUANTITIES FOR USE IN THE PREPARATION OF EPHEMERIDES

It is recommended that the values given in the following list should normally be used in the preparation of new ephemerides.

1. Masses of minor planets

Minor Planet	Mass in solar mass
(1) Ceres	5.9×10^{-10}
(2) Pallas	1.1×10^{-10}
(4) Vesta	1.2×10^{-10}

2. Masses of satellites

Planet	Satellite	Satellite/ Planet mass
Jupiter	Io	4.70×10^{-5}
	Europa	2.56×10^{-5}
	Ganymede	7.84×10^{-5}
	Callisto	5.6×10^{-5}
Saturn	Titan	2.41×10^{-4}
Neptune	Triton	2×10^{-3}

3. Equatorial radii in km

Mercury	2 439	Jupiter	71 398	Moon	1 738
Venus	6 052	Saturn	60 000	Sun	696 000
Earth	6 378.140	Uranus	25 400		
Mars	3 397.2	Neptune	24 300		
		Pluto	2 500		

4. Gravity fields of the planets

Earth	$+0.001\ 082\ 63$ J_2	-0.254×10^{-5} J_3	-0.161×10^{-5} J_4
Mars	$+0.001\ 964$	$+0.000\ 036$	
Jupiter	$+0.014\ 75$		$-0.000\ 458$
Saturn	$+0.016\ 45$		$-0.001\ 0$
Uranus	$+0.012$		
Neptune	$+0.004$		

Mars	$-0.000\ 055$ C_{22}	$+0.000\ 031$ S_{22}	$+0.000\ 026$ S_{31}
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5. Gravity field of the Moon

$\gamma = (B-A)/C = 0.000\ 227\ 8$	$C/MR^2 = 0.392$	
$\beta = (C-A)/B = 0.000\ 631\ 3$	$I = 5\ 552.7 = 1^\circ\ 32'\ 32.7$	
$C_{20} = -0.000\ 202\ 7$	$C_{30} = -0.000\ 006$	$C_{32} = +0.000\ 004\ 8$
$C_{22} = +0.000\ 022\ 3$	$C_{31} = +0.000\ 029$	$S_{32} = +0.000\ 001\ 7$
	$S_{31} = +0.000\ 004$	$C_{33} = +0.000\ 001\ 8$
		$S_{33} = -0.000\ 001$

IV. NOTES ON RECOMMENDATIONS

NOTES ON RECOMMENDATION 1

Units

The constants of this revised system are generally expressed in terms of the SI units in order to ensure compatibility with the usage in related sciences. In astronomy it is, however, necessary to use the astronomical system of units of length, mass and time. The astronomical unit of time (day) is redefined in terms of the SI second, which was itself defined so as to be equal to the ephemeris second to within the error of the determination. Specifically it is the SI second at mean sea level.

1. The Gaussian gravitational constant serves to define the astronomical unit of length when the corresponding astronomical units of time and mass are already defined. The value for k is that adopted by the IAU in 1938. The value (rounded) of $k/86400$ is 1.990 983 675 $\times 10^{-7}$.
2. The value for the speed of light is that recommended by the fifteenth General Conference on Weights and Measures in 1975. It is understood that this value will be unchanged even if the metre is redefined in terms of a different wave-length from that now used.
3. The value of the light-time for unit distance (1 astronomical unit of length) is based on radar measurements of planetary distances. It is numerically equal to the number of light-seconds in 1 astronomical unit of length. Its reciprocal (0.002 003 988 81) is equal to the speed of light in astronomical units of length per second. The speed of light in astronomical units per day is 173.144 633.
4. The term "equatorial radius for Earth" refers to the equatorial radius of an ellipsoid of revolution that approximates to the geoid. (See also note 15.) The values given for constants 4, 5, 6 and 15 are those recommended by the International Association of Geodesy at Grenoble in 1975 as currently representative estimates of fundamental geodetic parameters.
5. The term "dynamical form-factor for Earth" refers to the coefficient of the second zonal harmonic in the expression for the Earth's gravitational potential as defined in Trans. IAU XIIB (1964), 117-8, 1966. (See also notes 4 and 15.)
6. The geocentric gravitational constant is appropriate for use for geocentric orbits when the units are the metre and the second; E denotes the mass of the Earth including its atmosphere. (See also note 4.)
7. The value for the constant of gravitation is that given in the CODATA system of physical constants of 1973 (CODATA Bull. No. 11).
8. The value for the mass ratio is based on recent data from lunar and planetary spacecraft. (Reference as Note 3.) The mass of the Earth includes the atmosphere. The reciprocal of 0.012 300 02 is 81.3007.

9. The value of the general precession in longitude has been derived on the basis of recent determinations of the correction to Newcomb's value of the lunisolar precession (Ref: Fricke, W., 1967 Astron. J. 72, 1368; 1971 Astron. & Astrophys. 13, 298) and on the basis of a new value of the planetary precession derived from the new planetary masses. For convenience of those making differential corrections the exact value $\Delta p_4 = +1''.10$ has been adopted in computing the new value of p for 2000. The four decimal places of p are required in order to secure consistency with computations based on the current value for 1900 and the correction Δp_4 . A corresponding set of numerical formulae for precessional reductions will be made available. (Ref: Lieske, J., in press.)

10. The value of the obliquity of the ecliptic results from applying secular terms computed with the new values of the planetary masses to the current value for 1900. (Ref: Lieske, J., in press.)

11. The value of the constant of nutation results from applying the secular term given by Woolard (Astron. Papers American Ephemeris 15, 153, 1961) to the current value for 1900. The value will have to be changed as soon as it is possible to adopt a new theory of nutation based on a non rigid model of the Earth. In consideration of the symposium on nutation to be held in Kiev in 1977, it was agreed at Grenoble that the adopted recommendations concerning nutation may be amended by Commission 4.

12.-19. The values of the derived constants have been computed from the values of the defining and primary constants. All the values are consistent with those determined more directly from observations.

