THE INTERNATIONAL EARTH ROTATION SERVICE: CURRENT MISSION AND RECOMMENDATIONS FOR THE FUTURE

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1. INTRODUCTION

The six topics discussed at the Paris Workshop (October 1996) are listed in Table1.

Table 1. Topics of the 1996 IERS Workshop

Topic	Description	Topic Coordinators
1	Assessment of current missions	G. Beutler, I. Mueller
2	Astronomical reference frames	J. Kovalevsky, M. Standish
3	Vertical references, incl. geoid, sea level, etc	C. Boucher, B. Carter
4	Topography and crustal deformations	B. Engen, J.B. Minster
5	Unification of regional reference systems	W. Augath, J. Manning
6	Earth rotation dynamics and geophysical fluids	V. Dehant, C. Wilson

One of the duties of the Coordinators was to prepare a position paper with a small team of experts. The team for Topic 1 is that of the authors of the present report.

According to the instructions received the following questions had to be adressed (Table 2).

Table 2. Questions to be addressed under Topic 1. Assessment of Current Mission.

Number	Question
1.1	International Terrestrial Reference Frame (users, requirements, access)
1.2	International Celestial Reference Frame (users, requirements, access)
1.3	Earth Orientation Information (users, requirements, access)
1.4	IERS Conventions (Standards) (update rate, software for users)
1.5	Assessment of the structure of the IERS (Directing Board, Coordinating Centers, Bureaus, etc.)
1.6	Extension of IERS Missions

Obviously our Topic is the only one which is not primarily of a technical nature. In Topic 1 the organizational aspects are studied and modifications to the structure may be recommended. It is clear that our recommendations must be broad enough to accomodate any changes that might emerge from Topics 2 to 6.

The only question reaching in our opinion into the other fields is No 1.6, Extension of the IERS Mission. Without making the attempt to solve the other Topic Coordinators problems we would like that the following considerations are taken into account:

(1) We believe that the IERS should be a cooperative service shared by Astronomy, Geodesy and Geophysics. The three components should be kept in a balance.

(2) We believe that the global character of the service should be retained, without going too much into details that might be covered by other existing services like the IGS, PSMSL, IGeS, ICET, IGB or regional organizations. With reference to Table 1 we believe that

- the establishment and maintenance of the Astronomical Reference Frame must continue to be one of the primary responsibilities of the IERS

- only the global aspects of Topic 3 should be within the IERS responsibility (this is the case today),

- Topic 4 looks like a regional problem which should be addressed by IERS users in close cooperation with the ITRF section of the IERS,

- Topic 5 is a very desirable goal to achieve, but obviously the responsibility to perform such a task cannot be taken away from the government bodies responsible for mapping and cartography.

(3) We believe that instead, the IERS should revise its products to better serve these communities. The IERS must be a service in support of the national geodetic institutions (responsible for regional networks) with the IERS products, but should not make the attempt to replace them.

(4) In summary we believe that only Topics 1, 2 and 6 and the global aspects of Topic 3 are clearly within the IERS responsibilities. This is certainly true in view of the Terms of Reference as they are today (Appendix A).

(5) From the point of view of Space Geodesy, the IERS is the multi-technique service par excellence. It is e.g., clear from the outset that VLBI cannot produce a geocenter, neither can GPS or SLR produce UT1 and nutation series with good long-term stability. This multitechnique aspect should be given more emphasis in future. We would even argue that everything that does not involve at least two space geodetic techniques does NOT deserve the label "IERS". The exception to this statement is of course the celestial reference frame - at least in its present realization.

If we adopt this principle as an axiom we would have the perfect argument for a continuation of the optical reference frames - based today on the HIPPARCOS catalogue and new Earth-and space-based CCD astrometry techniques.

A first look at our task (Topic 1) made it clear that most of the questions that we have to address were already dealt with in detail at workshops held in the 1980's. In particular we would like to draw attention to the Airlie Workshop (Walters, 1984), to the Erice Workshop (Mueller and Zerbini, 1989), and, last but not least, to the Coolfont Report (NASA, 1991). It cannot be the task of our position paper to reproduce these studies; on the other hand it is clear that we have to base our considerations on these reports and to try to take into account the changes that took place since - of course only insofar as they are relevant to the IERS.

