

Project MERIT and the Formation of the International Earth Rotation Service

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Abstract. Project MERIT was an international programme to Monitor Earth Rotation and Intercompare the Techniques of observation and analysis. It was conceived by a working group that was set up by the International Astronomical Union in 1978 and was carried through with additional support from the International Union of Geodesy and Geophysics. The first objective was to encourage the development of the use of new techniques, such as laser ranging and radio interferometry, for the regular determination of universal time and polar motion. A successful 'short campaign' of observations by six techniques was carried out during the period 1980 August to October. Operational and analysis centres were set up for each technique and a coordinating centre was established at the Bureau International de l'Heure (BIH). The results were reported and discussed at the first MERIT Workshop in 1981.

The preparations for the 'main campaign', which was held from 1983 September 1 to 1984 October 31, and the plans for the activities that were to follow it were reviewed at the second MERIT Workshop in 1983. Important additional features of the campaign included the use of 'MERIT Standards' for the reduction and analysis of the data, the use of electronic techniques for the distribution of data, the comparison of the results with the changes in the angular momentum of the atmosphere and special emphasis on the improvement of the terrestrial reference frame. Proposals for a new International Earth Rotation Service were prepared at the third MERIT Workshop in 1986. The MERIT programme was continued from 1984 until the new service formally started on 1988 January 1. Over the decade the accuracy of the Earth-rotation parameters improved considerably.

1. Introduction

The principal objective of Project MERIT was to Monitor Earth Rotation and Intercompare the Techniques of observation and analysis. It stemmed from demonstrations during the 1970s that new techniques of observation could be used to determine the parameters that represented the variations in the rotation of the Earth. It was claimed that it would be possible to achieve a higher accuracy than was possible with the classical technique of optical astrometry. This technique was then used by the astronomical observatories whose results were used by the Bureau International de l'Heure, in Paris, France, and the

International Polar Motion Service, in Mizusawa, Japan. The former (BIH) was primarily concerned with the determination of Universal Time, which depended on the variations in the rate of rotation of the Earth, while the latter (IPMS) determined the changing coordinates of the pole of rotation of the Earth with respect to the pole of figure.

This topic was discussed at IAU Symposium 82 on 'Time and the Earth's Rotation,' which was held at San Fernando, Spain on 1982 May 8–12, and a recommendation for the setting up of an appropriate working group was adopted. Consequently, a Working Group on the Determination of the Rotation of the Earth was set up by Commissions 19 and 31 of the International Astronomical Union (IAU); the chairman was G. A. Wilkins. The group held its first meeting at Columbus, Ohio, in 1978 October and decided to put forward a proposal for action that became known as Project MERIT. Details of the proposal were elaborated by correspondence and position papers on each of the techniques and other aspects of the proposal were written by appropriate experts.

The *Draft Proposal for Project MERIT* was endorsed by the General Assembly of the IAU that was held in Montreal, Canada, in 1979 August. Additional position papers were added before the proposal was presented at the General Assembly of the International Union of Geodesy and Geophysics (IUGG) that was held in Canberra, Australia, in 1979 December. In supporting the proposal, the IUGG suggested that a Joint Working Group be set up. This was done, and the project also received the support of COSPAR through its Interdisciplinary Scientific Commission B.2. The documents that formed the *Draft Proposal* were subsequently incorporated in a widely distributed report (Wilkins 1980), which contained over 100 references and a list of about 90 organisations and observatories that had already agreed to participate in the project.

The Joint IAU/IUGG Working Group initially had 30 members to ensure a wide coverage by discipline and country. It had a steering committee that consisted of the chairman (Wilkins), the vice-chairman (I. I. Mueller) and eight 'principal coordinators', each of whom was assigned responsibility for the organisation of a specified activity; some other members of the group also had specific responsibilities. (These numbers changed later.)