12. The number of metres in one astronomical unit of length is now treated as a derived constant.

13. The rounded value $8''.794$ for the solar parallax may be used except where extra figures are required to ensure numerical consistency.

14. The constant of aberration is the ratio of the mean speed of the Earth to the speed of light, and is conventionally expressed in seconds of arc. It is calculated in radians from the expression $\frac{F k_A}{86400}$ where F is the ratio of the mean speed of the Earth to the speed of a hypothetical planet of negligible mass moving around the Sun in a circular orbit of unit radius. The value of F for epoch 2000 is 1.000 1414, and is given by

$$F k = n a (1-e^2)^{-\frac{1}{2}}$$

where n is the sidereal mean motion of the Sun in radians per day, a is the perturbed mean distance of the Sun in astronomical units of length, and e is the mean eccentricity of the Earth's orbit.

The rounded value $20''.496$ may be used for k except where the extra figures are required to achieve numerical consistency.

15. The flattening factor for the Earth is derived from the adopted values of the primary geodetic parameters using the condition that the corresponding ellipsoid of revolution shall be an equipotential surface. (See Note 4.) (Ref: Geodetic Reference System 1967, IAG Spec. Pub. No. 3, 1971)

16. The heliocentric gravitational constant is appropriate for use for heliocentric orbits when the units are the metre and the second.

17.-20. The values given for the reciprocal masses of the planets include the contributions from atmospheres and satellites. For Mercury, Venus and Mars values close to the best spacecraft determinations are adopted. For the Earth the mass is that derived from the adopted values of A , GE and μ . For Jupiter, Uranus and Neptune the modern determinations do not indicate the necessity to change the Newcomb values; The value for Saturn is the unweighted mean of the most reliable determinations. The value for Pluto is based on analyses of the motion of Neptune.

(Ref: Howard H. T., et al, Science 185, 12 July 1974; Anderson, J., Trans AGU 55, May 1975; Duncombe, R. L., et al, Highlights of Astronomy 3, 1973.)

The values given for the reciprocal masses are to be treated as exact, except that for Earth+Moon the gravitational constant should be calculated from $GE(1+\mu)$, that is from the exact values of the primary constants, if numerical consistency is required.

The mass of the Sun in kilograms is given to indicate the relationship between the astronomical and SI units of mass; it is known only to the low precision with which the constant of gravitation is known in SI units. The corresponding values of the masses of the planets are:

Mercury	3.302 2 X 10 ²³ kg	Jupiter	1.899 2 X 10 ²⁷ kg
Venus	4.869 0 X 10 ²⁴ kg	Saturn	5.685 6 X 10 ²⁶ kg
Earth	5.974 2 X 10 ²⁴ kg	Uranus	8.697 8 X 10 ²⁵ kg
Moon	7.348 3 X 10 ²² kg	Neptune	1.029 9 X 10 ²⁶ kg
Mars	6.419 1 X 10 ²³ kg	Pluto	7 X 10 ²³ kg

Ranges of uncertainty for the constants

The true values of the primary constants are believed to lie between the following limits:

c :	299792456.8 - 299792459.2	G :	(6.668 - 6.676) X 10 ⁻¹¹
T :	499.004 776 - 499.004 788	μ :	0.012 300 06 - 0.012 299 97
a^A :	6 378 135 - 6 378 145	p :	5028.95 - 5029.25
$\frac{a}{J_2}$:	0.001 082 62 - 0.001 082 64	e :	23°26'21".35 to ... 21".55
GE :	(3.986002 - 3.986 008) X 10 ¹⁴	N :	9".200 - 9".211

Correspondingly, the limits for the derived constants are:

A	: (1.495 978 68 - 1.495 978 72) X 10 ¹¹
π_0	: 8".794 141 - 8".794 155
κ	: 20".495 518 - 20".495 520
f	: 0.003 352 79 - 0.003 352 83
\overline{GS}	: (1.327 124 33 - 1.327 124 43) X 10 ²⁰
$\overline{S/E}$: 332 945.7 - 332 946.3
\overline{S}	: (1.9879 - 1.9903) X 10 ³⁰

The limits for the reciprocal masses of the planets are believed to be:

Mercury:	6 020 000 - 6 027 000	Jupiter:	1 047.330 - 1 047.380
Venus :	408 521 - 408 526	Saturn :	3 497 - 3 500
Earth +			
Moon:	328 900.0 - 328 901 .0	Uranus :	22 650 - 23 100
Mars :	3 098 600 - 3 098 760	Neptune:	19 300 - 19 450
		Pluto :	2 000 000 - 15 000 000

NOTES ON RECOMMENDATION 2

1. The new standard epoch is one Julian century after 1900 January 0^d.5, which corresponds to the fundamental epoch of Newcomb's planetary theories. The new standard epoch is expressed in terms of dynamical time, instead of Universal Time. Specifically for precise planetary and lunar theories, it is expressed in terms of the time scale of the equations of motion with respect to the barycentre of the Solar System.

2. In the new system a Julian epoch is given by
$$J2000.0 + (JD - 2\ 451\ 545.0)/365.25,$$
where JD symbolizes the Julian date. If the Besselian epoch is still required, it is given by

$$B1900.0 + (JD - 2\ 415\ 020.313\ 52)/365.242\ 198\ 781.$$

The Besselian year is here fixed at the length of the tropical year (365^d.242 198 781) at B1900.0 (JD 2 415 020.313 52).

The prefixes J and B are used to distinguish Julian and Besselian epochs; they may be omitted only where the context, or precision, makes them superfluous.

NOTES ON RECOMMENDATION 3

1. Failure to distinguish between the catalogue equinox of the FK4 (that is its zero point of right ascension on the equator) and the dynamical equinox (the crossing point of the ecliptic on the equator) has been the cause of much difficulty. The FK4 equinox was based on determinations of the dynamical equinox before 1930.