We notice moreover that most of the aspects of Question 1.2, International Celestial Reference Frame (users, requirements, access) would better be dealt within the frame of Topic 2, Astronomical Reference Frame. We will thus only address this issue when necessary in the context of the other issues of the present report.

The program for the 1996 IERS Workshop in Paris was distributed through the IERS Gazette (distribution list containing about 500 addresses). It is thus not surprising that we obtained spontaneously a few individual and voluntary comments and suggestions regarding our work. These contributions are appreciated and taken into account in this report. We decided to ask for additional comments from experts in the field such as the extended IERS Governing Board and others.

A first version of this position paper was made available to all workshop participants well before the beginning of the workshop. This distributed version served as the basis for the sessions devoted to Topic 1. As expected, the paper and its recommendations attracted much attention and created very useful and sometimes controversial discussions at the 1996 IERS Workshop. The attempt was made at the workshop to come up with a revised set of recommendations which seemed to reflect the general opinion of the workshop participants.

The last step consisted of thoroughly revising the position paper for Topic 1 after the 1996 IERS Workshop in Paris. Let us mention in particular, that Section 4 was completely rewritten to reflect the discussions at the Paris Workshop and to contain the adopted recommendations.

The revised version of the position paper is structured as follows:

Section 2: Current Situation of the IERS
Section 3: User Requirements
Section 4: Recommendations

2. CURRENT SITUATION OF THE IERS

Charter and Structure

Let us briefly review the Charter of the IERS as contained in the Terms of Reference. The current version was made available to us by Martine Feissel, Director of the Central Bureau and secretary of the IERS Directing Board, and is contained in Appendix A of this report.

The IERS Terms of Reference are short and clear: the IERS is responsible for the definition and maintenance of the Celestial and Terrestrial Reference Systems and for the determination of the Transformation Parameters between the reference frames of these systems. The latter part obviously consists of time series for polar motion, UT1, and precession/nutation. In addition the IERS is responsible for organising operational activities, management of data and results.

The IERS consists of the Central Bureau, Coordinating Centers and the Directing Board. According to Martine Feissel (private communication) the IERS Central Bureau is organized in the following way:

The Central Bureau is a joint effort of Paris Observatory and Institut Géographique National. The seat of the Central Bureau is at Paris Observatory. The work on Earth orientation and reference frames is performed by sections of the Central Bureau, as listed in the Table3.

Table 3. Organization of the IERS Central Bureau

Section	Institute	Head
Celestial reference frame	Observatoire de Paris	F. Arias
Terrestrial reference frame	Institut Geographique National	C. Boucher
Earth orientation	Observatoire de Paris	D. Gambis

The activity (Direction plus the three sections) add up to a workload of 7 man-years per year. It is performed by a total of 12-15 persons.

The Central Bureau is responsible for combining the various types of data and to disseminate the information on the appropriate information on Earth orientation and the two reference frames.

There are two IERS Sub-Bureaus, the Sub-Bureau for Rapid Service and Predictions (U.S. Naval Observatory), and the Sub-Bureau for Atmospheric Angular Momentum (NOAA, Washington) to accomplish well-defined tasks.

The Coordinating Centers are responsible for developing and organizing the activities within each technique. At present there are five Coordinating Centers (for VLBI, LLR, GPS, SLR, DORIS).

The IERS Directing Board is composed of representatives of

- the Central Bureau,
- all Coordinating Centers,
- IAU, IAG/IUGG, FAGS.

According to the current director of the Central Bureau, Sub-Bureau representatives and representatives of the Central Bureau Sections were also treated de facto as members of the Directing Board. More information concerning the work of the IERS components may be found in Appendix B (using the year 1996 as an example).

Products

Appendix C contains the list of regular publications of the IERS with some explanations as described in the IERS Annual Reports, Appendix D contains the distribution list for these reports. Most of the material is available in paper form and in electronic versions.

This aspect is in particular true and important for IERS Bulletins A and B.

The IERS Annual Reports contain the necessary information for the best current realizations of the ITRS and the ICRS as well as an evaluation of the time series for the transformation parameters between the two frames.

Not explicitly in the list, but probably one of the most important and outstanding products of the IERS, are the IERS Standards, or, as they are called today, the IERS Conventions. So far three versions of the Standards/Conventions were prepared and made publicly available (McCarthy, 1989, 1992, 1996).

