MERIT + COTES

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JOINT SUMMARY REPORT OF THE IAU/IUGG WORKING GROUPS ON THE ROTATION OF THE EARTH AND THE TERRESTRIAL REFERENCE SYSTEM

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ABSTRACT. The Working Group on the Rotation of the Earth was established in 1978 and developed a programme of international collaboration to Monitor Earth-Rotation and Intercompare the Techniques of observation and analysis (MERIT). The MERIT Short Campaign was held in 1980 to test and develop the organisational arrangements required during the MERIT Main Campaign in 1983-4. The Working Group on the Terrestrial Reference System was established in 1980 to prepare a proposal for the establishment and maintenance of a new Conventional Terrestrial Reference System (COTES) that would be based on the new techniques of space geodesy. The Working Groups collaborated closely and organised two intensive campaigns in 1984 and 1985 that were aimed primarily at determining the relationships between the reference systems of the six different techniques that were used to determine earth-rotation parameters. Observational data were obtained from 35 countries; analyses and intercomparisons of the results were carried out in 7 countries. The Working Groups reviewed the results at the Third MERIT Workshop and recommended that a new International Earth Rotation Service be set up in 1988 and that it be based on the use of very-long-baseline radio interferometry and both satellite and lunar laser ranging.

1. BACKGROUND AND OBJECTIVES

1.1 Rotation of the Earth

The practical and scientific importance of the monitoring of the rotation of the Earth has long been recognised. The International Latitude Service was established in 1899 to study polar motion (that is the motion of the axis of rotation with respect to an axis "fixed" in the Earth), and was succeeded by the International Polar Motion Service, now based in Japan. The Bureau International de l'Heure was established in 1913 to provide an international time-scale based on the rotation of the Earth, and today it is responsible for the international scales of

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atomic time and of universal time, and hence for the basic data on the variations in the rate of rotation of the Earth. An accurate knowledge of universal time and polar motion is required for practical purposes, such as geodetic surveying and precise navigation, but it is also of great scientific value since it provides information about the interior of the Earth and geophysical phenomena that cannot be obtained in other ways.

In 1978 the participants at IAU Symposium No. 82 on "Time and the Earth's Rotation" (McCarthy & Pilkington, 1979) recognised that new techniques of observation, such as laser ranging and radio interferometry, promised to provide an order of magnitude improvement in the precision of the data and accordingly recommended the appointment of "a Working Group to promote a comparative evaluation of the techniques for the determination of the rotation of the Earth and to make recommendations for a new international programme for observation and analysis in order to provide high-quality data for practical applications and fundamental geophysical studies".

The Working Group met at Columbus, Ohio on 1978 October 5-6 and agreed on its objectives and an outline programme of international collaboration to Monitor Earth-Rotation and Intercompare the Techniques of observation and analysis, for which it adopted the acronym Project MERIT. A draft proposal was presented and endorsed at the General Assemblies of the International Astronomical Union in Montreal in 1979 August and of the International Union of Geodesy and Geophysics in Canberra in 1979 December. The documentation for this proposal was subsequently published as a separate report (Wilkins, 1980) containing reviews of each of the techniques of observation to be evaluated, together with background notes about such topics as: the importance of studies of earth-rotation; the objectives, programme and organisation of Project MERIT; the current status of the international services; and reference frames.

Project MERIT has involved the cooperation of a large number of individuals and organisations in many countries. The technical activities have been coordinated by a small number of persons, each of whom has taken responsibility for one technique of observation or for some activity of general concern. Valuable operational experience and new scientific results were obtained during the 3-month MERIT Short Campaign, which was held in 1980 August-October. There was an interval of 3 years before the MERIT Main Campaign to allow for further development of the observational techniques, of the operational procedures and of the software for the analysis of the data. The MERIT Main Campaign took place during the 14-month period 1983 September 1 to 1984 October 31.

The main objectives of the Working Group were summarised as:

1. To make recommendations on the observational basis and organisational arrangements for future international services on earth

rotation.

2. To obtain and analyse data on earth-rotation by both current and new methods in order to improve our knowledge about the variations in the rate of rotation, about the motions of the axis of rotation in space and in the Earth, and about correlations with other geophysical phenomena, and hence to increase our understanding of the causes and effects of these changes.