2. The objectives of Project MERIT

The first objective of Project MERIT was to foster the development of new techniques for monitoring Earth-rotation parameters (ERPs), and in so doing to obtain precise data on these ERPs. The second objective was to make recommendations on future international services, which should be effective, economical and permanent. From 1981 onwards the objectives were extended to include the establishment of a new conventional terrestrial reference system in cooperation with the new Working Group (referred to as COTES) under the chairmanship of I. I. Mueller.

3. Techniques used in Project MERIT

Six different observational techniques were used throughout Project Merit. They were as follows:

Optical Astrometry (OA). This classical technique is based on the observation, by visual or photographic methods, of the times and zenith distances of the transits of selected stars across the local meridian, often near the zenith to reduce the effects of refraction in the atmosphere.

Doppler Tracking of Satellites (DTS). This technique made use of the observation of the Doppler shifts in the radio emissions of the system of artificial satellites that was operated by the U.S. Navy and used for navigational purposes. The coordinates of the pole were a by-product of the orbit computations and were already made available to the BIH for its 'rapid service' for polar motion.

Satellite Laser Ranging (SLR). This technique uses the results from the analysis of the times of propagation of pulses of laser light to and from satellites that are fitted with retroreflectors. Particular use was made of the observations of the spherical satellite Lageos that was launched in 1976 for geodetic purposes.

Lunar Laser Ranging (LLR). In this case the retroreflectors are on the Moon and so LLR is more technically demanding than SLR. The results from LLR have been of great importance but only a very few observatories have succeeded in making the regular observations over long periods that are needed for Earth-rotation purposes.

Connected-Element Radio Interferometry (CEI). This technique uses observations of distant radio sources by a minimum of two fully-steerable radio antennas that are connected directly by cable or radio to a correlator that can analyse the data in real-time.

Very-Long-Baseline Radio Interferometry (VLBI). In this case, the signals from the antennas, which are separated by much greater distances than is possible for CEI, are recorded on magnetic tapes which are sent to a central correlation facility for analysis.

In addition, the project involved several features that contributed to the eventual success of the project. Most importantly, there was the coordination of, and cooperation among, the many different observational groups that participated in the project. The speedy and reliable transmission of data was vital and was achieved partly by telex, but mainly by the pioneering use of the commercial computer-network system known as GE Mark III, which was an ancestor of the Internet.

At the start of the project the various groups involved used a wide variety of sets of parameters and methods for the reduction and analysis of the observations. Standardization was essential to the understanding of the significance of the differences between the results from different groups using the same or different observational techniques or sets of data. The value of the 'MERIT Standards' that were developed during the project was so great that they were subsequently adopted in other fields of astronomy and geophysics.

The colocation of observational facilities for different techniques on the same site was another feature of the project that proved to be of great value in the comparison of the techniques and in the establishment of consistent coordinate reference frames for general use.

Perhaps the most significant decision that was taken was to organize an early 'Short Campaign' that would, it was hoped, demonstrate the feasibility of the project, encourage participation and provide a firm basis of experience on which to base the planning for the 'Main Campaign'. These hopes were fulfilled.

It was later realized that it would be of value to organize 'intensive campaigns' of observation in order to provide dense data sets over short intervals. Such data could be analyzed for special purposes, such as better intercomparisons of the techniques, the improvement of the terrestrial reference frame or the detection of short-period terms in the variations in the ERPs, for which the regular data were inadequate.

4. Participation in Project MERIT during the Short Campaign in 1980

The MERIT Short Campaign was held during the three-month period 1980 August 1 to October 31 and observations were made at over 150 stations in 35 countries. The distribution of the stations by technique was as follows: OA, 63, with 85 instruments; DTS, 31; SLR, 32; LLR, 3; CEI, 2; VLBI, 6 + 3(DSN).

The Coordinating Centre for the project was at the BIH and there were one or two 'operational centres' (usually from USA and/or France) for each technique of observation. In addition, 17 organisations, from 6 countries, acted as 'analysis centres', some of them for two techniques. The arrangements for the electronic interchange of data were made in a seventh country, and so the responsibilities were shared on a truly worldwide basis.