3. USER REQUIREMENTS

The IERS, as probably each service, makes well defined products available to a broad variety users. Let us adopt for the following considerations a simplified scheme by introducing three types of users:

- Standard Users (SUs) of the IERS products. Government agencies like topographic services, navigation/geodetic services, geological services etc., are considered as SUs.

- Internal Research oriented Users (IRUs) directly involved in the work (technologies) of the IERS. In this category are e.g., scientists in the VLBI, SLR or GPS Analysis Centers who contribute directly to the IERS products.

- External Research oriented Users (ERUs) not involved in the operation of the IERS. Typical ERUs are researchers addressing fundamental issues related to the stability of the Earth, i.e., the temporal deformations and the variable rotation of the Earth on a variety of time scales.

The common requirement of the SUs and IRUs is the availability of correct transformation parameters (albeit with different levels of accuracy) between their respective terrestrial and astronomical frames of reference in use, while the ERUs are more interested in studies of the driving mechanisms of the transformation parameters (precession, nutation, polar motion and UT1) and/or in modeling them.

The SUs astronomical frame of reference is directly tied to their observations (e.g., stars in astronomical positioning) and they require IERS to provide transformation parameters based on internationally adopted reference systems so that they can provide coordinates which refer to an internationally adopted terrestrial frame.

The IRUs astronomical (inertial) frame is technique dependent (e.g., defined by a catalogue of radio sources or by the ephemerides of artificial satellites) and the transformation parameters have to be consistent with the technique dependent terrestrial frame as defined by the adopted coordinates of selected observatories or tracking stations. The transformation parameters usually are part of the solutions producing source coordinates (VLBI) or satellite ephemerides and station coordinates, and therefore the IRUs generally do not depend on the IERS to the same extent as the other users do. An exception is the quasi-daily measurement of UT1 by VLBI which benefits from independent determinations of polar motion by other techniques and which is used in turn by satellite geodetic IRUs.

Because the astronomical and terrestrial frames may be different for different techniques, the resulting transformation parameters may be different for different IRUs and their comparison or combination into a single series as a separate undertaking (primarily for the use of the ERUs) is a necessity. In any case the combined series (possibly several of them) should be made available through the IERS publications.

The ERUs requirements essentially are the same as those of the IRUs, except that there is neither the need nor the wish to deal with the IRUs individual series. Using current IERS combined products is problematic for various reasons, however (e.g., because of constraints inherent in the IERS products due to the current weighting and/or smoothing procedures) and at present they need access to one or more individual series more suitable for their specific applications.

In summary, one might say that the SUs and the ERUs are typical IERS users and that the IRUs are IERS "insiders". How to serve all user types? One option for the IERS would have been to generate different types of products for different types of users. This idea was not supported, however, by the majority of the participants of the 1996 IERS Workshop. A broad consensus was reached, instead, that the IERS should meet the most demanding requirements in one series of products which would then satisfy all types of users (ERUs, IRUs, and SUs). This was considered as a logical continuation of the policy pursued so far by the IERS.

In order to recognize these most demanding requirements we will elaborate on specific research requirements, based on the programmatic documents mentioned above (NASA, 1991, pp. 14-15; Walters, 1984, pp. 36-37).

As mentioned above the primary scientific objectives are related to the stability of the Earth, i.e., the temporal deformations and variations in Earth rotation on a variety of time scales. The challenge at the moment is to separate the noise from the signals and this is where multiple techniques become important, and where fundamental analyses that do not force results to pre-conceptions of the Earth behavior are needed.

The scientific objectives include the following (see also Topic 6 report):

- To observe and understand the interactions of air and water (oceans, ground water, ice) with the rotational dynamics of the Earth, and their contribution to the excitation of Earth rotation variations, over the time scales of hours to centuries.

- To observe and understand the effects of the Earth's crust and mantle on the dynamics and excitation of Earth rotation variations, over the same time scales.

- To observe and understand the effects of the Earth's core on the rotational dynamics of the Earth and excitation of Earth rotation variations over time scales of a year and longer.

- To establish, refine and maintain terrestrial and astronomical reference frames.

These objectives reflect the unique strength of studying Earth rotation variations to provide an absolute reference frame for geodynamics; provide global measures of mass redistribution and deformation due to hydrological and meteorological variability, tectonic activity, mantle convection, glacial melting, sedimentation and erosion; constrain the rheology of the lithosphere through observation of Earth rotation variations at the time of earthquake activity; study physical properties of and motions within the inaccessible core; and constrain magnitudes of viscous, magnetic, and pressure torques acting on the core mantle boundary.

