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THE INTERNATIONAL EARTH ROTATION AND REFERENCE SYSTEMS SERVICE (IERS)

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Abstract. The International Earth Rotation and Reference Systems Service (IERS) was established by the IAU and the IUGG in 1987. A short outline of its history, its services to the astronomical, geodetic and geophysical communities and of its future prospects is given. Special emphasis is made on IERS' relation to astronomy.

1. Overview

The International Earth Rotation and Reference Systems Service (IERS) is a large organization established by IAU and IUGG. Its primary objectives are to serve the astronomical, geodetic and geophysical communities by providing the following:
• The International Celestial Reference System (ICRS) and its realization, the International Celestial Reference Frame (ICRF).
• The International Terrestrial Reference System (ITRS) and its realization, the International Terrestrial Reference Frame (ITRF).
• Earth Orientation Parameters (EOP) required to study earth orientation variations and to transform between the ICRF and the ITRF.
• Geophysical data to interpret time/space variations in the ICRF, ITRF or earth orientation parameters, and model such variations.
• Standards, constants and models (i.e., conventions) encouraging international adherence.

IERS is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS).

The central IERS web site <www.iers.org>, maintained by the Central Bureau in Frankfurt am Main, provides detailed information on IERS and gives access to all other IERS web sites. It includes also comprehensive lists of links to IERS-related institutions, activities and fields, including astronomy.

2. The prehistory of the IERS

The phenomenon of precession was known since antiquity, but only Copernicus explained it by a changing direction of the rotation axis of the Earth. Nutation was discovered by James Bradley in 1744.

After Leonhard Euler's prediction of polar motion in 1765 it took about 120 years before the pioneering works of Seth Chandler at Harvard and Friedrich Küstner at Berlin gave final observational evidence for this phenomenon. Simultaneous measurements at Waikiki and Berlin in 1891 were the crucial test for its existence. In 1895 the International Latitude Service (ILS) was founded by the Internationale Erdmessung, sometimes also called the International Geodetic Association, and started its regular operation in 1899.

The Bureau International de l'Heure (BIH) was founded in 1919. It soon became responsible for the coordination of Universal Time (UT), a unification of the previous Standard Time determined independently in the respective countries. In 1955 BIH established the Service International Rapid (SIR), including an own polar motion determination.

In 1962 the ILS was superseded by the International Polar Motion Service (IPMS) by including independent stations. IPMS and BIH were using almost the same observational data, thus duplicating the work to a certain degree.

Another milestone was the Project MERIT (Monitor Earth Rotation and Intercompare the Techniques of observation and analysis). One of its main objectives was to encourage the development of the use of new techniques, such a laser ranging (SLR, LLR) and radio interferometry (VLBI). Proposals for a new International Earth Rotation Service were prepared at a MERIT Workshop in 1986.

In 1987 the IPMS and the Earth Rotation Section of the BIH were combined to form the IERS.

For more details about this development see the papers in Dick et al. (2000).

3. The IERS 1988 to 2004

The IERS was established as the International Earth Rotation Service in 1987 by the International Astronomical Union (IAU) and the International

Union of Geodesy and Geophysics (IUGG). It began operation on 1 January 1988. In difference to the IPMS, IERS included also a responsibility for celestial and terrestrial reference systems.

After a decade, IERS was reorganized by its Directing Board for the following reasons: Firstly the various techniques (GPS, Laser tracking to the Moon and to artificial satellites and also VLBI) had already been reorganized into the international services IGS, ILRS and IVS, respectively in 1994, 1998 and 1999. Secondly more visibility was to be given to the different components of the IERS. Thirdly the IERS had to be opened the service to new scientific groups which had developed in various countries in the meantime. As of 1 January 2001 the new structure became operational. In 2003 the IERS was renamed to International Earth Rotation and Reference Systems Service to reflect the equal importance of reference systems besides the Earth Orientation Parameters in its tasks.

The old structure of IERS gave certain priority to EOP, which were calculated by the Central Bureau. Sections and Sub-Bureaus of the Central Bureau were responsible for reference frames, standards and geophysical data. The new structure includes different autonomous Product Centres being independent from the Central Bureau, which is now responsible for general organization and administration. New elements of the structure are Combination Research Centres, ITRS Combination Centres and the Analysis Coordinator. External services like IGS, ILRS, IVS and IDS serve as Technique Centres for the IERS.

For an overview about IERS' first ten years see Mueller (2000). For more details about the reorganization see the IERS Annual Reports 1999 to 2001 and Vondrák (2001).

