<u>FOR IMMEDIATE RELEASE</u> **13 October 2011**

The proposed redefinition of Coordinated Universal Time, UTC

- In January 2012 in Geneva, Government representatives at the World Radio Conference of the International Telecommunication Union will vote on the adoption of a new definition of the world's time scale, Coordinated Universal Time UTC, in which there will no longer be leap seconds.
- Today, leap seconds keep UTC, a time scale based on atomic clocks, in phase with the slightly variable rotation of the Earth.
- The possibility of dropping the leap seconds in UTC has created misconceptions in the popular press as to what is at stake.
- There are an increasing number of users of precise timing for whom the leap second causes serious technical problems.
- The permanent decoupling of the world's time scale would, however, lead to problems of a different kind, although as far as the general public is concerned the effect will be imperceptible.
- The measure of time and its unit the second are matters of international cooperation and all important decisions are made by intergovernmental organizations.
- In November this year, prior to the World radio Conference, a discussion meeting will take place at the Royal Society in the UK on the features of the world's time scale for the 21st century.

There is a need to set out clearly the reasons for the change and what is involved. This is the **<u>purpose of what follows:</u>**

<u>The international character of the world's time scale</u>

The measure of time and its unit the second are matters of international cooperation. Up until the middle of the 20th century, time scales were based on astronomical observations of the rotation of the Earth and the movement of the Earth in its orbit round the Sun. These had been within the purview of astronomers for centuries and, since the 1920s, had been the concern of the International Astronomical Union (IAU). With the invention of the atomic clock in 1955, however, everything began to change. By then, the irregular rate of rotation of the Earth and the practical difficulties in the realization of ephemeris time, based on the period of the Earth's orbit round the Sun, made it necessary to move to a time scale based on the atomic clock. The 14thGeneral Conference on Weights and Measures (CGPM) in 1971 recommended International Atomic Time (TAI) as the fundamental basis of the world's time scale with the atomic definition of the second adopted by the 13th CGPM in 1967 as its unit.

It was still necessary, however, to have access to accurate time related to the rotation of the Earth for such applications as celestial navigation and observational astronomy. After many discussions, the relevant international organizations agreed on the definition of a new time scale to be called Coordinated Universal Time with the acronym UTC. This was, of course, none other than International Atomic Time but synchronized to the time defined by the rotation of the Earth (UT1) by the application of one-second steps (so-called “leap seconds”) whenever necessary to keep the two scales within a difference of at most 0.9 seconds. At present leap seconds are inserted about once a year but they are not completely predictable as the small irregularities in the earth’s rotation are not predictable, although the overall trend is, see below.

Coordinated Universal Time (UTC) was defined by the International Telecommunication Union (ITU-R) in 1972 and has been maintained since 1988 by the International Bureau of Weights and Measures (BIPM) in cooperation with the International Earth Rotation and Reference Systems Service (IERS). Coordinated Universal Time is the common time reference for coordination of broadcast time and frequency services worldwide, and it constitutes the basis of legal times in almost all countries.

The BIPM is an intergovernmental organization under the authority of the General Conference on Weights and Measures and the supervision of the International Committee for Weights and Measures. The BIPM acts in matters of world metrology, particularly concerning the demand for measurement standards of ever increasing accuracy, range and diversity, and the need to demonstrate equivalence between national measurement standards and the development and maintenance of the International system of Units, SI (see www.bipm.org).

The Time Department of the BIPM calculates UTC on the basis of the contributions from some 400 atomic clocks held in some 70 national metrology institutes, observatories and other institutions located in 48 nations. This world-wide distribution of timing centres guarantees the perennity and broad dissemination of UTC. The link to the SI second comes from primary frequency standards, mostly caesium fountains, held in a small number of national metrology institutes.

From astronomy to atomic time, some history

The origin of the adoption of a conventional time for the world was at the International Meridian Conference in Washington, in 1884, when, the meridian of Greenwich was adopted as the prime meridian. The Conference also recommended that the universal day be the mean solar day which should begin for the world at the moment of mean midnight on the prime meridian. In other words, it recommended Greenwich Mean Time, GMT, as the world’s time scale. This was fine as regards Great Britain except that GMT, as it was then formally defined by astronomers and used by the Royal Navy, was indeed solar time on the Greenwich meridian but with the day beginning at noon. This was in contrast to the civil use of Greenwich Mean Time in which, of course, the day began at midnight, and which had been made legal time in Great Britain by Act of Parliament in 1880. In 1925 the British Admiralty together with the French Navy agreed that their day should begin at midnight and persuaded the astronomers to agree also. The astronomers than decided that the resulting time scale could no longer be called GMT as it might lead to confusion so in 1928 the International

Astronomical Union recommended the name “Universal Time”, acronym UT , to replace GMT, reckoned from midnight. Henceforth, the name Greenwich Mean Time was progressively replaced by Universal Time. The Bureau International de l’Heure (BIH), located at the Paris Observatory was responsible at that time for time coordination. It remained responsible until the end of 1987 when responsibility passed to the BIPM. The unit of time, the second, continued to be defined as a fraction of the mean solar day.