Each operational centre was responsible for coordinating the observational activities for a group of stations by, for example, issuing predictions or schedules. It would receive and process quick-look data from the stations and forward the results to the Coordinating Centre for use in the compiling the rapid-service results. Each operational centre would later receive the final data from the stations and forward them to the Coordinating Centre and to those analysis centres that had offered to analyze them. In turn, the analysis centres sent their results to the Coordinating Centre at BIH, which had the tasks of publishing them, of making a combined solution to give the final results from the Campaign, and of archiving the data for use in any further analyses. Some of the analysis centres also made combined solutions.

During the Short Campaign the principal coordinators were as follows: OA: K. Yokoyama (Japan); DTS: F. Nouel (France); LR: E. Silverberg (USA); CEI: W. J. Klepczynski (USA); VLBI: W. E. Carter (USA); Coordinating Centre: M. Feissel (France); and Standards: W. G. Melbourne. In addition, L. Aardoom (Netherlands) and J. D. Mulholland (USA) acted as coordinators for SLR and LLR, respectively, while P. Morgan (Australia) managed the use of the GE Mark III network for data communications.

Similar arrangements were made during the Main Campaign and were continued by the new International Earth Rotation Service (IERS), although it uses the names 'Coordinating centre for technique' and 'Central Bureau' instead of 'Operational centre' and 'Coordinating Centre'.

5. The subsequent programme of PROJECT MERIT

The operational experiences of the Short Campaign were reviewed at the First MERIT Workshop, which was held on 1981 May 19–21 at Grasse, France, immediately before IAU Colloquium 63 on 'High-precision Earth rotation and Earth-

Moon dynamics' (Calame 1982), during which many results from the Short Campaign were presented. The primary purpose of the Workshop was to consider what changes of procedure would be required and what further action should be taken to prepare for the Main Campaign. It was agreed that this should be held between 1983 September 1 and 1984 October 31 and that the Second MERIT Workshop should be held in 1983 May to provide an opportunity to review progress and to take any further decisions that might be required. An account of the proceedings of the first Workshop was published with reports by the coordinators of the Short Campaign (Wilkins and Feissel 1982); tabulations of results were also included.

During 1982 the proposals of the MERIT and Cotes Working Groups were submitted and endorsed at the General Assembly of the International Association of Geodesy (IAG), which met at Tokyo in 1982 May, and at the General Assembly of the IAU, which met at Patras in 1983 August.

The Second MERIT Workshop was held at the Royal Greenwich Observatory at Herstmonceux Castle, Sussex, England, on 1983 May 15–19. It provided opportunities to review recent developments and for discussions and decisions about the plans for the Main Campaign that would start a few months later. Particular attention was paid to matters of common concern, such as the MERIT standards, COTES and colocations, data flow, communications and the publication of results. Reports on the plans for the contributions by the USSR and China were also received. The report of the Workshop (Wilkins 1984) also includes a note about the role of the coordinators and notes on two other MERIT-related activities. Firstly, on the discussion meeting on short-period fluctuations in Earth-rotation that was held by the Royal Astronomical Society in London on May 13 just before the MERIT Workshop; the programme shows that several members of the MERIT Working Group presented papers about their work. Secondly, on the General Assembly of the IUGG that was held in Hamburg in August; the main conclusions of further discussions on MERIT activities are given, relevant contributions at the meetings of IAG Sections and at IAG Symposia are listed, and the texts of several IUGG resolutions are reproduced.

The attendance at MERIT Workshops was not restricted to members of the MERIT Working Group; rather the meetings were open to all who were participating in the project. The proceedings were informal, with a mixture of plenary sessions and technical meetings to discuss particular techniques or issues. There was much discussion between sessions as the workshops were held at places where there were communal meals and accommodation at hand. Every effort was made to reach decisions by consensus, and voting was rare. Members of the Working Group, and especially members of the Steering Committee, took other opportunities to meet, and to publicise the MERIT project, while attending other conferences. The chairman of MERIT also issued MERIT Newsletters from time to time, and progress reports were published in IAU Information Bulletins and in the IUGG Chronicle, so that the astronomical and geodetic communities were aware of past and proposed activities.