Recent determinations of the equinox corrections have to be taken into account in the determination of the system of the FK5 such that the equinox error will be removed as far as currently possible together with the removal of an erroneous motion of the equinox of the FK4. The corrections to equinox motion and precession must be applied together to avoid introducing an additional fictitious rotation into the stellar proper motions in right ascension.

2. The current expression for Greenwich mean sidereal time is given in the Explanatory Supplement to the Astronomical Ephemeris on page 75.

NOTES ON RECOMMENDATION 4

1. The elliptic component in the Earth's velocity has traditionally been omitted in the computation of the day numbers, and the so-called E-terms of aberration have remained imbedded in the mean places of celestial objects. This practice has caused much confusion and it is convenient to use the occasion of other changes to remove E-terms from mean places and to include them in the reduction from mean to apparent place so that the apparent places will not be changed. The mean places in the FK5 will not contain E-terms and so tables will be given in the FK5 for reducing mean places with E-terms included (for example, mean places in the N30 catalogue) to mean places without E-terms.

2. Nutation is taken into account in the current procedure for computing true places by a reduction from the mean celestial pole of date to a celestial pole which approximates to the direction of the instantaneous axis of rotation of the Earth. It has, however, been demonstrated that observations give the place of a pole whose position with respect to the mean pole of date can be obtained by the procedure described in Recommendation 4 (b). This pole may continue to be called the true celestial pole of date. The prescribed procedure may be achieved by removing the seven small forced periodic-terms in Woolard's equations 55 (Astron. Papers American Ephemeris 15, 133, 1953), by substituting the corresponding terms in equations 54 (page 132), and by scaling.

The equation of the equinoxes (nutation in right ascension on the equator) causes periodic variations in the location of the true equinox of date and hence a variation in apparent sidereal time. In certain applications it may be convenient to remove the effects of these periodic variations by subtracting the equation of the equinoxes, but the origin of apparent right ascension shall continue to be the true equinox of date.

3. It is intended that formulae and tabulations will be made available for use in rigorous, direct reductions without the intermediate formation of the mean place for the beginning of the year. For users who do not require the highest precision, Besselian day numbers will still be provided.

NOTES ON RECOMMENDATION 5

1. The time-like arguments of dynamical theories and ephemerides are referred to as dynamical time-scales. While it is possible, and desirable to base the unit of a dynamical time-scale on the SI second (which is used in the draft IAU (1976) system of astronomical constants), it is necessary to recognize that in relativistic theories there will be periodic variations between the unit of time for an apparent geocentric ephemeris and the unit of the corresponding time-scale of the equations of motion, which may, for example, be referred to the centre of mass of the Solar System. (In the terminology of the theory of general relativity such time-scales may be considered to be proper time and coordinate time, respectively.) The time-scales for an apparent geocentric ephemeris and for the equations of motion will be related by a transformation that depends on the system being modelled and on the theory being used. The arbitrary constants in the transformation can be chosen so that the time-scales have only periodic variations with respect to each other. Thus, it is sufficient to specify the basis of a unique time-scale to be used for new, precise, apparent geocentric ephemerides.

The dynamical time scale for apparent geocentric ephemerides of Recommendation 5(a) and (b) is a unique time-scale independent of theories, while the dynamical time-scales referred to the barycentre of the Solar System are a family of time-scales resulting from the transformations of various theories and metrics of relativistic theories.

2. This recommendation specifies a particular dynamical time-scale for apparent geocentric ephemerides that is effectively equal to TAI + 32^s.184. (There are formal differences arising from random and, possibly, systematic errors in the length of the TAI second and the method of forming TAI, but the accumulated effect of such errors is likely to be insignificant for astronomical purposes over long periods of time.) The scale is specified with respect to TAI in order to take advantage of the direct availability of UTC (which is based on the SI second and is simply related to TAI), and to provide continuity with the current values and practice in the use of Ephemeris Time. Continuity is achieved since the chosen offset between the new scale and TAI is the current estimate of the difference between ET and TAI, and since the SI second was defined so as to make it equal to the ephemeris second within the error of measurement. It will be possible to use most available ephemerides as if the arguments were on the new scale. Before 1955, when atomic time is not available, the determinations of ET can be considered to refer to the new scale. The offset has been expressed in the recommendation as an exact decimal fraction of a day since the arguments of theories and ephemerides are normally expressed in days.
3. In view of the desirability of maintaining the continuity of TAI and of avoiding the confusion that could arise if it were to be redefined retrospectively, no step in TAI is proposed. Although the recommendation is in terms of TAI, in practice astronomers will use UTC and convert directly to the dynamical time-scales.
4. The terminology and notation for dynamical time-scales require further consideration in due course.
5. Recognizing that the TAI second differed from the SI second between 1969 and the present by $(10 \pm 2) \times 10^{-13}$, a step will be introduced in the scale interval of TAI. Therefore, the epoch of the dynamical time-scale for apparent geocentric ephemerides was adjusted to 1977 from 1958 at a subsequent meeting of Commissions 4 and 31.