These objectives were achieved and it is clear that in addition Project MERIT stimulated the faster development of the new techniques, which are now contributing regularly to the international services for earth-rotation. A valuable byproduct is the set of MERIT Standards (Melbourne, 1983), which were prepared for use in the analysis of data from the MERIT Main Campaign but which are being used more generally. The group also collaborated (see below) with the Working Group on the Conventional Terrestrial Reference System (COTES) to the mutual advantage of both groups.

A list of the members of the Working Group on the Rotation of the Earth is given in annex 1A.

1.2 Terrestrial Reference System

By 1980 it was clear that the current definition of the terrestrial coordinate system was inadequate, and so the participants in IAU Colloquium No 56 on "Reference Coordinate Systems for Earth Dynamics" (Gaposchkin & Kolaczek, 1981) recommended the setting up of a working group to prepare a proposal for the establishment and maintenance of a new conventional terrestrial reference system that would be based on the new techniques of space geodesy. It seemed likely that the new techniques (such as laser ranging and VLBI) could each determine the coordinates of stations, or the distances between them, with a precision of a few centimetres. On the other hand, the frames in which these coordinates are defined could differ from each other by much larger amounts; as a consequence coordinates determined by different techniques could not be combined together to the same precision. Moreover the relations between the terrestrial and celestial reference frames would be technique-dependent so that the earth-rotation parameters could not be determined uniquely.

Some members of this COTES Working Group held informal discussions with the MERIT Steering Committee at the first MERIT Workshop (in 1981 May) about the possibility of cooperation between the two groups. It was agreed that as a first step the papers about reference systems that were being prepared for the MERIT subcommittee on standards should be made available to the Working Group on the reference system. In the longer term it was agreed that further consideration should be given to the possibility of extending the aims of the MERIT Main Campaign to include the preparation of a catalogue of precise, consistent station coordinates; it was thought that this would require that some special

observations be made to ensure that the reference systems for the various techniques are accurately linked together. It seemed likely that one service could effectively monitor the changes in station coordinates as well as the rotation of the Earth. Subsequent investigations suggested that there were two ways in which the differences between the reference frames could be determined: firstly, by determining the coordinates of the stations by using two or more techniques simultaneously at each station, and secondly, by determining the diurnal differences (if any) between the earth-rotation parameters obtained by each of the techniques. The former is referred to as the method of 'colocation'. It was decided to hold a special 3-month intensive campaign in 1984 April to June during which all MERIT stations would be asked to observe as often as possible and during which special efforts would be made to colocate mobile systems with permanent systems for different techniques. It was also decided to use the Doppler technique to determine the coordinates of all the stations participating in the MERIT Main Campaign.

The intensive campaign did not achieve all its objectives but it served to establish the existence of variations in the earth-rotation parameters with characteristic periods of only a few days. The data that were obtained during this intensive campaign will undoubtedly be extremely useful in establishing the new terrestrial system and will also have many other applications. A second intensive campaign was held during the period 1985 May to July to provide for a better evaluation of the lunar laser ranging technique.

A list of the members of the Working Group on the Terrestrial Reference System is given in annex 1B.

2. PROGRAMMES OF OBSERVATION AND ANALYSIS

2.1 MERIT Short Campaign

The principal objective of the MERIT Short Campaign was to test and develop the organisational arrangements that would be required during the Main Campaign. The Campaign involved six techniques of observation (see annex 1C) of which only two, optical astrometry and Doppler tracking, were in use for the regular determination of earth-rotation parameters. The principal coordinator for each technique was required to identify the groups that would carry out the observations, one group that would act as an operational centre and at least two groups that would act as analysis centres. The operational centres were primarily concerned with the distribution of information and observational data and with the speedy generation of earth-rotation results from the (quicklook) data supplied by the participating observing stations. The analysis centres were responsible for deriving earth-rotation and other parameters from all the (full-rate) data obtained for each technique. The MERIT Coordinating Centre, which was at the Bureau International de l'Heure, was responsible for combining the results from the various techniques to provide both a rapid service and a

final reference set of earth-rotation parameters for the period of the campaign.

The first MERIT Workshop was held at Grasse, France, on 1981 May 21 to review the activities of the Short Campaign and to initiate the preparations for the Main Campaign. The report on the Short Campaign and this Workshop (Wilkins and Feissel, 1982) shows clearly that the campaign received widespread support and stimulated the improvement of the current techniques as well as the development of the new techniques. Preliminary scientific results from the campaign were presented on May 22 at IAU Symposium No 63 (Calame, 1982) and many papers that have utilised the MERIT dataset have since been published.