The MERIT Main Campaign ran from 1983 September 1 to 1984 October 31 under arrangements that generally followed the same pattern as for the Short Campaign. The participation was, however, substantially greater for the new techniques. It included the COTES Intensive Campaign during the period 1984 April 1 to June 30, and it was followed by the Second COTES Campaign during

1985 May 1 to July 31. The Coordinating Centre at BIH published Monthly Circulars that contained the reports and results that had been received from the coordinators for each technique. The improvements in the quality of the results that were being obtained by laser ranging and VLBI were so clear that their levels of activity were maintained and even increased after the end of the Main Campaign.

During the Main Campaign the principal coordinators were as follows: LLR: O. Calame (France); VLBI: W. E. Carter (USA); Coordinating Centre: M. Feissel (France); CEI: W. J. Klepczynski (USA); DTS: M. Lefebvre (France); Standards: W. G. Melbourne (USA); SLR: B. E. Schutz (USA); and OA: K. Yokoyama (Japan). Other coordinators were: Colocations by DTS: C. D. Boucher (France); Atmospheric angular momentum studies: J. O. Dickey (USA); Intercomparison of techniques: R. W. King (USA); Colocations by SLR and VLBI: P. Wilson (Germany); and Data communications: N. Withington (USA).

The phases of the MERIT-COTES Main Campaign may be summarised as follows.

1. Planning, including the development of standards, scheduling, communications, procedures and publications.
2. Observations by 6 techniques from a worldwide set of stations.
3. Analysis of the observational data for current Earth-rotation parameters, the evaluation of errors, the improvement of models (and reference systems), and a consistent set of station coordinates.
4. Review, including comparisons of the results and the critical evaluation of the techniques taking into account many different factors.
5. Preparation of recommendations for future international services for Earth rotation and reference frames.

The Third MERIT Workshop took place on 1985 July 29 to 30 at Columbus, Ohio, in advance of the International Conference on 'Earth Rotation and the Terrestrial Reference Frame' that was held on July 31 to August 2. This was followed on August 3 by a joint meeting of the MERIT Steering Committee and the COTES Working Group. The main purpose of the Workshop was to provide a firm basis for recommendations on the future international services for monitoring the rotation of the Earth and for the establishment and maintenance of a new conventional terrestrial reference system. Unfortunately, the chairman of the MERIT Group failed to complete the preparation of the report of the proceedings of the Workshop before other tasks took up all his time; this was planned to be Part I of the report on the MERIT-COTES campaign. The proceedings of the Conference were, however, published as Part II (Mueller 1986) and the observational results on Earth-rotation and reference systems were published in Part III (Feissel 1986). The latter reproduces the Monthly Circulars that were issued during the campaign and includes the results of analyses of the data that were submitted by the analysis centres after the end of the campaign.

The final details of the MERIT-COTES recommendations were settled by correspondence and then submitted to the IAU for consideration at the IAU General Assembly that was held in Delhi on 1985 November 19–28. The recommendations included statements of the concepts that should be used in the specification of new reference systems for terrestrial and celestial reference sys-

tems. A joint summary report was presented by Wilkins and Mueller (1986) at a joint meeting of Commissions 19 and 31. The recommendations (with minor amendments) were later endorsed by the General Assembly. In particular it was agreed (1) to establish a new 'International Earth Rotation Service' (IERS), (2) to continue the MERIT-COTES programme in the meantime, (3) to set up a Provisional Directing Board for IERS and (4) to invite proposals for participation in IERS. Wilkins and Mueller later became the chairman and vice-chairman, respectively, of the board.

The board met at various conferences during 1986 and 1987 to discuss progress towards the establishment of the IERS and the details of the arrangements for the management of the new organisation, which would depend almost entirely on local support for the financing of its operations. One fundamental decision to be made concerned the selection of the techniques that would be used in the new service. A suggestion that the service should be based solely on VLBI did not find general favour as most felt that SLR should continue to contribute regularly. There was, however, a greater division of opinion about the role of LLR as it was not clear that this technique would be funded at a level that would enable it to contribute at its full potential. Eventually it was agreed that it should be included, especially as it could, for example, make a unique contribution to the linking of the terrestrial and celestial reference frames. Another important matter to be settled was the choice of the coordinating centres for the techniques that would participate regularly in the service. This was also a sensitive issue as it was agreed that the director of each coordinating centre should be a member of the Directing Board of IERS.