4. IERS products

As a service for scientific and general needs, the IERS provides "products", i.e. data sets, most of which are continuously being updated. The main products of the IERS are the ICRS, the ITRS as well as daily, weekly and monthly Earth Orientation Parameters. A new edition of the IERS Conventions containing conventional models, constants and standards was finalized in 2003 and will be published in 2004 (McCarthy & Petit, 2004). Data related to geophysical fluids (like Atmospheric Angular Momentum) and auxiliary data are also provided by IERS' Global Geophysical Fluids Centre. All products are available free of charge.

At its 23rd General Assembly in August 1997, the IAU decided that, as from 1 January 1998, the fundamental reference system shall be the International Celestial Reference System (ICRS), in replacement of the FK5. It is accessible by means of coordinates of reference extragalactic radio

sources, the International Celestial Reference Frame (ICRF).

The International Terrestrial Reference System (ITRS) is realized by estimates of the coordinates and velocities of a set of stations, called the International Terrestrial Reference Frame (ITRF).

The Earth Orientation Parameters (EOP), describing the irregularities of the Earth's rotation, are defined as translation parameters between the ITRS and the ICRS as a function of time. The EOP include Universal Time (UT1), the coordinates of the terrestrial pole and the celestial pole offsets. The latter are described in the IAU Precession and Nutation models.

The IERS is also responsible for the decision to introduce a Leap Second in Coordinated Universal Time (UTC). UTC is recommended by the International Telecommunication Union (ITU) to be used as the basis for legal time. UTC has the same scale as International Atomic Time (TAI), but it is adjusted to Earth' rotation. Technically, UTC differs from TAI by the total number of leap seconds, so that UT1–UTC stays smaller than 0.9 s in absolute value. Currently, the difference between UTC and TAI is 32 seconds.

5. IERS publications

The IERS issues the following publications, including electronic bulletins:
• IERS Bulletin A: rapid determinations and predictions for earth orientation parameters, issued weekly. (Please note that a better way to retrieve the most rapid data is to download a cumulative file which is being updated daily.)
• IERS Bulletin B: earth orientation parameters, issued monthly.
• IERS Bulletin C: announcements of the leap seconds in UTC, issued semi-annually.
• IERS Bulletin D: announcements of the value of DUT1 = UT1 – UTC to be transmitted with time signals, issued irregularly.
• IERS Annual Reports: overview of the structure, reports of all components and of IERS in general, addresses and other information.
• IERS Technical Notes: documentation of IERS products and proceedings of IERS workshops.
• IERS Messages: short information on the IERS, its products and related topics, conference announcements and news from the field, issued irregularly.
• ITRF Mail: short information related to the International Terrestrial Reference Frame, issued irregularly.

Subscription to all publications is currently free of charge. Since 2000, all printed publications are also available in electronic form for download at the IERS web site.

6. The structure of IERS

The main components of IERS are its Products Centres, which are responsible for the IERS products:
• Earth Orientation Centre • Rapid Service/Prediction Centre • Convention Centre • ICRS Centre • ITRS Centre • Global Geophysical Fluids Centre (GGFC)

The GGFC comprises 8 Special Bureaus (for the Atmosphere, for the Oceans, for Tides, for Hydrology, for Mantle, for the Core, for Gravity/Geocentre, and for Loading). The ITRS Centre is supported by three ITRS Combination Centres.

Four external services act as Technique Centres for the IERS:
• International GPS Service (IGS) • International Laser Ranging Service (ILRS) • International VLBI Service for Geodesy and Astrometry (IVS) • International DORIS Service (IDS)

These Technique Centres are responsible for developing and organizing the activities in each contributing observational technique. They include several hundred observation centres, as well as combination centres and other components. At the time being, only the IGS is able to produce combination products to be submitted to IERS. However, the other Services are working on similar outputs.

Further components of the IERS are 11 Combination Research Centres, an Analysis Coordinator, the Central Bureau, and the Directing Board. Recently, three IERS Working Groups have been established.

The IERS does not have its own finances. All components are maintained by their host institutions. Most components are based on a single institution, some are being organized as a cooperation of two or more groups in different countries. Altogether, several hundred people are involved directly in the IERS. Together with all observation groups and other collaborators of the Technique Centres, probably several thousand people are working directly or indirectly on the IERS products.

7. The IERS and astronomy

The work of IERS is based on several IAU resolutions, starting with Resolution B2 – Reference Frames –, adopted by the IAU General Assembly in November 1985 in New Delhi. Traditionally, IERS has close connections with IAU Commission 19 “Rotation of the Earth” and reports to this Commission each three years. The links to IAU Commission 8 “Astrometry” are weaker and should be intensified.

