National Standards Commission

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The Australian National Time System

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Introduction

From earliest times the periodic rotation of the earth has been used to define the time of day. However, it was also recognised from earliest times that the day was not exactly 24 hours long and that the length of the solar day varied through the year.

As mechanical timepieces such as clocks and watches became commonplace the difference between apparent solar time as shown by sun dials and mean solar time as shown by clocks and watches started to became more obvious. This difference is described by the equation of time which is shown in Figure 1.

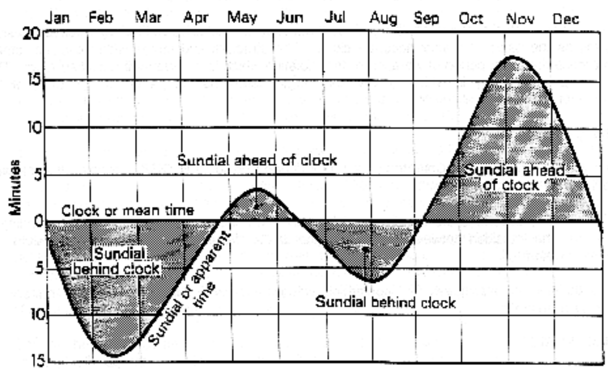

Figure 1. The Equation of Time

From the late eighteenth century many communities began to keep their own local mean solar time based on clocks and watches rather than apparent solar time. Initially the differences between these local times was not a great inconvenience as there were few travellers and the rate of travel was slow.

History of Civil Time

Civil time is time used for ordinary public purposes. Civil time is the most common use of time and it is where anomalies in the time system are felt most acutely.

The difficulties caused by a lack of civil time uniformity were highlighted by the coming of railways in Europe and North America from 1825, fast mail coaches and public and intercontinental telegraphy from 1843 and the transatlantic submarine cable commissioned in 1858.

In 1842 the Great Western Railway in the UK ordered that London time should be kept at all its stations and used throughout its timetables.

In 1852 telegraph enabled the Greenwich Observatory to institute a national time service for the UK and by 1855 98% of the public clocks in the UK were set to Greenwich Mean Time or GMT. However, GMT had no legal standing and differences between local time and GMT continued to cause confusion and disputation.

The problem was resolved in 1880 when a Definition of Time Act was enacted which recognised Greenwich Mean Time as legal time for the whole country.

Precise Time

Precise time is measured, kept and disseminated by various organisations throughout the world for purposes which include science, communications and navigation as well as to provide the basis for civil time.

Until 1956 time scales such as GMT were based on the earth's rotations, i.e. the length of the day. However, irregularities in this rotation arising from seasonal mass redistribution and geophysical effects combined with the effect described by the equation of time, led scientists to search for a more constant and accurate basis for time. Between 1956 and 1958 the length of the year was used as the basis of time scales in an attempt to minimise the effect of variations in the rate of the earth's rotation. Then in 1958 atomic clocks were used to provide a precise time scale which was completely independent of astronomical observations.

These atomic clocks relied on the precise frequency of radiation emitted by excited caesium atoms as the basis of a very accurate clock. The structure and forces within caesium atoms determine the exact period of vibration of the radiation which is emitted by the excited atom. This is similar to the way in which gravity and length determine the period of oscillation of the pendulum in mechanical clocks.

The Second

In 1967 the 13th General Conference of Weights and Measures or CGPM adopted the following definition of the atomic second:

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the 2 hyperfine levels of the ground state of the caesium 133 atom.

This definition is also given in Regulations empowered under the *National Measurement Act 1960* (the Act) in Australia.

Time Scales

A time scale is a system which enables us to assign a unique temporal or time coordinate to any event. Whilst this appears fairly straight forward when considered in terms of civil time, it has to be remembered that the same scale must also be able to describe relativistic effects on the space-time reference system.

Time scales can be divided into two basic types: integrated time scales and dynamical time scales.