The ERU goals include the following:

- Measurement of the rotation vector of the Earth with at least 0.1 mas precision and a temporal resolution nominally 4-6 times a day.

- Improve analysis and modeling capabilities to a level commensurate with the above spatial and temporal resolution.

- Geophysical, oceanographic and atmospheric data for the interpretation of the rotational and deformation data.

- Ties between the celestial and terrestrial reference frames at the few mm level.

- Plate motion measurements for at least three sites per major plate with auxiliary data such as gravity, seismic information at least at the key sites.

In closing, it should be pointed out that

- there never have been measurements on a global scale with the accuracy and time resolution now possible,

- large scale effects (such as pressure loading) deform the Earth more easily than small scale effects and that the response is very long wavelength. Therefore global (at least continental) scale measurements are more likely to see the effects than small scale measurements.

- there are many phenomena that ERUs expect to see (as deviations from steady state motion) but there are likely many that we do not know about yet, which is why the ERUs want as few constraints as possible on the data analysis,

- there is so much data that it is difficult for any one center to process it all.

4. RECOMMENDED FUTURE DEVELOPMENT

The current structure of the IERS was presented in Section 2: we have the Central Bureau consisting of the Celestial Frame Section (Observatoire de Paris), the Terrestrial Frame Section (IGN), and the Earth Orientation Section (Observatoire de Paris); currently there are two Sub-Bureaus and five Coordinating Centers (CCs). Figure 1 gives an impression of this structure. We made the distinction between two levels (not in a hierarchical sense), the Central Bureau Level and the Coordinating Center Level.

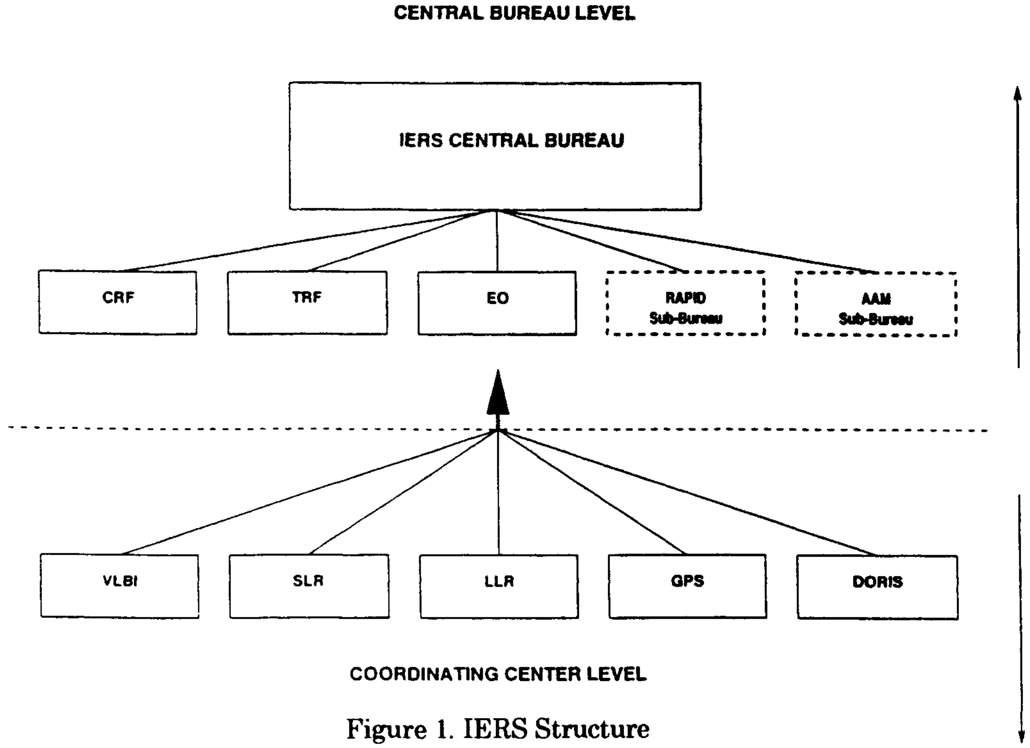

Figure 1. IERS Structure

We believe that this structure proved its usefulness in the past. We believe moreover that there is no obvious reason for dramatically changing the now existing IERS components, namely Central Bureau and Sub-Bureaus, Technique Coordinators, and Directing Board.