A major opportunity for presentations about the MERIT-COTES project, as well as for meetings of the IERS board, was provided by IAU Symposium 128, which was held on 1986 October 20–24 at Coolfont, near Washington, DC, USA. The local organisation was provided by the staff of the US Naval Observatory, many of whom had contributed greatly to the project. The published proceedings (Babcock and Wilkins 1988) provide a snapshot of the progress in our knowledge and understanding of the variations in the rotation of the Earth. It also contains a review of the achievements of project MERIT (Wilkins 1988) that complements and extends the summary given below.

The recommendations adopted by the IAU in 1985 were endorsed by the IAG and IUGG during the IUGG General Assembly that was held in 1987 August at Vancouver, British Columbia. The MERIT-COTES operations continued to the end of 1987 so that there was a smooth transition to the operation of the International Earth Rotation Service on 1988 January 1. A meeting of the Directing Board was held during the IAU General Assembly in 1988 August. Wilkins stated that he would not continue as chairman as he would be retiring from the Royal Greenwich Observatory during 1989; Y.A. Yatskiv, who was representing the IAU on the Board, was elected to succeed him.

6. Achievements of MERIT and COTES

The achievements of the MERIT and COTES Working Groups and of all those who participated in the project may be summarised as follows.

1. Faster development of new techniques, giving results of improved accuracy at shorter intervals of time.
2. Greater cooperation between groups in different techniques and countries.
3. MERIT Standards in widespread use.
4. New scientific results, such as: the correlation between the length of day (LoD) and the angular momentum of the atmosphere (AAM); the demonstration of the smooth motion of pole; and the determination of relative motions of the stations.
5. Extensive data sets for further analysis (see Boucher *et al.* 1987).
6. New techniques in regular use now.
7. Agreement on proposals for a new International Earth Rotation Service and on concepts of new reference systems.
8. Good progress on new reference systems.

7. Factors contributing to the achievements of Project MERIT

Some of the factors that contributed to the achievements of Project MERIT are as follows, but there may well be others that have been overlooked during the preparation of this paper.

1. The enthusiasm and expertise of the coordinators and others with responsibilities for carrying through the programme.
2. The effort that went into the initial development of the proposal which gave the background, objectives, significance and outline programme, together with position papers for each of the techniques.
3. The wide distribution of information about the aims, plans and progress of the project.
4. a. The delegation of responsibility to principal coordinators for the activities in their areas.
b. The full involvement of the coordinators in the making of decisions about matters of common concern.
5. The wholehearted responses of local groups to the challenge and promise of the proposed campaigns.
6. The support given by national agencies (especially NASA) to the activities.
7. The extension of MERIT to include collaboration with the Working Group on the terrestrial reference system (COTES).
8. The way in which cooperation developed between competitive groups (perhaps as a result of the informal workshops).
9. The soundness of the initial planning plus flexibility in modifying the programme and the procedures while keeping within the original aims and timetable.
10. The decision to depend on local funding for almost all activities so that the Working Group could concentrate on technical matters.

Finally, the value of the acronym MERIT must not be overlooked.

8. Conclusion: a personal note

When I accepted in 1978 the unexpected nomination to be the chairman of the IAU Working Group on the Rotation of the Earth, I did not realize that it would play a dominant role in the next ten years of my life. Nor did I anticipate that I would gain so much satisfaction from my participation in the task that the group was asked to accomplish. I was delighted to be given the opportunity in 1998 to talk at an IERS Workshop in Potsdam about the MERIT activities and to meet again many of the colleagues with whom I had shared the 'MERIT experience.' In this paper I have tried to give an account that will be of interest to those who work in or with IERS, but who did not participate in its formation. Unfortunately, it has not been possible to convey any real impression of the way in which the project developed and of how differences of opinion were resolved amicably as those involved shared the same aim and had come to respect the viewpoints of others in the Group.