Integrated time scales are based on a unit of duration, i.e. a time interval derived from a physical phenomenon. By fixing an origin and then continuously accumulating units of that duration a time scale is constructed. Examples of this type of time scale are Coordinated Universal Time and International Atomic Time.

Dynamical time scales are based on data derived from the observation of a dynamic physical system, for example planetary motion. This type of time scale depends upon the observed system being described by a mathematical model where time is one of the parameters that unambiguously identifies the configuration of the system. The time measurement can then be considered to be a measurement of position with units defined as a specified duration. Examples of this type of time scale are Universal Time and Ephemeris Time.

Universal Time

Universal Time (UT1) is a dynamical time scale based on observations of the Earth's rotation about its axis. The constant of proportionality and phase are such that the 24 hours of UT1 closely corresponds to the mean duration of the day and 0 h UT1 corresponds, on average to midnight at the Greenwich Meridian in the UK.

UT1 is coordinated and issued by the International Earth Rotation Service (IERS) and was the reference time scale and the basis of legal time until 1972 when it was replaced by the atomic time scale.

Ephemeris Time

Ephemeris Time (ET) is a dynamical time scale based on the Earth's rotation around the Sun. Its expression in terms of the mean longitude of the Sun had an initial phase selected so that ET and UT1 were almost coincident in the year 1900. The ephemeris second defined the second in the International System of Units (SI) from 1960 until 1967.

International Atomic Time

International Atomic Time (TAI) is an integrated time scale that became available in 1955. The atomic second defined by this time scale has provided the SI second since 1967.

In 1970 the International Committee of Weights and Measures (CIPM) approved the definition of TAI which was then recognised by the CGPM in 1971. Under this definition the origin of TAI coincides with UT1 on 1 January 1958. Since 1988 responsibility for TAI has rested with the Time Section of the International Bureau of Weights and Measures (BIPM) in Paris, France.

TAI is generated by collecting and combining the data from a world-wide ensemble of atomic clocks. This compensates for the failures and malfunctions of individual clocks which are inevitable with any physical device. In 1994 there were 17 independent, local atomic-time scales, designated TA(k), related to TAI, including TA(AUS). Each TA(k) is generated from an ensemble of carefully maintained atomic clocks within one country.

One of the major benefits of TAI is that the second can be realised in a laboratory using commercially available caesium clocks with an accuracy of 1 part in 10^{12} and up to 1 part in 10^{14} using an ensemble of primary frequency standards operating in conjunction.

An important consequence of the improved accuracies in the realisation of the second is that relativistic effects become significant. As a result clock comparisons must now be corrected for the effects of variations in gravitational fields caused by: clocks not being at rest with respect to each other, clocks not being in the same vicinity and clocks being located at varying heights with respect to sea level.

Coordinated Universal Time (UTC)

In 1972 an international time scale based on the atomic second and called Coordinated Universal Time (UTC) was defined by BIPM, and in 1975 the 15th General Conference of Weights and Measures recommended that UTC should replace GMT as the basis of legal time.

UTC represents a combination of the two time scales TAI and UT1. For any given date UTC and TAI differ by an integer number of seconds and the difference between UTC and UT1 is maintained to less than 0.9 s which is sufficient for the purposes of astronomical navigation. By definition UTC also has the same metrological properties as the atomic time TAI.

UTC forms the general basis of time around the world and all local times are derived from it generally using a shift of an integer number of hours. The UTC time scale is synthesised from time data provided by many countries around the world.

In 1994 there were 45 local representations of this time scale designated UTC(k), including UTC(AUS). Each UTC(k) is generally linked to the output of a specific clock making them a physical signal accessible in real time. The chosen clock may be subject to frequency correction and steering designed to maintain UTC(k) to within ± 1 μs of UTC. In future it is proposed to maintain each UTC(k) to within ± 100 ns of UTC.

The UTC(k) provide real-time synchronisation and in particular they are used as references to link time signals broadcast by TV, radio and speaking clocks to UTC. UTC is administered by the BIPM in Paris.