As one of the Product Centres of the IERS, the ICRS Centre is responsible for the maintenance of the ICRS and the ICRF. It is a cooperation of astronomers from several institutes, mainly in France and the USA.

Figure 1. The 20-m radio telescope of BKG (Federal Agency for Cartography and Geodesy) at Wettzell, Germany, contributing data for ICRS, ITRF and EOP.

The International VLBI Service for Geodesy and Astrometry (IVS) as one of IERS' Technique Centres is in close connection with the ICRS Centre. It provides also updates to the ICRF produced by individual IVS Analysis Centres.

The ICRS and ICRF are the basis for all astronomical measurements of celestial positions. Their documentation as well as auxiliary information are available online at the web pages of the ICRS Centre (for links see <www.iers.org>). The ICRS/ICRF are also documented in an IERS Technical Note (Ma & Feissel 1997). A new Technical Note on the ICRS is in preparation.

The models, constants and other standards to be used for the ICRS are given in the IERS Conventions. The latest version (McCarthy & Petit 2004) is available since November 2003. It contains also a short documentation of the ICRS/ICRF itself.

The IAU 2000 Resolutions, which are to a large extend related to the ICRS, and their implementation were discussed in an IERS Workshop at Paris in 2002, the Proceedings of which were published as an IERS Technical Note (Capitaine et al. 2002).

8. Current activities and future prospects

The currents IERS products are created more or less independent from each other. Studies have shown that, e.g., the EOP series are not consistent with the ITRF. To overcome this situation, the IERS started a "Combination

Pilot Project" in February 2004. This should be a major step towards more consistent, routinely generated IERS products. "Weekly" solutions made available by the various Technique Services and containing site coordinates, EOPs, and, possibly, quasar coordinates, shall be rigorously and routinely combined into consistent weekly IERS products.

Currently, the IERS Central Bureau is working on an IERS Data and Information Centre (Richter et al., 2004). Its objectives are to archive all products and data of the IERS at one place and to make them available in a user-friendly way. To describe all products in a comparable way, Metainformation on the products will be stored in a database which may be searched by users. A first prototype of the system has been realized. It allows to automatically collect and archive the various products from the IERS components, to automatically extract the Metainformation and to search the archive by means of this information, as well as to download the data. The system will be made publicly available in the course of 2004.

For several years now, the "Special Rapporteur Group 7A on the Future of the UTC Time Scale", established by ITU, has been thinking on the future of the Leap Second. The main reasons for this are the technical problems connected with a discontinuous time scale, the introduction of leap seconds at unpredictable moments of time, and the existence of three major time scales (UTC, TAI and GPS Time). This could be, e.g., a security problem for air transportation: GPS uses GPS Time, whereas for the European GALILEO system UTC is the projected time scale. This would mean that the time scales of both navigation systems would differ by nearly half a minute currently, and even more in the future. In May 2003, the Special Rapporteur Group 7A held a Colloquium in Turin. There was no overwhelming consensus on whether the status quo should be maintained or an alternative should be pursued. However, one proposal seemed to be preferred. The essence of this proposal is: Any change should slowly evolve from the current UTC Standard by transition to a uniform timescale. It should be a continuous atomic time scale, without Leap Seconds, that is synchronized with UTC at the time of transition (cf. the Proceedings at <http://www.ien.it/luc/cesio/itu/ITU.shtml>). Such a time scale would disrupt the close connection of our chronology with the diurnal motion of the Earth, with the consequence that around the year 5000 the Sun could rise at midnight. Besides such long-term effects, the disconnection of the time scale from UT1 would be a problem for telescope pointing systems which use UTC as an approximation for UT1. For these users, IERS would provide a low-precision UT1 time service. There is also an IAU Working Group on the Definition of UTC, which is in close connection with IERS and participates in the discussion.

Ground-based global astrometric observations depend on the knowledge

of the Earth Orientation Parameters. On the other hand, EOP determinations which use observations of celestial bodies need precise positions of these objects in a well-defined celestial reference frame. Also a Terrestrial Reference Frame needs to be established with sufficient accuracy to enable EOP determinations. This has been the basis of the close relation between fundamental astrometry and geodesy in the 19th and 20th centuries. Future space-based determinations of a celestial reference frame with GAIA and possibly other satellites will achieve an accuracy better than the current ICRF and will be completely independent from the knowledge of EOPs. This means that on the long term the role of IERS in maintaining the ICRF has to be re-defined.

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