The Short Campaign served to show where improvements in the operational procedures were needed; it became clear, for example, that the principal coordinators must be at operational centres where they could be in touch with both the observing stations and the analysis centres. The need for a regular circulation of information about the progress of the project was also made apparent, and so the Coordinating Centre was given the further task during the Main Campaign of preparing and distributing a monthly circular giving reports from the coordinators together with a comparative table of results.

The extent of the participation in the MERIT Short Campaign is included in annex 1C. It was a truly international project in which all of the data obtained has been made available for further analysis. The distribution of stations and the frequency of the observing periods in some cases was not sufficient to provide results on both polar motion and universal time but they did serve to demonstrate the potential of the method and to provide data for analysis and intercomparison. Nevertheless, the Short Campaign was more successful than might have been expected in view of the short length of time between the conception of the project and the start of the test period. One quite unexpected result was an improvement in the results from optical astrometry following an increase in the number and quality of the instruments and in the frequency of the observations.

2.2 MERIT Main Campaign

The MERIT Main Campaign started about three years after the end of the Short Campaign and during this intervening period operational networks, with additional stations and better equipment, were developed by several of the new techniques. There were some changes in the principal coordinators and operational centres, and more groups were recognised as analysis centres. A second MERIT Workshop was held in Herstmonceux Castle, England, on 1983 May 15-19 to review the operational arrangements for the Main Campaign and to plan in broad outline the subsequent activities. The report (Wilkins, 1984) indicates clearly the extent and depth of the preparations for the MERIT Main Campaign.

A very important part of the preparation for the Main Campaign was the

development of a set of MERIT Standards that specified the constants, models and reference systems to be used by the observing stations and by the operational and analysis centres. It was considered essential that all techniques used compatible, if not identical, standards in the reduction and analysis of the observations so that the significance of the differences between the results from the different techniques could be more easily determined. The MERIT Standards were based on the new IAU system of astronomical constants and celestial coordinate frames that were due to be introduced in the astronomical almanacs at the beginning of 1984, but in addition it was necessary to specify, for example, relativistic effects and the models to be used for computing the various effects of tides on the techniques. The preparation of these standards by a MERIT Committee was itself an extremely useful activity since it involved critical examinations of the relative merits of proposed values and models, and the published document (Melbourne, 1983) is now in widespread use in other related fields.

The monthly circulars that were issued by the MERIT Coordinating Centre (at BIH) during and after the Main Campaign show clearly the great extent of the world-wide participation in both observing and analysis and the marked improvement in the quality of the earth-rotation parameters that were derived from the observations. The circular also shows major changes in the relative contributions of the different techniques to the combined solution published in BIH Circular D. At the beginning of the campaign optical astrometry was the dominant contributor to the determination of UT while at the end VLBI was dominant; the weight of SLR in the determination of polar motion increased while the weights of both optical astrometry and Doppler tracking decreased markedly. It may be noted that SLR provided good determinations of the short-period (50d) variations of UT and of the rate of rotation (or length of day) but lacked the long-term stability to be the primary source of UT.

The extent of the participation in the MERIT Main Campaign is indicated in Annex 1C, although it does not reflect the very large improvement in the number and quality of the observations made by the new techniques. Interim reports were presented by the principal coordinators during the International Symposium on Space Techniques for Geodynamics held at Sopron, Hungary in 1984 (Mueller, 1984), and their full reports were presented at the Third MERIT Workshop held at Columbus, Ohio, in July 1985 (Wilkins, 1986). The first results from the analyses of the observations were presented at the conference that followed the Workshop (Mueller, 1985), and a catalogue of these results will be published to facilitate their further study and intercomparison (Feissel, 1986).

The Main Campaign achieved its objectives in demonstrating that the new techniques can be used to provide high-precision data on earth-rotation and in providing a wealth of data for further study of the various physical phenomena that cause, or are affected by, the variations in the rotation of the Earth. The intercomparison of the results from the different techniques will also lead to further improvements in

the precision and accuracy of the results. The principal disappointment was that the number of lunar laser ranging stations that were operational was insufficient to demonstrate the potential of the technique for determining both polar motion and UT with high precision and short delay. Special efforts were made during 1985 May to July to obtain a regular series of results from the 3 stations then operational. Some of the data that were obtained were of very high precision and showed clearly that LLR could make a valuable contribution to the determination of earth-rotation and reference-system parameters.