NOTES ON RECOMMENDATION 6

1. There are not enough independent determinations of the masses of Ceres, Pallas and Vesta to derive ranges of uncertainty, but the internal standard errors are $\pm(0.3, 0.2, 0.1) \times 10^{-10}$, respectively. (Ref: Schubart, J., Astron. & Astrophys. 30, 289, 1974 and 39, 147, 1975; Hertz, H. G., Science 160, 19 April 1968.)
2. Masses of satellites of Jupiter are derived from Pioneer 10. Mass of Titan is derived from the motion of Iapetus. Mass of Triton is estimated from the motion of Neptune. (Ref: Anderson, J. D., et al, J. Geophys. Res. 79, 3661, 1974; Duncombe, R. L., et al, Fundamentals of Cosmic Physics 1, 119, 1973.)
3. For Mercury, Venus, Earth, Mars and Moon the values refer to the planet's crust. A value for Venus including the height of the cloud layer is 6110 km. The radius of the Moon implicit in Watts' profile of the lunar limb is 1 738.065 km. For Jupiter the value is based on determinations from Pioneer 10 and 11. For Saturn, Uranus, and Neptune the values are means of the best optical measures by double image micrometer and heliometer. The value for Pluto is a crude estimate. (Ref: Howard, H. T. et al, Science 185, 12 July 1974; Bulletin Geodesique 118, 365, Dec. 1975; Anderson, J. D., Review of Geophysics and Space Physics 13, July 1975; Null, G. W., Anderson, J. D., Wong, S. K., Science 188, 476, 1975; Anderson, J. D., EOS of Amer. Geophys. Union 55, May 1974; Kaula, W., et al, Geochimica et Cosmochimica Acta 3, 3049, 1974; Dollfus, A., Surfaces and Interiors of Planets and Satellites, Academic Press, New York, 1970.)

4. For notation see Eckhardt, D. H., The Moon 6, 127, 1973.
Earth - coefficients are given for the only three terms that have a significant effect on the orbital motion of the Moon. They should not be considered as defining the dynamical model of the Earth. They are consistent with the first three terms of the presently available models of the Earth's potential, but end figures are subject to change.
Mars - derived from Mars-orbiter data. The coefficients given are the ones having a significant effect on the orbital motion of satellites.
Jupiter - derived from Pioneer 10 and 11 results.
Saturn and Neptune - derived from motions of their nearby satellites.
Uranus - based on optical measures of the flattening and is in reasonable agreement with the dynamical determination. (Ref: Bulletin Geodesique 118, 365, Dec. 1975; Anderson, J. D., EOS of Amer. Geophys. Union 55, May 1974; Null, G. W., Anderson, J. D., Wong, S. K., Science 188, 476, 1975.)

5. The values are best estimates based on lunar laser ranging data and spacecraft data. (Ref: Liu and Laing, Science 173, 1017, 1971; Sjogren, W., J. Geophys. Res. 76, 7021, 1971; Gapcynski, et al, Geophys. Res. Lett. 2, 353, 1975; Williams, J., EOS Trans. AGU 56, 236, 1975.)

6. Several additional quantities must be specified before ephemerides can be completed, but definitive values cannot be selected at the present time. Such quantities are the secular acceleration of the Moon, the corrections to the equator and equinox of the FK4, and the rotational elements of the planets.

Commission 8 (Positional Astronomy/L'Astronomie Position)

1. Commission 8 approves the new program (proposed by the Institute of Theoretical Astronomy in Leningrad) concerning observations of the selected minor planets for solving the problems of fundamental astrometry and asks the observatories having appropriate equipment to take part in the observations according for this program. The results should be presented in such a manner that later improved reference star positions can be taken into account.

2. Commission 8 approves the initiative of the Kiev University Observatory which has begun compilation of the general catalogue of the Bright Stars (BS) and asks the observatories which have taken part in the observations of these stars to send their results to the Kiev Observatory. In addition, it is agreed that the Kiev University Observatory shall make the data available to other establishments working on the same program.

3. Commission 8 supports the plans of the Hamburg-Bergedorf Observatory for a fourfold coverage of the northern hemisphere on overlapping plates.

4. Commissions 8 and 24 endorse the collaboration between Denmark and the United Kingdom for operating the automated Carlsberg Meridian Circle on a good observing site and support the proposed observing program for this and other automated meridian circles for solving the problems of fundamental astrometry and providing positions of reference stars and of stars of astrophysical interest.

5. Commissions 8 and 24 together, noting the great progress which may become possible by the use of space astrometry in defining the reference system, in trigonometrical parallaxes, and in proper motions, support strongly the study and possibly the realization as quickly as possible of astrometric observations from space. This must not affect the planning of ground-based programmes before the accuracy, reliability and long-term continuity of space astrometry have been assured.

6. In accordance with Resolution No 5 of Commission 8 adopted at the XVth General Assembly at Sydney, Commission 8 resolves that:

a. All SRS observations of each star for each night should be made available by the observatories together with the final positions derived from them.

b. The observations of the FK4 stars made with the SRS observations should be made available in the same way.

c. The SRS observations should be reduced to an improved FK4 system which is to be derived jointly by the Pulkovo Observatory and the U.S. Naval Observatory in consultation with the Astronomisches Rechen-Institut on the basis of absolute and/or semi-absolute observations near the epoch 1970. This system shall be called SRS Preliminary System. The relation between the SRS Preliminary System and the FK4 has to be specified explicitly.

d. A complete SRS catalogue should be preserved at the U.S. Naval Observatory and at the Pulkovo Observatory. This should be made available on request. In addition to the mean values for each star, this catalogue should include all individual observations with the weights and the systematic corrections which were used in forming the mean values.

e. The AGK3R and SRS catalogues should be made available in the system of FK5.

f. In order to ensure that the AGK3R and SRS will provide an adequate reference system in the future the observations of SRS must be repeated and it is strongly recommended that the AGK3R be also reobserved.

7. Commission 8 recommends the application of Kreinin and Murri's method of determining absolute declinations at a station situated near the Earth's equator.

8. Noting the great improvements of accuracy and efficiency of observations by means of photographic and photo-electric techniques already obtained, and to be expected, Commission 8 encourages observers to employ these new techniques.

9. For the refinement of astrometric measurements for the establishment of a highly accurate fundamental system Commission 8 agrees that the development and application of optical astrometric instruments (transit circles, astrolabes, et cetera), radio interferometers and space telescopes are necessary.

Commission 10 (Solar Activity/L'Activite Solaire)

Resolution 1

Royal Greenwich Observatory Heliograph - The Royal Greenwich Observatory has served the solar physics community for one hundred years by the production of high quality, homogeneous, photoheliographic observations. Commission 10 of the IAU expresses its gratitude to the RGO for this valuable service to the scientific community and notes with regret that the RGO will terminate its photoheliographic program at the end of 1976.