MERIT was a truly international project and so I visited many places that I would not otherwise have seen. More significantly, I made friendships that have enriched my life. I would like to take this opportunity to thank all those who gave me their support and assistance during MERIT; not only the members of the Group, but also the staff of the Royal Greenwich Observatory who assisted me directly or who had to take over work that I would otherwise have done. I also owe apologies to Dr. C. Boucher, who took on the job of secretary of the Federation of Astronomical and Geophysical Services after I gave up the position in 1978, and to Dr. P. K. Seidelmann, as I did not have the time to share with him the task of producing a new edition of the *Explanatory Supplement to the Astronomical Almanac*. I hope that they too found satisfaction in their extra work.

Acknowledgments. Although it is, perhaps, unjust to mention only two of the many persons who contributed to the MERIT project, I should like to acknowledge with grateful thanks the support of Professor Ivan Mueller and Dr. Martine Feissel throughout the whole of the project. Ivan hosted the first meeting of the Working Group and it was Martine who suggested the acronym MERIT, over lunch after the completion of the formal business of that meeting.

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Appendices

Further details about Project MERIT are given in the two appendices to this paper. The first gives a list of the meetings and other related activities that took place during the period 1978 to 1988; it both summarises the information given in the paper and supplements it by drawing attention to other meetings at which the project was discussed. The second appendix gives additional references to papers about the project that were written by the author as part of his attempts to encourage worldwide participation in the project and to obtain support for such activities.

Appendix 1. List of meetings and activities for Project MERIT

1978 May 8–13. IAU Symposium 182 on ‘Time and the Earth’s Rotation’ at San Fernando Spain. The meeting recommended the setting up of an IAU Working Group to promote the comparative evaluation of the techniques for the determination of the rotation of the Earth and the regular provision of high-precision data for technical applications and scientific analysis, with G. A. Wilkins as chairman. (It was known as the IAU WG on Earth Rotation.)

1978 October 5–6. First meeting of IAU WG at Columbus, Ohio, at invitation of Prof. I. I. Mueller. Agreed on outline of proposals for Project MERIT. The acronym was suggested by Martine Feissel for ‘Monitor Earth Rotation by International Techniques,’ but it was subsequently used for ‘Monitor Earth Rotation and Intercompare the Techniques of observation and analysis.’

1979 August 15–21. IAU General Assembly at Montreal. A draft proposal for the project was endorsed by the IAU at a joint meeting of Commissions 4, 19 and 31.

1979 December 3–15. IUGG General Assembly at Canberra. The GA endorsed the proposal and recommended that the WG be reconstituted as a Joint IAU/IUGG Working Group.

1980 July. The Royal Greenwich Observatory (Herstmonceux Castle) and Insitut für Angewandte Geodäsie (Frankfurt) jointly issued ‘A review of the techniques to be used during Project MERIT to monitor the rotation of the Earth.’

1980 August to October. The preliminary ‘MERIT Short Campaign’ was held to provide experience of the techniques for observing and for the communication, reduction and analysis of the data. A catalogue of the results was published by the Bureau International de l’Heure, Paris.

1980 September 8–12. IAU Colloquium 56 on ‘Reference Coordinate Systems for Earth Dynamics’ at Warsaw. The MERIT WG met and held an open meeting. The Colloquium adopted a recommendation for the establishment of a joint IAU/IUGG working group to prepare a proposal for the establishment and maintenance of a Conventional Terrestrial Reference System. The WG was subsequently established with Prof. I. I. Mueller as its chairman; it was known by the acronym COTES.

1981 May 18–21. First MERIT Workshop at Grasse, France. The activities during the Short Campaign were reviewed and planning for the Main Campaign was continued. It was agreed that observations to support the COTES objectives should be included.

