The Role of the IERS in the Leap Second

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Background

The International Earth Rotation and Reference Systems Service (IERS) provides the international community with:

- the International Celestial Reference System and its realization, the International Celestial Reference Frame (ICRF);
- the International Terrestrial Reference System and its realization, the International Terrestrial Reference Frame (ITRF);
- Earth orientation parameters (EOPs) that are used to transform between the ICRF and the ITRF;
- Conventions (*i.e.*, standards, models, and constants) used in generating and using reference frames and EOPs;
- Geophysical data to study and understand variations in the reference frames and the Earth's orientation.

The IERS was created in 1987 and began operations on 1 January 1988. It continued much of the tasking of the Bureau International de l'Heure (BIH), which had been created early in the 20th century. It is responsible to the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG). For more than twenty-five years, the IERS has been providing for the reference frame and EOP needs of a variety of users.

Time

The IERS has an important role in determining when the leap seconds are to be inserted and the dissemination of information regarding leap seconds. In order to understand this role, it is important to realize some things regarding time. For instance, there are two different kinds of "time" being related: (1) a uniform time, now based on atomic clocks and (2) "time" based on the variable rotation of the Earth. The differences between uniform time and Earth rotation "time" only became apparent in the 1930s with the improvements in clock technology.

Coordinated Universal Time (UTC) is the standard for everyday time usage worldwide. In addition, it plays an important role in such diverse applications as communications, computer network synchronization and navigation (through Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS)). Due to the accuracy of current atomic clocks, UTC is accurate at the level of several nanoseconds (billionths of a second).

Historically, timekeeping was based on the rotation of the Earth. The repetitive passage of astronomical bodies (*e.g.*, the Sun) provided a convenient method to mark the passage of time. Time based on the observations of the rotation angle of the Earth in a celestial reference system continues to play a role in modern timekeeping.

Today, the measure of the Earth Rotation Angle (ERA) is provided by a linear relationship with a time-like quantity called UT1 that is observed using a worldwide network of radio telescopes. Earth rotation data are provided to users in the form of a quantity UT1–UTC. The rotational speed of the Earth is highly variable due to tides, changes in weather, oceans and other geophysical effects. Consequently, the only way to provide this information reliably is to monitor the Earth's rotation on a regular basis. It is measured by fixing devices to the surface of the Earth and observing objects in space. Very Long Baseline Interferometry (VLBI), using radio telescopes to observe distant radio sources called quasars, can measure UT1 to an accuracy of a few tens of microseconds (millionths of a second).

Leap Seconds

Leap seconds were implemented in 1972 as an attempt to ensure synchronization between clock time and Earth rotation. Per Recommendation of the International Telecommunication Union (ITU)-R TF-460.6:

- "A positive or negative leap-second should be the last second of a UTC month, but first preference is given to the end of December and June, and second preference to the end of March and September."

- "A positive leap-second begins at 23h 59m 60s and ends at 0h 0m 0s of the first day of the following month. In the case of a negative leap-second, 23h 59m 58s will be followed by 0h 0m 0s of the first day of the following month."

Because the IERS is responsible for monitoring and predicting the quantity UT1–UTC, it provides a vital contribution to the determination of when leap seconds will need to be inserted in order to keep |UT1–UTC| < 0.9s as specified by the ITU. In recognition of this, ITU-R TF 460-6 provides that

- "The IERS should decide upon and announce the introduction of the leap-second, such as an announcement to be made at least eight weeks in advance."

Since their inception, there have been 25 leap seconds. Through the implementation specified in ITU-R TF-460.6, leap seconds ensured that the absolute value of the difference between UTC and UT1 would never exceed 0.9s. In effect, leap seconds allowed users to approximate UT1 with UTC to an accuracy of roughly one second. While in the 1970s, this level of approximation may have only been a slight degradation, it should be noted that with today's technology, real-time estimates of the difference between UT1 and UTC can be determined to more than 4 orders of magnitude better accuracy.

IERS Products

The IERS provides algorithms that enable users to utilize EOPs in their operations. These algorithms are developed by subject-matter experts and tested thoroughly in geodetic and geophysical applications to ensure their quality. They and associated software are available free of charge through the IERS Conventions web sites (http://tai.bipm.org/iers and http://maia.usno.navy.mil/conv2010).

As tasked by the IAU and IUGG, the IERS helps to coordinate the regular measure of all Earth orientation components, including the Earth's variable rotation. The IERS combines these Earth orientation observations four times per day. For real-time EOP users, the IERS provides high-quality EOP predictions (see http://maia.usno.navy.mil). All of these data sets are provided to the worldwide community through various computer transfer protocols free of charge.

Announcements of upcoming leap seconds are made through the IERS Bulletin C (see http://hpiers.obspm.fr/iers/bul/bulc/bulletinc.dat). Bulletin C is released usually in January and July and announces whether it will be necessary to insert a leap second within the next six months. This scheduling meets the "8 weeks in advance" requirement of the ITU.

Future considerations

In recognition of rapidly changing technology, the IERS recently held a retreat in order to better position the IERS to meet the emerging needs of its users. As part of this retreat, the IERS agreed to create new products, utilizing more modern data file formats that should improve usability of the IERS data. In addition, the IERS will investigate the possibility of creating a real-time EOP transfer protocol. This latter product would provide UT1 directly to users that currently choose to approximate UT1 using UTC. It would have the advantage of maintaining the same simplicity of implementation that users currently enjoy while increasing the accuracy of the data by more than four orders of magnitude at no cost to the user. The IERS is prepared to meet any future requirements of users by the most convenient means.

Summary

The IERS has served the international scientific community and operationally oriented efforts through its service for more than twenty-five years. This includes providing Earth orientation information, algorithms and software to utilize EOPs, and leap second notifications to the world. With recent efforts, the IERS has positioned itself to more completely serve the needs of its users whether the current definition of UTC is retained or whether UTC is redefined to eliminate leap seconds. Either way, the ITU can rely on the IERS to support its users with the data and software needed.