Recognizing the need of ensuring the continuation of this long series of homogeneous reports performed during one century and noting the capability and interest of the Debrecen Observatory to continue such a program, Commission 10 encourages the Debrecen Observatory to undertake the following responsibilities:

- To carry out direct photoheliographic observations at Debrecen and,
- To organize cooperation between other observatories willing to contribute to such a project
- With the assistance of the Greenwich Observatory to ensure a homogeneous continuity of the gathering, reduction and publication of such data
- To ensure the archiving of the original photographs and this access to interested scientists from around the world.

Resolution 2

SOON SYSTEM - Commission 10 is pleased to note the development of the Solar Optical Observing Network (SOON) and thanks the U. S. Air Force for their generous offer to make the solar data gathered available to the international scientific community. Commission 10 hopes that the representatives of the U. S. Air Force and the World Data Centers will consult frequently in the near future to assure that continuity will be maintained between the new data to be generated by the SOON system and the older data of the international flare reporting system.

Recommendation 1

Flare Reporting - Considering the essential role of flare patrols in current solar research and in the study of solar terrestrial physics and the growing interest in possible long-term variation in the level of solar activity and noting the increasing gap in 24 hour coverage of the sun, Commission 10 recommends that the solar community support a continued, viable program for flare patrol and flare reporting during the next solar cycle.

Recommendation 2

Support of Solar Research - Reflecting upon the continuing contribution of research at ground based observatories, plasma laboratories, and theoretical institutes on the nature of solar flares;

Recognizing that large gaps in solar observations will occur between individual space missions, and being deeply concerned about the many recent abandonments of ground based programs due to lack of funds; Commission 10

Recommends: that the various national funding agencies support a balanced program of space and ground based solar research with appropriate recognition of the vital role played by ground based observatories, theoretical institutes, and plasma physics laboratories.

Commission 15 (Physical Study of Comets, Minor Planets and Meteorites/L'Etude Physique des Comètes, des Petites Planètes et des Meteorites)

a) A resolution concerning priorities in comet radio observations is carried and transmitted to the Executive Committee for further action. It reads:

The transitory nature and unpredictable appearance of most comets prevent astronomers from scheduling time on large radio telescopes. In order to exploit the potential for unique comet data as indicated by recent radio observations, the XVIth General Assembly of the International Astronomical Union strongly recommends the priority allocation of time on short notice for comet observations on large centimeter and millimeter wavelength telescopes.

b) A resolution concerning the importance of searches for cometary antitails is carried to be brought to the attention of observers. It reads:

Although the association of meteor streams with short-period comets is well established, direct information concerning separation of large dust particles from the nuclei of short-period comets, available in principle through observations of antitails, is lacking. Because of the special geometrical circumstances required and the general faintness of short-period comets, the opportunities for appropriate observations are rare. Commission 15 therefore calls to the special attention of observers with access to fast, wide-field telescopes the importance of searches for antitails.

Commission 16 (Physical Study of the Planets/L'Etude Physiques des Planètes et des Satellites)

1. Joint Resolution of Commissions 4 and 16 on Cartographic Coordinates and Rotational Elements of the Planets and Satellites. (Adopted by Commissions 4 and 16)

Commissions 4 and 16 noting that

- (a) confusion exists regarding the present rotational elements of some of the planets
- (b) extensive amounts of new data from radar observations and by direct imaging from spacecraft have made cartography of the surfaces of the Moon, Mercury, Venus, and Mars a reality
- (c) there will be an extension of these techniques to the mapping of larger satellites of Jupiter and Saturn in the near future

assert that

- (a) to avoid a proliferation of inconsistent cartographic and rotational systems, there is a need to define the rotational elements of the planets and satellites on a systematic basis and to relate the new cartographic coordinates rigorously to the rotational elements.

and therefore recommend that

- (1) Commission 4 (Ephemerides) and Commission 16 (Physical Study of Planets and Satellites) establish a Joint Working Group to study the cartographic coordinates and rotational elements of the planets and satellites and to report recommendations thereon at the next general assembly of the IAU.

2. Joint Resolution of Commissions 4 and 16 on The Physical Ephemeris of Mars.
(Adopted by Commissions 4 and 16)

Considering that recent new determinations of the rotational elements of Mars indicate the need for a revision of the elements currently adopted in the physical ephemeris of Mars, and that a new approach to the definition of the origin of areographic longitudes appears useful (G. de Vaucouleurs, M. E. Davies and F. M. Sturms, Jr., J. Geophys. Res. 78, 4395, 1973), Commissions 4 and 16 recommend

- (1) that the tie between the new and current physical ephemeris of Mars be firmly established by appropriate comparisons between ground-based and Mariner coordinate systems, and
- (2) that new elements and a new definition of the origin of the areographic longitudes consistent with the results of (1) above and the definitions adopted previously (IAU Trans. XVB, 107, 1973) be incorporated in the physical ephemeris of Mars as soon as deemed practicable in the judgement of the cognizant Directors of the National Ephemerides Offices.

Commission 17 (The Moon/La Lune)

The following resolutions were passed without objection:

1. The International Astronomical Union noting that improved values of the second harmonic are critical to theories of the lunar interior and noting further that the free librations of the moon provide an important clue to its past (impact or volcanic) urges that subsatellites be put in polar orbit round the Moon, to determine its gravitational field, especially for the low harmonics, as precisely as possible.
2. We recommend that the long-established practice of referring lunar crater coordinates to the center of the crater at the mean elevation of the rim be continued, noting that such coordinates pertain, in general, to positions elevated above the immediate surroundings.