Before offering our specific recommendations for the future development of the IERS, it is useful to consider some broad themes that we expect will be increasingly important, namely

- improved communications,
- distributed combination efforts, and
- an even more dynamic evolution than in the past.

First, global instantaneous communication techniques have undergone revolutionary changes since the founding of the IERS. This creates the opportunity for faster and easier ways to exchange information among groups and individuals worldwide. Naturally, the IERS has taken advantage of this revolution in many ways, as reflected partly by the distribution modes used for IERS products presented in Appendix D. E-mail, ftp file transfers, and WWW-pages are routinely used to facilitate information exchange among all components of the IERS and its users. We acknowledge these developments and encourage the IERS Central Bureau to lead in the exploitation of new technologies. For example, feedback of results from combinations to the Analysis Centers could be improved in frequency and comprehensiveness. Likewise, the Analysis Centers and the proposed specialized (Combination) Centers (see Recommendation 3, below) should provide full and timely information concerning the technique solutions to the IERS Central Bureau and the Sub-Bureaus.

Second, the ability to transfer large data files easily between groups makes if feasible for combination efforts to be efficiently distributed among more groups than the Central Bureau alone. The value of multiple combination efforts has been demonstrated already by the IGS for GPS. We propose to encourage similar technique-specific combinations for the other techniques in the IERS. The Coordination Centers are asked to organize these. In addition, we believe that new multi-technique combination groups within the IERS structure would stimulate a "friendly competitive" environment that would ensure the best possible approaches emerge.

Finally, the more dynamic environment that we envision for the IERS will allow the organization to evolve naturally in response to rapidly changing conditions. It is clear that new techniques will soon contribute to the IERS which must be evaluated thoroughly and efficiently. We believe the multi-lateral comparison and coordination efforts proposed below will enhance this possibility.

We propose that specialized Analysis Centers are created to study state-of-the-art combination of results stemming from different space techniques to complement the existing IERS structure together with the already existing centers (Recommendation 3). It is left to the IERS Directing Board whether these new Analysis Centers will be considered as Analysis Centers (and represented by a Coordinating Center on the corresponding level in Figure 1), as Sub-Bureaus, or even as Central Bureau Sections (on the corresponding level in Figure 1.

We also propose to create a Network Coordination Group and we encourage the IERS to consider the creation of one or more new Coordinating Center(s) e.g., for monitoring the fluid angular momentum (geophysical fluids) (see Recommendation 2, below).

Let us now present our commented recommendations. We will always start with the recommendation(s) first and let the explanations follow.

Recommendation 1: Each Coordinating Center (CC) should strengthen overall control of observations,quality control, and data processing for products of interest to the IERS (coordinates, EOP series,etc.) in accordance with the IERS Terms of Reference. Combinations of individual solutions into technique specific products are strongly encouraged.

When the IERS started working in 1988 there was no strong coordination within each technique (possibly with the exception of VLBI, where the observations had to be coordinated very closely). The work within each technique was more of development-type rather than that of a full fledged service. The procedure thus adopted by the IERS was simple: the IERS Central Bureau and the Sub-Bureaus worked directly with each individual group generating and/or processing data for a single technique and it had access to each individually generated series of coordinates, EOPs, etc. The role of the Coordinating Center was that of a spokesman for these groups in the IERS Directing Board.

Meanwhile a number of developments within and outside the IERS took place: we have seen the development of the IGS with a clear structure, namely the Central Bureau, several Analysis Centers, the Analysis Center Coordinator, Global, Regional, Operational Data Centers, and, last but not least, a truly global network of about 100 stations. The IGS, as the name implies, is itself a service with a well-defined list of official products that are based on the products of the individual IGS Analysis Centers and that are expressed in the IERS System, according to the IGS Terms of Reference.

The DORIS group is organized very much along the same lines as the IGS. The VLBI links to the IERS were considerably improved lately by the call for participation issued by the IERS in 1995. The SLR group, as the second rather old established IERS contributor, at present considers modifications pointing to the direction given in Recommendation 1 to keep the technique competitive.

We conclude that this process of change on the level of the individual techniques should be reflected in a modified role of the Coordinating Centers (CCs).

Recommendation 1 has to be passed on from the IERS Directing Board to each single CC. There should be a clear signal coming from the IERS Directing Board that strong, service-like contributions are expected from each CC. Although the CCs are contributing to the work of the IERS, they need not be IERS components (e.g., the IGS).