2.3 COTES Campaigns

The three-month period 1984 April to June was chosen for an Intensive Campaign in which all stations, or networks, were requested to observe as frequently as possible in the hope that it would thereby become possible to detect diurnal variations in the differences between the earth-rotation parameters from different techniques due to differences between the reference systems implicit in the reduction procedures for these techniques. (Differences could also arise between different determinations for the same technique if different analysis centres used different models in the reduction of the observations.) This period of intensive observations was also intended to provide data that would be useful in establishing consistent sets of coordinates for the stations for each technique; by colocating mobile systems with permanent systems it would then be possible to determine the systematic differences between these sets of coordinates. (See Feissel & Wilson, 1983)

A further aim of the intensive campaign was to determine whether the earth-rotation parameters show variations of very-short-period due to physical causes, such as a transfer of angular momentum from the atmosphere. If so, this would not only be of great scientific interest, but it would also effect the level of operation required for any new international service since at present the values of the parameters are published at an interval of 5 days and very-short-period effects are smoothed out.

During the period of the intensive campaign there was a general increase of activity in optical astrometry and satellite laser ranging, and particular efforts were made by the VLBI network of the International Radio Interferometric Surveying Group (IRIS) to obtain data more frequently; for example, one-hour observing sessions were held on most days with the Westford-Wettzell interferometer in order to determine UT.

The number of colocations with mobile SLR and VLBI systems was smaller than had been hoped for, but it is hoped that the planned colocations will be made soon. There were, however, several Doppler campaigns during the MERIT Main Campaign as well as a special campaign (MERITDOC) during the Intensive Campaign. Further efforts are being made to obtain Doppler coordinates for all stations that observed during the

MERIT Main Campaign. A Directory of MERIT Sites (DOMES) is being compiled so that coordinates and local survey data will be readily available for all sites.

3. REVIEW OF CONCLUSIONS

3.1 Comparison of techniques

By the end of the MERIT Main Campaign it had become clear that laser ranging and radio interferometry were able to provide more precise estimates of polar motion, universal time and length of day than could optical astrometry and the Doppler tracking of satellites, which were the prime contributors to the international services in 1978. This conclusion has since been substantiated by the more detailed analyses of the data that have been reported at the MERIT Workshop and Conference held at Columbus, Ohio, on 1985 July 29 to August 2. The accuracy of the regular determination of the coordinates of the poles by SLR and VLBI is about 5 cm, compared with 30 cm by optical astrometry and Doppler tracking while for UT and excess length-of-day the accuracy is about 0.2 ms and 0.06 ms, compared with 1 ms and 0.2 ms.

It must be realized, however, that other factors besides precision had to be taken into account before recommendations about the future international services could be formulated. Perhaps the most important factor was whether it is reasonable to expect that the organisations concerned are likely to continue to make and process observations at an appropriate level and to make the results available to the international community without restriction. The MERIT Main Campaign was a period of special activity and it cannot be assumed that any technique would provide results of the same high quality (as judged by the combination of precision, accuracy, frequency, reliability and promptness) on a long-term basis.

The International Latitude Service was initially set up as a set of five dedicated stations, but it was eventually replaced by the International Polar Motion Service which relied on receiving data from a much larger number of instruments which provided local services and data for other scientific purposes as their prime justification. It is to be expected that any new International Earth-Rotation Service will also have to depend largely on the use of observations and results that are obtained for other national and international programmes.

In particular it must be recognised that an important application of the Service will be the establishment and maintenance of the new conventional terrestrial reference system. The permanent stations used for monitoring earth-rotation will comprise a primary geodetic network of large-scale and high-precision that will be densified, partly by the use of mobile systems using the same techniques, but mainly by the use of other geodetic techniques, such as the use in radio-interferometric mode of signals from navigation satellites.

The choice of the techniques to be used in the new service depends on the subjective evaluation of many factors and not merely on a comparison of the potential quality of the determination of earth-rotation parameters. Although it is conceivable that a single VLBI network could provide an adequate international earth-rotation service the general conclusion of the discussions in the MERIT and COTES Working Groups is that the new service should be based on both laser ranging and VLBI and should also utilise any other appropriate data that are made available to it.

3.2 Organisation of the international services

The success of the MERIT Main Campaign suggests that the organisational structure and procedures for the new service should be modelled on those adopted for the campaign, but with modifications to suit the smaller scale and different requirements of the new service.

The principal features of the proposed organisation are as follows:

(1) A Central Bureau that would receive rapid and final results from the coordinating and analysis centres and would derive and disseminate earth-rotation parameters and information relating to the reference frames.