Commission 19 (Rotation of the Earth/Rotation de la Terre)

recognizing

that the activities of the International Polar Motion Service and of the Bureau International de l'Heure are complementary, and that they both make essential contributions towards the determination and understanding of the motion of the pole, and

recognizing

that the new laser and radio techniques will make an important contribution to the study of polar motion but that it is at present too early to determine the form of a new service based on these techniques, and

noting

with satisfaction that the International Polar Motion Service multi-station derivation of polar motion has attained the precision needed to resolve long-standing problems,

recommends

that the International Polar Motion Service continue to operate in its present form, and that the Scientific Council of the International Polar Motion Service and the Directing Board of the Bureau International de l'Heure jointly keep under continuous review the possibility of the utilisation of modern techniques on a permanent basis, and

urges

that the international and national agencies concerned continue their support of the Central Bureau of the International Polar Motion Service and of each cooperating observatory.

The International Astronomical Union, in accordance with previous resolutions of the International Astronomical Union and of the International Union of Geodesy and Geophysics,

recommends

that the five ILS observatories (or their replacements) be equipped with photographic zenith tubes and Doppler satellite tracking equipment, and that their existing visual zenith telescopes be not phased out until there has been a sufficient overlap of simultaneous observations.

Commission 20 (Minor Planets, Comets and Satellites/Petites Planètes, Comètes et Satellites)

Resolution 1

Commission 20 commends the efforts that have led recently to the discovery with powerful wide-field instruments of objects of unusual interest, including MINOR PLANETS of the Apollo and Amor types, of unusually high orbital inclination or eccentricity, or in motion commensurable with that of Jupiter; COMETS, both new ones of short period and long-period objects of great perihelion distance; and two new SATELLITES of Jupiter. At the same time, Commission 20 calls attention to the urgent need for, and great importance of, follow-up astrometric observations of these and other objects over the longest possible arc. Many of these objects are faint and the use of large telescopes with efficient detectors capable of good astrometric precision is required. Such observations are essential to the determination of reliable orbital elements upon which both future observations and studies of the dynamical evolution of these bodies can be based.

La Commission 20 reconnaît les efforts qui ont abouti récemment à la découverte, à l'aide d'instruments appropriés à grand champ, d'objets d'un intérêt particulier, comprenant les petites planètes du type Apollo et Amor, ainsi que des objets ayant une grande inclinaison orbitale ou excentricité, ou ayant un mouvement commensurable avec Jupiter; des comètes nouvelles à courtes périodes et des objets à grandes périodes ayant une grande distance perihélique; enfin deux nouveaux satellites de Jupiter. Au même temps, la Commission 20 attire l'attention sur un but urgent et de très grande importance, la poursuite des observations astrométriques de ces objets et d'autres sur un arc le plus long possible. La plupart de ces objets sont faibles et nécessitent l'usage de télescopes puissants avec des techniques permettant une bonne précision astrométrique. Les observations sont essentielles pour la détermination des éléments orbitaux sur lesquels seront basées les observations futures et l'étude de l'évolution dynamique de ces corps.

Resolution 2

Commission 20 endorses the following resolution of Commission 8:

"Commission 8 approves the new program (proposed by the Institute for Theoretical Astronomy in Leningrad) concerning observations of the selected minor planets for solving the problems of fundamental astrometry and asks the observatories having appropriate equipment to take part in the observations according to this program."

La Commission 20 soutient la résolution suivante de la Commission 8:

"La Commission 8 approuve le nouveau programme (proposé par l'Institut d'astronomie théorique à Leningrad) concernant l'observation de petites planètes choisies, afin de résoudre les problèmes fondamentaux de l'astrométrie, et demande les observatoires ayant les instruments appropriés de prendre part aux observations selon ce programme."

Recommendation

The following recommendation concerning the contents of the annual volume of Minor Planet Ephemerides prepared at the Institute for Theoretical Astronomy, Leningrad, was approved:

In order to make the annual volume of Minor Planet Ephemerides more suited to the current requirements of observers, the Institute for Theoretical Astronomy is requested to give consideration to the following suggestions and the possibility of introducing them into the 1979 edition:

(a) That osculating elements be derived for all numbered minor planets (except for those that are hopelessly lost) for all epochs when the Julian Date divided by 200 leaves remainder 0.5 and that each annual volume tabulate that set which corresponds to the last of these epochs falling during the corresponding year; these elements should be given with the increased precision used for the new elements introduced at the beginning of, e.g., the 1976 edition.

(b) That the lists of bright (say, to opposition magnitude 12.5) and unusual planets for which special ephemerides are prepared be extended and that the precision of these ephemerides be increased to 0.^m01 in right ascension, and 0.1 in declination.

(c) That the magnitudes in special ephemerides include the opposition effect with the phase according to the precepts set out by Gehrels; in the ordinary ephemerides, where the magnitude is given only for the fourth tabulated date, no allowance should be made for phase or opposition effects, and in these same ephemerides the precision of the mean anomaly should be increased to 0.1; for absolute magnitudes the symbol B(1,0), rather than g, should be used.

Commission 22 (Meteors and Interplanetary Dust/Météores et la Poussière Interplanétaire)

The following resolutions were proposed and carried without dissent; a preliminary text of Resolutions 1 and 2 had been circulated to members of the Commission prior to the business meeting.

1. Commission 22 recommends that a cooperative long-term program of radar observations of meteor showers from several points on the earth be initiated with the aim of studying meteor stream cross-sections and longitudinal structure.

2. Commission 22 recommends that a meteor data centre in Lund, Sweden be established for the collection of meteor observations by radio and photographic techniques. The Commission expresses the hope that sufficient financial support will be forthcoming to ensure the operation of such a data centre.

3. Commission 22 notes with interest the programme for Fireball Photography initiated by the B.A.A. and the operation of an International Centre for Meteor Observations for the collection of visual meteor data. The Commission appreciates the value of these programmes and endorses their continuing operation. The commission expresses the hope that sufficient financial support will be forthcoming to ensure continued operation.

4. Commission 22 approves the Progress Report by the "Committee on Radar Observations of Meteor Rates and Radiants, and Anomalies at the Base of the Thermosphere" established at the XV IAU Congress. The Committee is requested to continue its efforts to develop a widely acceptable design for an economical Meteor Rate-measuring Radar System.