Leap Seconds

Since 1972 leap seconds have been added to UTC in order to keep this atomic time scale in step with the Earth's rotation and UT1. The decision to make a leap second adjustment to UTC is made by the IERS who monitor the Earth's rotation and measure its (slight) variations, and announced by BIPM. Leap seconds have been added at the rate of approximately one a year since 1972.

Daylight Saving

In locations where daylight saving or summer time is observed an hour is inserted into UTC together with the time zone offset by the administration of individual countries or regional groups before the time is disseminated to the community. This changes the arbitrary zero of time of day and transfers some of the wasted daylight from the early morning to the evening.

Other Time Scales

Navigation and timing applications are also supported by globally available time scales disseminated by satellites. The two principal scales are: the Global Positioning System (GPS) time scale from America, and the Global Navigational Satellite System (GLONASS) time scale from Russia. Both of these are based on local representations of UTC; UTC(USNO) for GPS and UTC(SU) for GLONASS.

Time Zone System

The problems caused by the lack of civil time uniformity over large distances was highlighted by the railways.

In the United States each railway company maintained its timetables based on the time at their principal operating centre. Hence at Pittsburgh Railway Station there were six different time standards for the arrival and departure of trains and there were a total of eighty different time standards on the various railroads. To overcome this problem in 1883 the United States and Canada introduced a 'railroad time system' based on time zones of 15° of longitude (= 1 hour) apart and based on time at the Greenwich Meridian.

The introduction of time zones by North America precipitated moves to introduce a global system of civil time. In October 1884 an International Meridian Conference in Washington, DC recommended the introduction of a global system of time zones based on the Greenwich Meridian with zones of one hour difference for every 15° of longitude from the Greenwich Meridian. The one hour zones were accepted as an appropriate compromise between standard time and local time.

Local differences within the zones were eliminated, differences between zones were multiples of one hour and clocks varied at most by 30 minutes from local time. These time zones have been adopted by all nations with some variations for local conditions and state or province boundaries. Some notable exceptions include:

(a) The Russian Federation

The former USSR spanned eleven time zones and their time was permanently advanced by one hour from that appropriate for each time zone.

(b) Some Parts of Europe

Western and central continental Europe spans two time zones but operates on a uniform time zone based on longitude 15°E, one hour ahead of UTC. This zone covers all members of the European Community (EC) except the United Kingdom, the Republic of Ireland, Greece and Turkey (although the United Kingdom and Ireland may soon come into line with the majority of Europe), all members of the European Free Trade Association (EFTA) except Finland, as well as Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Albania, Hungary, the Czech Republic and Poland. As a result Paris (longitude 2°20'E) is 51 minutes ahead of local mean solar time and Madrid (longitude 3°41'W) is 75 minutes ahead.

(c) China

China, whilst covering five time zones, operates across the nation on a single time appropriate for the capital Beijing, with the result that Western China has two to three hours 'daylight saving' all year.

Time Zones in Australia

Note: In Australia the setting of time zones and daylight saving are the responsibility of the State and Territory governments.

In November 1892 an intercolonial conference of surveyors was held in Melbourne to consider the Washington proposals and recommended the introduction of three time zones for Australia in which the standard times would be the mean solar times of 120°, 135° and 150° east of Greenwich. All States and Territories enacted time acts in the 1890s which defined the time zones and the mean solar times for use within those zones and it is under these acts that the State and Territory governments provided for daylight saving.