(2) Coordinating Centres, each of which would be responsible for coordinating the observational and data processing activities associated with one technique or task. Within a given technique it may be necessary to include operational network centres and analysis centres in order to spread the load of work and make the best use of the available expertise.

(3) 'Observatories' that would be willing to supply observational data regularly to the appropriate coordinating centre. (An 'observatory' in this context could be a network of stations administered by a single organisation.)

(4) A Directing Board that would consist of representatives of the Unions and of the Central Bureau and Coordinating Centres and that would exercise general administrative and technical supervision of the activities of the Service, and would ensure that it continues to meet the changing needs of the wide user community.

In the first instance there would be coordinating centres for (1) very long baseline radio interferometry (VLBI), (2) satellite laser ranging (SLR) and (3) lunar laser ranging (LLR). Additional coordinating centres may be designated for the improvement of the determination of the earth-rotation and reference-frame parameters by other techniques or for related activities. The service would be concerned with all aspects of the rotation of the Earth, including the precession and nutation of the pole of rotation in space as well as the motion of the pole within the Earth. The primary task of the service would be to

monitor the changing orientation of the Earth in space, but it would also endeavour to ensure that relevant data on the atmosphere, oceans and seismic events are available for operational purposes and research.

3.3 Fundamental concepts

The improvement in the precision with which it is possible to determine the earth-rotation parameters and the positions of the observing stations makes it necessary to define more precisely the reference frames to which the coordinates and the parameters apply. The crust of the Earth is subject to deformation on local, regional and global scales and so it is not possible to define a terrestrial reference frame simply in terms of a principal axis and one station to define zero longitude. The only feasible alternative is to adopt a catalogue of coordinates and their rates of change for a set of (fundamental) reference stations. (This will be analogous to the catalogue of the positions and proper motions of the fundamental stars that now defines the stellar reference frame.) It is recommended that the data in this catalogue be chosen to preserve continuity with the present reference frame and to have no net rotation of the reference stations with respect to the frame.

The usual earth-rotation parameters (UT and the coordinates of the pole) relate the terrestrial reference frame to the celestial reference frame of date, which is related to the celestial reference frame of J2000.0 through the adopted numerical theories of precession and nutation. This fundamental frame is defined by a catalogue of bright stars, whose positions and proper motions have been chosen so that the frame shall correspond as closely as possible to the dynamical reference frame used in constructing the fundamental ephemerides of the planetary system. The VLBI observations determine the orientation of the terrestrial reference frame directly with respect to an adopted catalogue of positions of extragalactic sources and it is recommended that in the future the conventional celestial reference system be defined by such a catalogue together with the appropriate astronomical theories that relate it to the celestial reference frame of date.

4. RECOMMENDATIONS

The three recommendations given in annex 2 were adopted, subject to editorial amendment, at a joint meeting of the MERIT Steering Committee and the COTES Working Group that was held at Columbus, Ohio, on 1985 August 3. Earlier drafts had been subject to critical review at the MERIT Workshop on July 30 and by interested participants in the Conference on Earth Rotation and Reference Systems held on July 31 to August 2. The joint meeting also adopted a draft resolution for consideration by a Joint Meeting of IAU Commissions 19 and 31 on 1985 November 22 during the XIXth General Assembly of the IAU at New Delhi. Amended versions of this resolution were adopted by the Joint Meeting and subsequently by the Union on 1985 November 28; the principal

change was the insertion of a recommendation that "an optical astrometric network be maintained for the rapid determination of UT1 for so long as this is recognised to be useful". A further recommendation concerning the assignment of responsibility within the IAU for matters relating to the celestial and terrestrial reference systems was adopted by the MERIT/COTES meeting on August 3 and served to stimulate a discussion within the IAU, but no decision was announced.

The final version of the IAU resolution on the MERIT/COTES programme and recommendations is given in annex 3. In effect the resolution endorsed this report and the principal recommendations on concepts, organisation and interim arrangements. As a consequence the MERIT and COTES Working Groups will be replaced by Provisional Directing Board for the new International Earth Rotation Service which it is hoped will come into operation on 1988 January 1. The IAU resolution will be submitted to the Executive Committee of the International Association of Geodesy for endorsement. The recommendations of the Provisional Directing Board will be considered by the IUGG during its XIXth General Assembly in Vancouver, BC, in 1987.