By the 1940s, the rotation of the Earth was recognized as non-uniform, and consequently not suitable for defining a precise time scale. The name“UT1” was used to designate the time that reflected the irregular rotation of the Earth – UT1 was for all practical purposes a representation of GMT with the day starting at midnight.

The next step in the search of a uniform time was the adoption by the IAU of ephemeris time, based on the orbital motion of the Earth around the Sun, which led the International Committee for Weights and Measures in 1956 to redefine the second as a fraction of a tropical year. The tropical year is defined by astronomers as the time interval of a seasonal circuit of the Sun, for example between two consecutive summer solstices. The problem with the definition of the second as proposed by the astronomers in 1956 was that the value they had chosen was a fraction of the tropical year 1900 which had been deduced from some three hundred years of astronomical observations having a mean date of about 1820. It had long been known that the rotation of the Earth was slowing down due to the friction of ocean tides caused by the gravitational attraction of the Moon, not by very much, but enough to result in an offset between 1820 and 1956 of about 2.3 thousands of a second in the length of the day. Thus in a year, the difference would be nearly one second. When the atomic time scale superseded the astronomical one in 1967 this difference was built into the atomic time scale and hence the need for leap seconds and in 1972 to the definition of UTC.

Why change the definition of UTC?

Leap seconds are now a serious problem for users of precise timing and synchronization who cannot easily adapt their systems to annual or nearly annual jumps of one whole second when they require time measurements to a millionth or a few thousand millionths of a second. Examples are the protocols for time dissemination and the internal times used for the synchronization of global navigation satellite systems (GNSS). Some of these systems use the leap second and others do not. The increasing number of such systems, today the United States GPS and the Russian GLONASS, and in near the future the European Galileo, the Chinese BeiDou, plus later on the regional systems in India and Japan, could see their interchangeability and interoperability weakened if the UTC reference maintains the present leap-second procedure for synchronizing to UT1.

Forty years after the adoption of the definition of Coordinated Universal Time at the International Telecommunication Union (ITU), and its adoption by the CGPM, we are close to the moment of making a decision on whether or not to continue the tight link of UTC to the rotation of the Earth embodied in UT1 with its consequent regular but actually unpredictable leap seconds. It has been a ten-year process of discussion, mainly at the International Telecommunication Union with the input of the International Astronomical Union, the BIPM and the Consultative Committee for Time and Frequency and other organizations. The majority opinion supports the abolition of the leap second based on the needs of developers and users of systems that need time synchronization to a stable and continuous reference timescale. Others insist on the necessity of keeping the leap-second strategy for serving some applications; if this is the case, the access of UT1 can be obtained with the IERS predictions with more precision that the present definition of UTC. It is requested that GNSS broadcast the values of UTC-UT1 in their navigation messages if the change in the definition of UTC is approved.

Consequences of the new definition of UTC for civil time keeping

There is also the feeling that a break in the present system of synchronization of UTC to the Earth rotation will de-correlate the human activities from solar time. It is true that UTC without leap seconds will little by little increase its offset with respect to UT1, and considering that at present in average, one leap second occurs every 1.5 years, we could expect to have a divergence of one minute between UTC and UT1 in the term of 60 to 90 years. Although this is a small difference increasing very slowly we recognize that it is an important matter of principle. In this respect we note, however, that the difference between the "true solar time" (that of a sundial, for example), and the "mean solar time" that corrects the irregularities due to the apparent annual path of the Sun can amount up to 16 minutes in one year and of course summer time brings in a step change of one hour in many countries.

The adoption of the new recommendation by the ITU

The international community, assembled at the International Telecommunication Union is close to make a decision on a new definition of UTC. A vote will be proposed to ITU Member States at the Radiocommunication Assembly in Geneva on 16 to 20 January 2012.

The meeting at the Royal Society in London

A Discussion Meeting to be held on 3-4 November 2011 at the The Kavli Royal Society International Centre (Chicheley Hall, Chicheley) will bring together all the principal players involved in the present discussions on how best to meet the needs of all users of time scales. It is the aim of the organizers, Dr. Terry Quinn CBE FRS, Emeritus Director of the BIPM and Dr. Felicitas Arias, Director of the BIPM Time Department, to reach a consensus on the most appropriate definition for the 21st century.

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