At present there are five IERS CCs, namely for VLBI, LLR, SLR, GPS, and DORIS. The IERS Directing Board may wish to re-consider this structure from time to time.

Recommendation 2: Coordinating Centers should be formed to promote the collection of other types of information relevant to EOPs such as atmospheric excitation functions, information on ocean circulation, global water level changes, etc.

There are observation techniques inside and outside the scope of space geodesy which are of importance for the IERS. Such techniques should be represented by a CC-type of organization and on the CC-level, organized in the sense of Recommendation 1, and represented by a Coordinating Center (Technique Coordinator).

We think in particular of observations concerning the atmospheric excitation function, of ocean currents, etc., where it should be possible to define clear products to be generated regularly. A good part of the activities considered in Topic 6 (Table 1) might fall into this category.

Recommendation 3: Combination of products from the various CCs shall be performed by at least two IERS Components such as Sub-Bureaus, specialized Analysis Centers, Central Bureau Sections. The Central Bureau should disseminate the state-of-the-art combined solutions and provide the official IERS products. The criteria for the selection or production of this official solution will be determined by the IERS Directing Board.

We believe that many institutions actually are interested today and should get involved in combining solutions performed at different centers. We conclude that such combinations must be studied within the IERS, and that the IERS should make the attempt to get as many experts and institutions involved as possible.

The above Recommendation is one of the important results of the Paris workshop which evolved slowly from the originally proposed text. After long discussions it was generally acknowledged that it is important

- to foster the collaboration of new research groups interested in combining the results stemming from all different techniques contributing to the IERS,

- to continue resp. maintain unique series of official IERS products for all types of IERS users,

- and that the IERS Directing Board is responsible for selecting resp. giving the directions for producing these official products.

Recommendation 4: It is desirable to form a Network Coordination Group to consider issues of network design, colocation, local ties, site quality, etc. as previously recognized and accepted by the IERS Directing Board.

All major space techniques contributing today to the IERS (VLBI, SLR, LLR, satellite microwave systems) will be relevant in future, too. The IERS thus must be interested not only in well organized technique-specific networks, but also in a close coordination and colocation of the networks.

This recommendation is a reminder that the IERS Directing Board should actually create the Committee on IERS Network Design and Implementation (CINDI) as announced in the minutes of the IERS DB Meeting, Tuesday, 11 July 1995 in Boulder. It was generally acknowledged that the IERS must be vitally interested in a well established and collocated ground tracking network.

Recommendation 5: Members of the Directing Board should include representatives of CCs, Sub-Bureaus, sections of the Central Bureau, selected Combination Centers (see Recommendation 3), the Director of the Central Bureau, and representatives of IAU, IAG/IUGG, and FAGS.

As stated in Section 2 representatives of Sub-Bureaus and Central Bureau Sections were considered de facto members of the IERS Directing Board. The above recommendation would change this de facto into a real membership. The recommendation also asks that the newly created group of Combination Centers (Recommendation 3) has (at least) one representative on the Board.

Recommendation 6: The IERS Conventions should be updated periodically at reasonable intervals. They should reflect state-of-the-art at the time of publication. In all cases, they should be consistent with the IAU and IUGG resolutions on reference systems (at present, the resolutions adopted in 1991). The IERS Conventions should be considered one of the IERS products for the use of the internal and external researchers. An IERS unit such as a Sub-Bureau shall be formed to maintain the IERS Conventions.

It was mentioned in Section 2 that the IERS Conventions (previously Standards) are a document of outstanding importance for the IERS and its users on all levels. The Directing Board should give this document a high priority. The conventions should appear in paper and electronic versions.

Recommendation 7: The IERS Central Bureau should continue its excellent work necessary to develop and make available information on the ITRF, the ICRF, and the transformation parameters between them. The Central Bureau should poll its distribution list to identify the various types of users and their specific requirements.

It became clear at the Paris workshop that the IERS Central Bureau is considered responsible for making available the information on the ITRF, the ICRF and the consistent transformation parameters. There were long discussions concerning the user types and the number of users within each type. It seems appropriate that the IERS distribution lists and the user requirements are carefully analysed in order to come up with a better understanding of the needs of "IERS customers".

Recommendation 8: The above Recommendations are intended to further enhance and improve the widely acknowledged excellent work performed by the IERS.