REFERENCES

Calame, O (ed), 1982. High-precision Earth rotation and Earth Moon dynamics: lunar distances and related observations. (Proceedings of IAU Colloquium No 63, Grasse, France, 1981 May 22-27.) Reidel, Dordrecht, Holland.

Feissel, M (ed), 1986. Catalogue of results of the MERIT/COTES Main Campaign, 1983 September 1 to 1984 October 31. (*Part 3.) Bureau International de l'Heure, Paris, France.

Feissel, M, & P Wilson (eds), 1983. MERIT campaign: connection of reference frames: implementation plan. Bureau International de l'Heure, Paris, France.

Gaposchkin, E M, & B Kolaczek (eds), 1981. Reference coordinate systems for Earth dynamics. (Proceedings of IAU Colloquium No 56, Warsaw, Poland, 1980 September 8-12.) Reidel, Dordrecht, Holland.

McCarthy, D D, & J D H Pilkington, 1979. Time and the Earth's rotation. (Proceedings of IAU Symposium No 82, Cadiz, Spain, 1978.) Reidel, Dordrecht, Holland.

Melbourne, W, (ch), 1983. Project MERIT standards. US Naval Observatory Circular no. 167.

Mueller, I I (ed), 1984. Meetings of the MERIT Working Group, Sopron, Hungary, July 10-12, 1984. CSTG Bulletin No 7, 97-147.

Mueller, I I (ed) 1985. Proceedings of the International Conference on Earth Rotation and the Terrestrial Reference Frame, Columbus, Ohio, July 31 - August 2, 1985. (*Part 2.) Department of Geodetic Science, Ohio State University, Columbus, Ohio, USA.

Wilkins, G A (ed), 1980. A review of the techniques to be used during Project MERIT to monitor the rotation of the Earth. Published jointly by Royal Greenwich Observatory, Herstmonceux,UK, and Institut für Angewandte Geodäsie, Frankfurt, GFR.

Wilkins, G A, & M Feissel (eds), 1982. Project MERIT: Report on the Short Campaign and Grasse Workshop with observations and results on earthrotation during 1980 August-October. Royal Greenwich Observatory, UK.

Wilkins, G A (ed), 1984. Project MERIT: Report on the Second MERIT Workshop and on other activities in 1983. Royal Greenwich Observatory, UK.

Wilkins, G A (ed), 1986. Report on the Third MERIT Workshop and Joint MERIT/COTES Meeting, Columbus, Ohio, 29-30 July & 3 August 1985. (* Part 1.) Royal Greenwich Observatory, UK.

* These three reports are parts 1, 2 and 3 of the series "Report on the MERIT/COTES Campaigns on Earth Rotation and Reference Systems".

ANNEX 1. PARTICIPATION IN THE MERIT AND COTES PROGRAMMES

A. IAU/IUGG Joint Working Group on the Rotation of the Earth (MERIT)

Chairman: G A Wilkins (UK, Royal Greenwich Observatory)
Vice Chairman: I I Mueller (USA)

Steering Committee and other coordinators for Project MERIT

C D Boucher (France)	Colocations by Doppler tracking
O Calame (France)	Lunar laser ranging
W E Carter (USA)	Very-long-baseline radio interferometry
J O Dickey (USA)	Atmospheric angular momentum studies
M Feissel (France)	Coordinating Centre
W J Klepczynski (USA)	Connected-elements radio interferometry
R W King (USA)	Intercomparison of techniques
M Lefebvre (France)	Doppler tracking of satellites
W G Melbourne (USA)	Standard models and constants
B E Schutz (USA)	Satellite laser ranging
P Wilson (Germany)	Colocations by SRL and VLBI
F N Withington (USA)	Data communications
K Yokoyama (Japan)	Optical astrometry

Other members of the Working Group:

L Aardoom (Netherlands)	V Abalakin (USSR)	R J Anderle (USA)
P Bender (USA)	J Campbell (Germany)	R Coates (USA)
*B Elsmore (UK)	Y L Kokurin (USSR)	Y Kozai (Japan)
*J M Latimer (USA)	D D McCarthy (USA)	P Morgan (Australia)
*J D Mulholland (USA)	*F Nouel (France)	P E C Paquet (Belgium)
*A R Robbins (UK)	D S Robertson (USA)	P Shelus (USA)
*E Silverberg (USA)	D E Smith (USA)	B D Tapley (USA)
S Tatevian (USSR)	R O Vicente (Portugal)	Y S Yatskiv (USSR)
Ye S (China)		

*Withdrawn

During the MERIT Short Campaign the coordinators for laser ranging were E Silverberg, L Aardoom (SLR) and J D Mulholland (LLR), and the principal coordinator for the Doppler tracking of satellites was F Nouel.