5. Commission 22 wishes to call to the attention of observers with access to fast, wide-field telescopes the importance of searches for comet anti-tails. The Commission notes that the association of meteor streams with short-period comets is well established from other studies, however, the observation of anti-tails provides in a more direct way evidence concerning the separation of large dust particles from the nuclei of short-period comets. Owing to special geometrical circumstances and the general faintness of short-period comets, this information is generally lacking.

Commission 24 (Photographic Astrometry/Astrométrie Photographique)

Recognizing the fundamental importance of trigonometric parallaxes for the establishment of the galactic distance scale and the calibration of stellar luminosities, and noting that the Yale general catalogue of trigonometric parallaxes is now more than twenty-five years old, Commission 24 recommends that a new general catalogue be compiled in consultation with interested individuals, and that every effort be made to derive a uniform system of absolute parallaxes.

Commission 28 (Galaxies/Galaxies)

Following a proposal by Dr. G. de Vaucouleurs the Commission decided to recommend to the Union "that in the standard correction of extragalactic redshifts for solar motion with respect to the Local Group $\Delta V = 300 \cos A$, the definition of the solar apex be changed from $l^{\perp} = 57^{\circ}$, $b^{\perp} = 0^{\circ}$ to $l = 90^{\circ}$, $b = 0^{\circ}$, but that no change be made in the conventional value of the solar velocity $V_{\odot} = 300 \text{ km s}^{-1}$ ".

Commission 29 (Stellar Spectra/Spectres Stellaires)

Resolution submitted to the General Secretary by Commissions 12, 14 and 29 (proposed by R. Garstang):

" The IAU highly values the activity of the United States National Bureau of Standards in the compilation and critical evaluation of atomic and molecular data, and considers these activities essential for the advancement of astronomy."

Resolution proposed by J. Pasachoff:

" Because the resonance lines of ionized magnesium at 2803 and 2795 Å are being increasingly studied in the Sun and stars, we propose that these lines be denoted by their wavelengths rather than by any letter."

Commissions 4 (Ephemerides/Ephémérides) and 31 (Time/L'Heure)

RESOLUTION NO. 1 BY COMMISSIONS 4 AND 31

Considering
the desirability of a clarification of the use of Greenwich Mean Time (GMT) and Universal Time (UT),

Notice
(a) that GMT and UT are used in the sense of UTC for Statutory, communications, civil use and other purposes in which maximum precision of timing is integer seconds,
(b) that GMT and UT continue to be used in the sense of UT1 as the independent argument of almanacs for astronomical navigation and surveying,

Recognize
that UT may be used in the place of UTO, UT1, UT2 and UTC in cases where the distinction between them is not needed,

Urge
that GMT be replaced by the appropriate designations, and

Recommend
that the unambiguous notations UTO, UT1, UT2 and UTC be used in all scientific publications whenever it is necessary to distinguish between them.

RESOLUTION NO. 2 BY COMMISSIONS 4 AND 31

Considering
(a) that the IAU has adopted for the dynamics of the solar system a new time scale based on the second of the International System of Units (SI),
(b) that the new time scale is closely related to International Atomic Time (TAI) and that high uniformity and accuracy in TAI are desired, and
(c) that it has been established by reference to improved primary standards that the present duration of the scale interval of TAI differs from the SI second at sea level by $(10 \pm 2) \times 10^{-13}$ s,

Recommend
that a single step adjustment of $+10 \times 10^{-13}$ s be made at 00^h00^m00^s TAI of 1 January 1977 to bring the duration of the scale interval of TAI into close agreement with the SI second at sea level, and that thereafter the uniformity and accuracy of TAI shall be maintained.

RESOLUTION NO. 3 BY COMMISSIONS 4 AND 31

Considering
(a) that various time scales are in current use which are based, for example, upon the rotation of the Earth or upon quantum transitions,
(b) that agreed designations of the time scales are desirable,
(c) that the time differences between time scales must be expressed unambiguously,
(d) the recommendations of the CGPM and CCIR,

Recognizing
that the designations of the time scales are also used as symbols for the expression of time instants read from the respective scales,

Recommend

- (1) that the following notations be used in all languages,
- (2) that the following rules be applied.

Time Scales

1. Atomic Time

TAI (International Atomic Time) is the time scale established by the BIH on the basis of atomic clock data supplied by cooperating institutions;

TA(i) is an atomic time scale established by the institution "i".

2. Universal Time

UTO(i) is the mean solar time counted from midnight of the origin of longitudes obtained from direct astronomical observation at the observatory "i";

UT1(i) is UTO(i) corrected for the effect of the polar motion at the observatory "i";

UT2(i) is UT1(i) corrected for the effect of the seasonal variation as published by the BIH, of the Earth's rotation.

The specification of the observatory may be omitted from UT1 and UT2, if it can be inferred unambiguously from the accompanying text. In the case of the BIH, this specification is usually omitted.

3. Coordinated Universal Time

UTC is the time scale maintained by the BIH which forms the basis of a coordinated dissemination of time signals and standard frequencies and has been recommended by the CGPM to be used as the basis of civil time. The UTC scale corresponds exactly in rate with TAI and differs from it by an integer number of seconds. It is adjusted by the insertion or deletion of seconds to ensure approximate agreement with UT1.

UTC(i) is a time scale realized by the institution "i" and adjusted to maintain agreement with UTC.

Where there is any possibility of misunderstanding, the designation UTC(BIH) should be applied.

Note. UT may be used to designate a time scale related to the diurnal rotation of the Earth in cases where the distinction between UTO, UT1, UT2 or UTC is not needed.