1981 May 22–27. IAU Colloquium 63 on ‘High Precision Earth Rotation and Earth-Moon Dynamics’ at Grasse. The colloquium was organised in connection with the EROLD project for determining ‘Earth Rotation by Lunar Distances’ (by lunar laser ranging), but the first day was held jointly with the MERIT WG and covered all techniques. A resolution recommending that the MERIT Main Campaign be dedicated to the memory of Seth Carlo Chandler was adopted.

1982 May 10–14. General Meeting of the International Association of Geodesy in Tokyo. Two meetings of the WG and one meeting of its steering committee were held. The IAG endorsed the MERIT and COTES proposals.

1982 August 19. IAU General Assembly at Patras, Greece. Progress reports on MERIT and COTES were presented during a joint meeting of Commissions

19 and 31 on August 19. A resolution of support for the IAG resolutions was adopted and was later endorsed by the General Assembly. A meeting of the MERIT Steering Committee was also held on August 19.

1983 May 13. Joint meeting of the Royal Astronomical Society and the Royal Meteorological Society on 'Short-period fluctuations in the rotation of the Earth and their excitation by meteorological and other geophysical processes' in London. Several members of the MERIT WG presented papers.

1983 May 15–19. Second MERIT Workshop at the Royal Greenwich Observatory at Herstmonceux Castle. Reviews and discussion of past and future activities.

1983 August 15–26. IUGG General Assembly in Hamburg. The WGs met and papers relating to the projects were presented by members of the WGs.

1983 September 1 to 1984 October 31. The 'MERIT Main Campaign' was held throughout this period and additional observations were made during the period 1984 October 1 to June 30 for the COTES Intensive Campaign.

A catalogue of the results of the MERIT Main Campaign was published by the Bureau International de l'Heure, Paris. Various guides on operational procedures and related matters were also issued, including: 'Project MERIT Standards' (as USNO Circ. 167); 'Connection of reference frames' (by BIH).

1984 July 10–12. Meetings of the MERIT and COTES Working Groups were held at Sopron, Hungary, under the chairmanship of Prof. Mueller, during an international symposium on 'Space Techniques for Geodynamics.'

1985 May 1 to July 31. A second intensive campaign to better demonstrate the potential of lunar laser ranging observations was held during this period.

1985 June 6–8. Discussions were held at the Paris Observatory to prepare the ground for the third MERIT Workshop, especially in respect of the resolutions to be forwarded to the IAU and IUGG.

1985 July 29–30. The Third MERIT Workshop was held in Columbus, Ohio, and was attended by members of both the MERIT and COTES Working Groups. A joint meeting of the MERIT and COTES Steering Committees was held on August 3 to tie up loose ends in regard to the wording of the resolutions and further action. The 'Joint Summary Report' of the two working groups was published by the IAU and elsewhere.

The proceedings of the Workshop have not yet been published. The draft reports of the Coordinators (except Doppler tracking of satellites), together with other material, including a narrative report on the discussions, are now being prepared for publication by the GeoForschungs Zentrum at Potsdam.

1985 July 31 to August 2. An International Conference on 'Earth Rotation and the Terrestrial Reference Frame' was held at Columbus, Ohio. Many papers relating to the projects were presented. The proceedings were published by Ohio State University and a catalogue of 'Observational results on earth rotation and reference systems' from the MERIT Main Campaign was published by the Bureau International de l'Heure.

1985 November 19–28. IAU General Assembly in New Delhi, India. The Joint Summary Report was discussed at a joint meeting of Commissions 19 and 31 and the recommendations (with minor amendments) were later endorsed by the GA. In particular it was agreed to establish a new 'International Earth Rotation Service', to continue the MERIT/COTES programme in the meantime,

to set up a Provisional Directing Board for IERS, and to invite proposals for participation in IERS. (Wilkins and Mueller became the chairman and vice-chairman, respectively, of the PDB.)

1986 April 30 to May 1. The PDB met twice during the 'Fourth International Symposium on Geodetic Positioning' at Austin, Texas.