B. IAG/IAU Joint Working Group on the Establishment and Maintenance of the Conventional Terrestrial Reference System (COTES)

Chairman: I I Mueller (USA)

Members:

E M Gaposchkin (USA)	B Guinot (France)
B Kolaczek (Poland)	J Kovalevsky (France)
D D McCarthy (USA)	W G Melbourne (USA)
P Melchior (Belgium)	K Yokoyama (Japan)

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C. Participation in MERIT and COTES Campaigns

Short Campaign (SC): 1980 August 1 to 1980 October 31

Main Campaign (MC): 1983 September 1 to 1984 October 31

First Intensive Campaign: 1984 April to 1984 June 30

Second Intensive Campaign: 1985 May 23/31 June 6/14 June 21/29
July 6/14 July 20/28

Technique of observation	Number of observing stations		Number of operational centres		Number of analysis centres		Number of countries
	SC	MC	SC	MC	SC	MC	
Optical astrometry (OA)	85	61	1	2	2	3	22
Doppler tracking of satellites (DTS)	31	20	2	2	2	3	12
Satellite laser ranging (SLR)	22+9*	27	2	2+2^{-}	6	8	19
Lunar laser ranging (LLR)	2+1*	3	1	1	4	3	4
Connected-elements radio interferometry (CEI)	2	1	2	1	-	-	2
Very-long-baseline radio interferometry (VLBI)	6+3*	5+3^{+}	1	1+1^{+}	3	4+1^{+}	5

Observing stations were operated in 35 countries; results were reported by analysis centres in 7 countries.

The positions of 203 sites were determined by Doppler tracking.

*The data from these stations were insufficient for use in the analyses.

-Separate data collection centres +Separate Deep-Space Network

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ANNEX 2. PRINCIPAL RECOMMENDATIONS OF THE MERIT AND COTES WORKING GROUPS

A. Technical recommendation on concepts

The IAU/IUGG MERIT and COTES Joint Working Groups recommend that the following concepts be incorporated in the operation of an international earth-rotation service:

1. The Conventional Terrestrial Reference System (CTRS) be defined by a set of designated reference stations, theories and constants chosen so that there is no net rotation or translation between the reference frame and the surface of the Earth. The frame is to be realized by a set of positions and motions for the designated reference stations.

2. The Conventional Celestial Reference System (CCRS) be defined by a set of designated extragalactic radio sources, theories and constants chosen so that there is no net rotation between the reference frame and the set of radio sources. The frame is to be defined by the positions and motions of the designated radio sources. The origin of the frame is to be the barycentre of the Solar System.

3. This international service should provide the information necessary to define the Conventional Terrestrial Reference System and the Conventional Celestial Reference System and relate them as well as their frames to each other and to other reference systems used in the determination of the earth-rotation parameters. The information should include, but not be limited to, pole positions, universal time, precession, nutation, dynamical equinox, positions of the designated reference stations and radio sources, and crustal deformation parameters.

B. Recommendation for the organisation of a new international earth-rotation service

The IAU/IUGG MERIT and COTES Joint Working Groups recommend that IAU and IUGG establish a new international service within FAGS for monitoring the rotation of the Earth and for the maintenance of the Conventional Terrestrial Reference System to replace both the International Polar Motion Service (IPMS) and the Bureau International de l'Heure (BIH) as from 1988 January 1.

The new service will be known as the International Earth-Rotation Service (IERS) and will consist of a Directing Board, a Central Bureau, coordinating centres and associated network centres, analysis centres and observatories. The Central Bureau, the centres and the observatories will be hosted by national organisations.

The Directing Board will exercise organisational, scientific and technical control over the activities and functions of the Service including such modifications to the organizational structure and participation in the Service as are appropriate to maintain an efficient and reliable service while taking full advantage of advances in technology and theory. The voting membership of the Directing board will consist of one representative each of the IAU, the IUGG, the Central Bureau, and each of the coordinating centres. Additional nonvoting members may be appointed to advise the Board on complex technical and scientific issues.

The Central Bureau will combine the various types of data collected by the Service to derive and disseminate to the user community the earth-rotation parameters in appropriate forms, such as predictions, quick-look and refined solutions, and other information relating to the rotation of the Earth and the associated reference systems. The Central Bureau will conduct research and analysis to develop improved methods of processing and interpreting the data submitted. The Central Bureau may include sub-bureaus that carry out some of the specific tasks of the Central Bureau.

