Updates

- Updated Website! Read more about the updates and the new layout.
- Leap second updates.

Useful Links

U.S. Naval Observatory

IERS Earth Orientation Centre

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What is a Leap Second?

Civil time is occasionally adjusted by one second increments to ensure that the difference between a uniform time scale defined by atomic clocks does not differ from the time based on the Earth's rotation by more than 0.9 seconds. Coordinated Universal Time (UTC), an atomic time, is the basis for our civil time.

In 1956, following several years of work, two astronomers at the U. S. Naval Observatory (USNO) and two astronomers at the National Physical Laboratory (Teddington, England) determined the relationship between the frequency of the cesium atom (the standard of time) and the rotation of the Earth at a particular epoch. As a result, they defined the second of atomic time as the length of time required for 9 192 631 770 cycles of the cesium atom at zero magnetic field. The second then became defined as a 1 / 31 556 925.9747 fraction of the year 1900. The atomic second was then set equal to an average second of time determined from observations of the Earth's rotation in the 19th century.

The Rapid Service / Prediction Center, as a sub-bureau of the International Earth Rotation and Reference System Service (IERS), located at the U.S. Naval Observatory, monitors the Earth's rotation. Part of its mission involves the determination of the non-uniform time scale, UT1, that is based on the current rate of Earth's rotation.

The Earth is constantly undergoing a deceleration caused by the braking action of the tides. Through the use of ancient observations of eclipses, it is possible to determine the tidal deceleration of the Earth to be roughly 1.5-2 milliseconds per day per century. This is an effect which causes the Earth's rotational time to slow with respect to the atomic clock time. Since it has been more than 1 century since the defining epoch, the difference would be roughly 2 milliseconds per day. Other factors also affect the Earth, some in unpredictable ways, so that it is necessary to monitor the Earth's rotation continuously. Currently, this rate has been decreasing and is now below 2 miliseconds per day, presumably because warming of the planet is causing the oceans to redistribute their mass.

In order to keep the cumulative difference in UT1-UTC less than 0.9 seconds, a leap second is added in UTC to decrease the difference between the two (Figure 1). This leap second can be either positive or negative depending on the Earth's rotation. Since the first leap second in 1972, all leap seconds have been positive (a list of all announced leap seconds). This reflects the general slowing trend of the Earth.

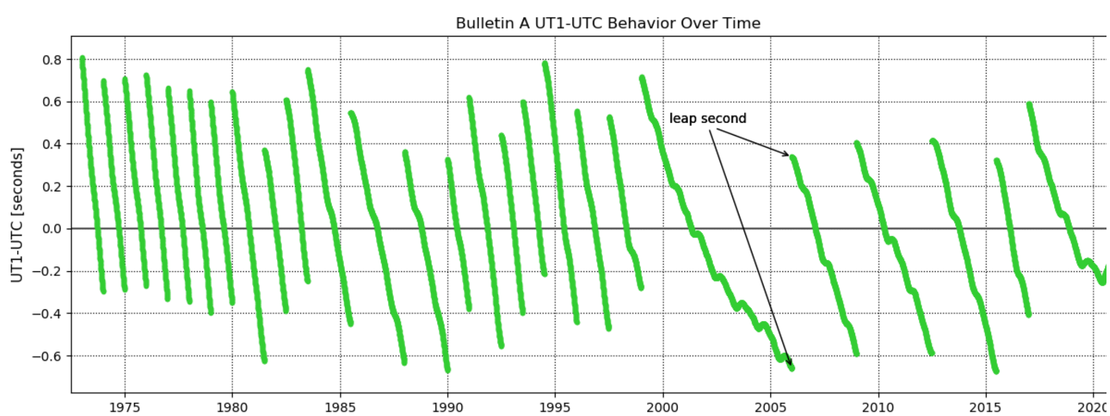

Figure 1. UT1-UTC since 1973. The intermittent breaks in the time-series are where a leap second has been added.

Confusion sometimes arises over the misconception that the regular insertion of leap seconds every few years indicates that the Earth should stop rotating within a few millennia. The confusion arises because some mistake leap seconds as a measure of the rate at which the Earth is slowing. However, the one-second increments are indications of the accumulated difference in time between the two systems. As an example, the situation is similar to what would happen if a person owned a watch that lost two seconds per day. If it were set to a perfect clock today, the watch would be found to be slow by two seconds tomorrow. At the end of a month, the watch will be roughly a minute in error (thirty days of the two second error accumulated each day). The person would then find it convenient to reset the watch by one minute to have the correct time again.

This scenario is analogous to that encountered with the leap second. The difference is that instead of setting the clock that is running slow, we choose to set the clock that is keeping a uniform, precise time. The reason for this is that we can change the time on an atomic clock while it is not possible to alter the Earth's rotational speed to match the atomic clocks. If the Earth were to run slow at roughly 2 milliseconds per day, the difference between the Earth rotation time and the atomic time would be one second after 500 days. Instead of allowing this to happen, a leap second is inserted to bring the two times closer together.

The decision to introduce a leap second in UTC is the responsibility of the IERS. According to international agreements, first preference is given to the opportunities at the end of December and June, and second preference to those at the end of March and September. Since the system was introduced in 1972, only dates in June and December have been used.

Keeping Track of Time

The official United States time is available from the Master Clock at the U. S. Naval Observatory (USNO). The Observatory is charged with the responsibility for precise time determination and management of time dissemination. Modern electronic systems, such as electronic navigation and communication systems, depend increasingly on precise time and time interval (PTTI). A well-known example is the satellite-based Global Positioning System (GPS). GPS is used for navigating ships, planes, missiles, trucks, and cars anywhere on Earth. For systems based on the travel time of electromagnetic signals, an accuracy of 10 nanoseconds (10 one-billionths of a second) corresponds to a position accuracy of about 10 feet.

Precise time measurements are needed for the synchronization of clocks in a network. Such synchronization is necessary, for example, for high-speed communications systems. Power companies use precise time to control power distribution grids and reduce power loss. Radio and television stations require precise time (the time of day) and precise frequencies in order to broadcast programs. Many programs are transmitted from coast to coast to affiliate stations around the country. Without precise timing the stations would not be able to synchronize the transmission of these programs to local audiences. All of these systems are referenced to the USNO Master Clock.

Very Long Baseline Interferometry (VLBI) is the principal means used to determine Universal Time (UT) based on the rotation of the Earth about its axis. VLBI is a technique that makes use of radio telescopes to generate images of distant radio sources, measure the rotation rate of the Earth, the motions of the Earth in space, or even measure how tectonic plates are moving on the surface of the Earth.

The U.S. Naval Observatory has been in the forefront of timekeeping since the early 1800's. In 1845, the Observatory offered its first time service to the public: a time ball was dropped at noon. Beginning in 1865 time signals were sent daily by telegraph to Western Union and others. In 1904, a U.S. Navy station broadcast the first worldwide radio time signals based on a clock provided and controlled by the Observatory.