1986 September 15–19. A special meeting was held during the Symposium on the 'Figures and Dynamics of the Earth, Moon and Planets' in Prague to encourage participation by scientists from eastern Europe in the new service.

1986 October 20–24. The second meeting of the PDB was held during IAU Symposium 128 on 'The Earth's Rotation and Reference Frames for Geodesy and Geodynamics' at Coolfont, Virginia. This provided a further opportunity for the presentations related to the MERIT/COTES project.

1986 December 9. Wilkins took the opportunity to publicise MERIT/COTES and the proposals for IERS at the AGU Fall Meeting in San Francisco in a paper on 'NASA's contributions to the MERIT Project.'

1987 March 20 and 21. The third meeting of the PDB was held at the Jet Propulsion Laboratory, California, prior to a meeting on NASA's Crustal Dynamics Project..

1987 August 9–22. The IAU recommendations were endorsed by the IAG and then the IUGG during the IUGG General Assembly in Vancouver, British Columbia. A meeting of the PDB was also held.

1988 January 1. The new 'International Earth Rotation Service' formally commenced operations, replacing the Bureau International de l'Heure and the International Polar Motion Service.

1988 April 14. The PDB met at the Paris Observatory.

1988 August 2–11. The first meeting of the Directing Board of IERS was held during the IAU General Assembly in Baltimore. Wilkins retired from the chairmanship and Y. A. Yatskiv was elected as the new Chairman.

1988 August 23–27. The development and activities of IERS were the subject of several papers during the Symposium on the 'Figures and Dynamics of the Earth and Planets' in Potsdam, East Germany.

Appendix 2. Supplementary list of papers on Project MERIT

The following papers were all prepared by the chairman of the Merit Steering Committee (G. A. Wilkins).

1979, (editor, anon.). Draft Proposal for Project MERIT to be presented at IAU General Assembly, Montreal, 1979 August, together with additional position papers. (Limited distribution)

1981. A note on the origin, objectives and programme of Project MERIT. In: E. M. Gaposchkin and B. Kolaczek (eds.), *Reference Coordinate Systems for Earth Dynamics*, 275–276.

1982. A note on the initial results and future plans of Project MERIT. In: W. Fricke and G. Teleki (eds.), *Sun and Planetary System*, 163–4.

1982. Progress report on Project MERIT. In: O. Calame, (ed.), *High-precision Earth-Rotation and Earth-Moon Dynamics*, 147–8. Reidel.

1984. The determination of the fluctuations in the rotation of the Earth. *Phil. Trans. R. Soc. Lond. A* **38**, 191–9.

1985. The terrestrial coordinate system and international earth-rotation services. *J. Nav. (London)* **38**, 216–7.

1985. International cooperation in monitoring the rotation of the Earth. *Vistas in Astron.* **28**, 329–335.

1986. The background to the MERIT/COTES recommendations on the terrestrial and celestial reference systems. In: J.P. Swings (ed.), *Highlights of Astronomy*, **6**, 81–84.

1986. NASA's contributions to the MERIT project. Invited paper at meeting of American Geophysical Union at San Francisco.

1987. Report on recent developments in international collaboration in monitoring the rotation of the Earth and in establishing new terrestrial and celestial reference systems. Invited paper; abstract only in: *Proc. Int. Symp. Figures and dynamics of the Earth, Moon and planets*, Prague, 1986 Sept. 15–20, Part 3, 713–4.

1989. International cooperation in the study of the rotation of the Earth. In: *Proc. IUGG Symp. U4*, Vancouver, 1987.

1989. The development and activities of the International Earth Rotation Service. In: H. Montag (ed.), *Geodesy and the physics of the Earth, Moon and planets*, Part 1, 17–21. Proceedings of International Symposium, Potsdam, 1988, Veroff. Zentralinstitut. Phys. Erde, No. 102.

In addition 8 MERIT Newsletters containing current information about the project, as well as agenda papers, minutes, *etc.*, were distributed from the Royal Greenwich Observatory. Progress reports were also published in IAU Information Bulletins and Commission Reports and in the IUGG Chronicle.