Coordinating centres will be designated for each of the primary techniques of observation to be utilized by the service as well as for other major activities which the Directing Board may deem appropriate. Initially, there will be three centres for (1) very long baseline interferometry (VLBI), (2) satellite laser ranging (SLR), and (3) lunar laser ranging (LLR). Additional coordinating centres may be designated for the improvement of the determination of the earth-rotation parameters and the maintenance of the conventional reference system by other techniques and to ensure that relevant data on the atmosphere, oceans and seismic events are available.

The coordinating centres will be on the same level as the Central Bureau in the organizational structure of the Service and will be responsible for developing and organizing the activities by each technique to meet the objectives of the service. Associated with the coordinating centres there may be network centres for subsets of observatories that may, for reasons of geometry or system compatibility, work more efficiently as autonomous units. There may also be associated analysis centres to process the observational data regularly or for special applications and studies; these centres may submit their results directly to the Central Bureau.

National Committees for the International Unions for Astronomy and for Geodesy and Geophysics will be invited to propose before 1987 January 1 national organizations and observatories that will be willing to host the Central Bureau or one of the centres and/or to provide observational data for use by the Service.

It is essential that the new service has redundancy throughout the organisational structure to ensure the uninterrupted timely production

of consistent, accurate and properly-documented earth-rotation and reference-frame parameters, even in the event that one of the host national organizations should terminate its participation. A widespread distribution of observatories that regularly make high-precision observations by one, or preferably more, modern space techniques by fixed and/or mobile equipment will be needed for this purpose, and national organisations are urged to provide appropriate resources.

C. Recommendation on interim arrangements

The IAU/IUGG MERIT and COTES Joint Working Groups recommend that the following actions be taken to consolidate the advances made as a result of the MERIT/COTES campaigns and to prepare for the establishment of the new international earth-rotation service:

1. That the MERIT/COTES programme of international cooperation in observation, analysis, intercomparison and distribution of results be extended until the new service is in operation.

2. That a Provisional Directing Board for the new service be set up, as soon as possible after the XIXth IAU General Assembly, for the following purposes:

(a) to draft terms of reference for the functions and organisation of the new service;

(b) to consider proposals from National Committees for organisations that offer to host the individual components of the new service, and then to recommend an appropriate organisational structure and composition; and

(c) to serve as the Steering Committee for the extended MERIT/COTES programme.

3. That the Provisional Directing Board consist of:

(a) a Chairman: the present chairman of the Joint Working Group on the Rotation of the Earth (MERIT);

(b) a Vice-Chairman: the present chairman of the Joint Working Group on the Terrestrial Reference System (COTES); and

(c) other persons selected by them from the Joint Working Groups and subject to the approval of the Presidents of IAG and of IAU Commissions 19 and 31.

4. The Provisional Directing Board shall report regularly to the Executive Committees of the IAU and IAG and shall submit its recommendations on the terms of reference, structure and composition of the new service for consideration at the XIXth IUGG General Assembly in 1987.

ANNEX 3. RESOLUTION OF INTERNATIONAL ASTRONOMICAL UNION (1985)

The following resolution was adopted at the XIXth General Assembly of the International Astronomical Union at New Delhi on 1985 November 28.

The International Astronomical Union,

recognizing the highly significant improvement in the determination of the orientation of the Earth in space as a consequence of the MERIT/COTES programme of observation and analysis, and

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

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

endorses the final report and recommendations of the MERIT and COTES Joint Working Groups;

decides (1) to establish in consultation with IUGG a new International Earth Rotation Service within the Federation of Astronomical and Geophysical Services (FAGS) for monitoring earth-rotation and for the maintenance of the Conventional Terrestrial Reference Frame; the new service is to replace both the IPMS and the BIH as from 1988 January 1;

(2) to extend the MERIT/COTES programme of observation, analysis, intercomparison and distribution of results until the new service is in operation;

(3) to recommend that an optical astrometric network be maintained for the rapid determination of UT1 for so long as this is recognised to be useful;

(4) to set up a Provisional Directing Board to submit recommendations on the terms of reference, structure and composition of the new service, and to serve as the Steering Committee for the extended MERIT/COTES programme;

invites National Committees for the International Unions for Astronomy and for Geodesy and Geophysics to submit proposals for the hosting of individual components of the new service by national organisations and observatories; and

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