RESOLUTION NO. 4 BY COMMISSIONS 4 AND 31

1. Take notice of CCIR Opinion 36-1 on Time Scales which invites the IAU to consider whether the UT scale could be considered henceforth as an angular measure and should be differentiated accordingly,

2. Agree that Universal Time may be considered as an angular measure of the rotation of the Earth, but

3. Are of the opinion

(a) that a useful time scale is generated by any process which enables dates to be assigned to events,

(b) that the designation Universal Time as a time measure is firmly established and of such great convenience in astronomy, geodesy, astronomical navigation and related applications that it would not be desirable to attempt to change this practice and that considering the need to express differences between other time scales, it is necessary to retain the existing designations in hours, minutes and seconds.

RESOLUTION NO. 5 BY COMMISSIONS 19 AND 31

This was adopted by the General Assembly specifically (Resolution No. 7).

Subjects to be considered by Commission 31

1. Fundamentals
 - (a) Time concepts
 - (b) Time units, time scale unit intervals and multiples
 - (c) Definition and nomenclature of time scales
 - (d) Legal aspects of time
2. Investigations about dynamical time scales, atomic time scales, and Coordinated Universal Time
3. Time determination
 - (a) Clocks and frequency standards
 - (b) Auxiliary equipment
 - (c) Overall review of the determination and coordination of Universal Time (in cooperation with Commission 19, which has the major responsibility in the determination of rotational time)
4. Time dissemination and synchronization
 - (a) Time signals, standard frequencies, time codes
 - (b) Methods of precise time dissemination
 - (c) Time coordination and synchronization
5. Applications of time
 - (a) Applications of time and frequencies to astronomy, space research, Earth sciences, and navigation
 - (b) Information about time and frequencies for users
6. Relativistic effects on time measurements
7. Cooperation with international organizations concerned with time

Commission 40 (Radio Astronomy/Radioastronomie)

III. RESOLUTION CONCERNING SYSTEM III FOR JUPITER

H. P. Palmer summarized a resolution on behalf of Bozyan, Riddle, Seidelmann and others, which was adopted by the Commission: 'RESOLVED, that the provisional rotation period adopted for Jupiter's System III (1957.0) longitude measure, being inadequate for current use, be replaced by a new System III measure for which the sidereal rotation rate of Jupiter is $870^{\circ}.536$ per Ephemeris day. The epoch shall be 1965 Jan. 1 $0^{\text{h}}0^{\text{m}}0^{\text{s}}$ ET, the longitude at epoch of the central meridian, as observed from Earth, shall be $217^{\circ}.595$, and the system shall be called System III (1965).'

IV. RESOLUTION CONCERNING THE STANDARD OF REST

Heidmann proposed, on behalf of De Vaucouleurs, a resolution which was adopted by the Commission: 'Commission 28, 30 and 40 RECOMMEND, that in the standard correction of extragalactic redshifts for solar motion with respect to the Local Group $\Delta V = 300 \cos A$, the definition of the solar apex be changed from $l^{\text{I}} = 57^{\circ}$, $b^{\text{I}} = 0^{\circ}$ to $l^{\text{II}} = 90^{\circ}$, $b^{\text{II}} = 0^{\circ}$, but that no change be made in the conventional value of the solar velocity $V_{\odot} = 300 \text{ km s}^{-1}$.'

V. RECOMMENDATION ON THE DEFINITION OF RADIAL VELOCITY

Menon outlined the conclusions of the joint working group set up by Commissions 30 and 40 in Sydney. There was considerable opposition to the introduction of a new symbol, v_r , to define the fictional velocity $c\Delta v/v_0$. Therefore the original recommendations were modified, to be considered further by Commission 30:

(1) The practice of calling the quantity $c\Delta v/v_0$ a radial velocity, and denoting it by the symbol v_r is confusing in extragalactic applications and should be discontinued.

(2) Astronomers who insist on publishing results in the form $c\Delta v/v_0$ should clearly indicate that they have done so.

Commission 50 (Identification and Protection of Existing and Potential Observatory Sites/Protection des Sites d'Observatoire existant et Potentiels)

I. RESOLUTION

The Commission approved with emendations the following resolution drafted by the working group on recommendations:

The IAU notes with alarm the increasing levels of interference with astronomical observation resulting from artificial illumination of the night sky, radio emission, atmospheric pollution and the operation of aircraft above Observatory sites.

The IAU therefore urgently requests that the responsible civil authorities take action to preserve existing and planned Observatories from such interference. To this end, the IAU undertakes to provide through Commission 50 information on acceptable levels of interference and possible means of control.

This resolution was submitted for approval and approved by the XVth General Assembly.

II. COMMISSION RECOMMENDATIONS

On the advice of the working group on recommendations, the Commission decided to make only the following general recommendations at this time:

(1) The Commission considers that the most vital problem is that of preserving those sites known to have a very high quality from adverse conditions of all kinds. The most urgent aspect is to limit artificial illumination to a small fraction of the natural sky brightness, making these sites available for observations of faint objects that cannot be made in any other way. The Commission therefore urges astronomers and civil authorities to give highest priority to this problem.

(2) The Commission recommends that at existing observatories where a more limited range of observations can be made despite considerable levels of light pollution, every effort should be made to prevent these levels from increasing.

(3) The Commission recommends that the power of radio transmitters be limited so as to avoid interference with sensitive electronic detectors. Present experience suggests that to avoid interference with electronic equipment used on optical telescopes, the power flux from radio transmitters should not exceed one millivolt per meter (or 1.6 microwatts per square meter) at the observatory site. (Note that this value supercedes that given in the Report of Commission 50, Trans. IAU XVIa).

(4) The Commission recommends that aircraft routes be planned to avoid the skies over observatory sites, so as to prevent interference by condensation trails. Restriction of this nature would involve flights at altitudes of $\geq 10^\circ$ as seen from the sites, which implies that civil air lanes should be placed at least 60 km from sites of very high quality. An example of the effectiveness of this type of restriction was reported by Cayrel: all air traffic over Haute Provence was banned for the total solar eclipse of 1961 February 15. The sky remained clear, but when air traffic was resumed in the afternoon, clouds were generated by the aircraft trails.