ACKNOWLEDGEMENTS:

The authors express their gratitude to Tom Herring and Kurt Lambeck for their review of the manuscript and their useful comments. Martine Feissel's effort in providing the material for the Appendices is also acknowledged with thanks. Valuable inputs by Jim Ray before, during and after the Workshop are also very much appreciated.

Many lively, animated, and sometimes controversial discussions took place during the sessions devoted to Topic 1. We acknowledge all contributions which were taken into account to the extent possible in the above revised version of the position paper.

Last but not least we express the likely feelings of all attendants of the 1996 IERS Workshop by thanking the IERS Central Bureau as the local organizer of the 1996 IERS Workshop for the cordial hospitality we could experience in Paris.

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APPENDIX A: IERS TERMS OF REFERENCE

The International Earth Rotation Service (IERS) was established in 1987 by IAU and IUGG and it started operation on 1988 January 1st. It replaces the International Polar Motion Service (IPMS) and the Earth rotation section of the Bureau International de l'Heure (BIH); the activities of BIH on time are continued at Bureau International des Poids et Mesures (BIPM). IERS is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS).

IERS should provide the information necessary to define a Conventional Terrestrial Reference System and a 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 orientation parameters.

IERS is responsible for :

- defining and maintaining a conventional terrestrial reference system based on observing stations that use the high-precision techniques in Space Geodesy;
- defining and maintaining a conventional celestial reference system based on extragalactic radio sources, and relating it to other celestial reference systems;
- determining the Earth orientation parameters connecting these systems, the terrestrial and celestial coordinates of the pole and universal time;
- organising operational activities for observation and data analysis, collecting and archiving appropriate data and results, and disseminating the results to meet the needs of users.

IERS consists of a Central Bureau and Coordinating Centres for each of the principal observing techniques, and is supported by many other organisations that contribute to the tasks of observation and data processing.

The Coordinating Centres are responsible for developing and organising the activities in each technique to meet the objectives of the service. The Central Bureau combines the various types of data collected by the service, and disseminates to the user community the appropriate information on Earth orientation and the terrestrial and celestial reference systems. It can include Sub-Bureaux for the accomplishment of specific tasks. The Central Bureau decides and disseminates the announcements of leap seconds in UTC and values of DUT1 to be transmitted with time signals.

The Directing Board is composed of representatives of

- the International Astronomical Union,

- the International Association of Geodesy/International Union of Geodesy and Geophysics,
- the Federation of Astronomical and Geophysical Data Analysis Services
- the Central Bureau,
- each of the Coordinating Centres.

The chairperson is a member of the Directing Board, elected by the Board for a term of four years, with the possibility of reelection for one additional term. He/she coordinates the activity of the Directing Board. He/she is the official representative of the Service at the meetings of IAU, IAG/IUGG, FAGS, and other outside organisations.

The Directing Board exercises general control over the activities of the service, including modifications to the organisation and participation that would be appropriate to maintain efficiency and reliability, while taking full advantage of the advances in technology and in theory. Most decisions are expected to be made by consensus or by a simple majority vote. Changes in the structure, membership and chairmanship of the Directing Board can be made at any time by a two third majority.

The secretariat of the Board is provided by the Central Bureau. The function includes the distribution of papers and the compilation of the annual administrative and financial reports.

The Board shall meet annually and at such other times as shall be considered appropriate by the Chairperson or at the request of two members.

APPENDIX B: WORK PERFORMED BY THE IERS IN 1996

The data analysis which yields the values of the Earth Orientation Parameters (EOP) published by IERS includes several steps, which are summarized below.

1. Observations by the VLBI, LLR, GPS, SLR and DORIS networks.

2. Analyses (quick-look and refined) by the IERS Analysis Centres. The quick-look results include only the Earth orientation information. They are transmitted weekly in parallel to the Rapid Service Sub-Bureau and to the Central Bureau. The refined results include, in addition, information on the reference frames. They are transmitted yearly to the Central Bureau, and published in issues of the IERS Technical Notes.

3. General analysis of IERS Celestial Reference Frame (ICRF), IERS Terrestrial Reference Frame (ITRF) and EOP by the Central Bureau, based on the refined results. This adjustment, performed yearly, provides the basis for determining the systematic corrections to be added to the individual series for the following year in order to bring them into the IERS Reference System; these corrections are used in step 4. The general results are described and published in the IERS Annual Report, Part II.

4. Determination of EOP by the Central Bureau in the form of normal and smoothed values at five-day and smoothed values one-day intervals. This involves the application of the systematic corrections determined in step 3 and statistical weighting. The results are published in the monthly Bulletin B with a delay of thirty days between the date of publication and the last date of the standard solution.

5. Determination of EOP by the Rapid Service Sub-Bureau in the form of smoothed solutions at one-day intervals. This involves the application of systematic corrections and statistical

weighting. The results are published in Bulletin A with a delay of about two to five days between the date of publication and the last available date with estimated EOP. The analyses of the Sub-Bureau for Rapid Service and Predictions are described in the IERS Annual Report, part III.

6. Prediction of EOP. Bulletins A and B provide predictions of the EOP for up to ninety days. In addition, the Rapid Service Sub-Bureau issues each week predictions at monthly intervals for one year in advance. The predictions use similar algorithms, based on seasonal filtering and autoregressive processing for x, y, UT1 and on an approximate, modelled correction for the celestial pole offsets.

APPENDIX C: IERS PUBLICATIONS IN 1996

Weekly Bulletin A	Earth orientation parameters (x,y, UT1, $d\psi$, $d\varepsilon$): Rapid Service, prediction. First issue covering observation dates in the last week in 1987.
Monthly Bulletin B	Earth orientation parameters (x,y,UT1, $d\psi$, $d\varepsilon$) combined solution and individual series. Information on UTC time scale. First issue covering observation dates in January 1988.
Annual Reports	Earth orientation parameters, terrestrial and celestial frames of the IERS Reference System: combined solutions and analysis of individual results. First issue, Report for 1988, published in July 1989.
Special Bulletin C	Announcement of the leap seconds in UTC.
Special Bulletin D	Announcement of the value of DUT1 to be transmitte with time signals.
Technical Notes on	Reports and complementary information of relevance to the work of IERS Earth orientation and the reference systems.

The precision of the published results depends on the delay of their availability. For the operational solutions of Earth rotation (weekly and monthly bulletins) it is of a fraction of one millisecond of arc. The prediction accuracy is in the range of 0.005-0.020" for x,y, 0.002-0.015s for UT and 0.002" for $d\psi$, $d\varepsilon$ (prediction lags of 10 and 90 days). For the scientific solution of reference frames and Earth orientation, the inaccuracy is lower than 0.0003" (1 cm).

The IERS publications are airmailed. Bulletin A is prepared and distributed by the Sub-Bureau for Rapid Service and Predictions; the other publications are prepared and distributed by the Central Bureau. Bulletins A and Bulletin B are also distributed by e-mail and available on anonymous FTP (File Transfer Protocol), see Section V. The Sub-Bureau for Rapid Service and Predictions makes available various results on a Bulletin Board (see Section III).

APPENDIX D: DISTRIBUTION AND USERS OF IERS CENTRAL BUREAU PUBLICATIONS IN 1996

Distribution of IERS publications in 1996 [and 1988] (1)

Publication	Interval	Contents	Airmail 1996	Airmail 1988	e-mail 1996	e-mail 1988	ftp/www(3) 1996	ftp/www(3) 1988
Bulletin B	monthly	Earth orient.	120	[360]	170	[0]	Yes	[No]
Bulletin C(2)	6 months	UTC time steps	80	[250]	220(2)	[0]	Yes	[No]
Bulletin D	8/year	UT1-UTC (0.1s)	50	[140]	150	[0]	Yes	[No]
Annual Rep.	yearly	Global anal.	400	[500]			part	[No]
Tech. Notes	2-3/year	Add. analyses	300	[200]			part	[No]
IERS Conv.	3-4 years	Models,...	1300	[1000]			Yes	[No]
Gazette	20/year	News			600	[0]	Yes	[No]

Notes 1. The distribution lists were revised in 1988 and 1996
2. Bulletin C is widely reproduced in national publications on Time
3. Dictinct users of the Central Bureau ftp,www site: 30/day , 400/month

Types of uses of IERS publications in 1996 [and 1988]

	1996	1988	Users Type
1. Space geodesy, reference frames	45%	[20%]	IRU, ERU
2. Operational reference	25%	[40%]	SU
3. Time service activities	10%	[20%]	SU
4. Geophysical investigations	10%	[10%]	ERU
5. Libraries, students	10%	[10%]	SU, ERU