Figure 2 shows the longitudinal basis of these time zones in Australia. They are:

(a) Western Zone
Based on the mean solar time of 120°E
Covering Western Australia and using time 8 hours ahead of UTC
Note: Perth's longitude is 115°31'E

(b) Central Zone
Based on the mean solar time of 135°E (amended to 142°30'E in 1898)
Covering South Australia, the Northern Territory and Broken Hill and now using time 9.5 hours ahead of UTC
Note: Adelaide's longitude is 138°35'E
Darwin's longitude is 130°52'E

(c) Eastern Zone
Based on the mean solar time of 150°E
Covering New South Wales, Australian Capital Territory, Victoria, Queensland and Tasmania and using time 10 hours ahead of UTC
Note: Sydney's longitude is 151°12'E
Melbourne's longitude is 146°58'E
Brisbane's longitude is 153°2'E
Hobart's longitude is 147°20'E
Canberra's longitude is 149°11'E

Due to the one hour width of these time zones, standard time can be up to half an hour ahead or behind the mean solar time. Further differences are created by using State boundaries as zone boundaries so that towns such as Mt Isa (longitude 139°29'E) which geographically is in the Central Time Zone is placed in the Eastern Time Zone to maintain uniformity of time with Brisbane. As a result standard time in Mt Isa is advanced by approximately 42 minutes with regard to mean solar time.

Darwin (longitude 130°52'E) is similarly geographically outside the Central Time Zone (due to the change in 1898 by the South Australian Government from 9 hours to 9 hours 30 minutes in advance of UTC). As a result standard time in Darwin is approximately 46 minutes in advance of the mean solar time.

In 1986 there were proposals to adopt Eastern Standard Time in South Australia. This would have resulted in Adelaide's standard time being 46 minutes ahead of the mean solar time. This proposal was again raised in 1994 when a Select Committee of the Legislative Council was set up to consider and report on the implications of altering the time zone to either 135°E, i.e. to UTC+9 hours or 150°E, i.e. to UTC+10 hours. The Committee hopes to report by the end of 1995.

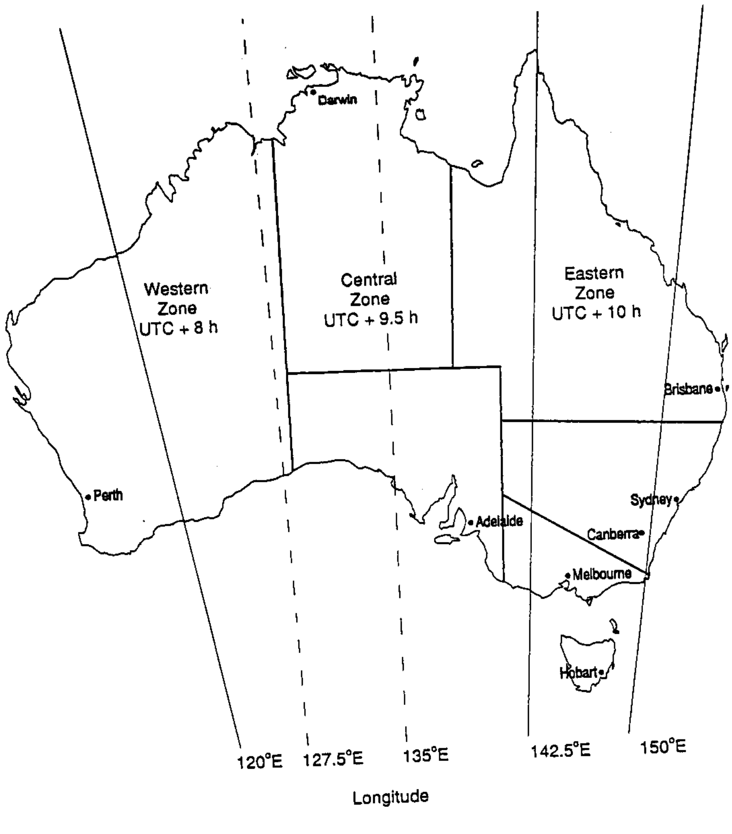

Figure 2. The longitudinal basis of Australia's three time zones

Time Zone Abbreviations

The table below shows the commonly used time zone abbreviations in Australia.

(Australian) Eastern Standard Time	(A)EST
(Australian) Central Standard Time	(A)CST
(Australian) Western Standard Time	(A)WST
(Australian) Eastern Daylight Saving (Summer) Time	(A)EDT
(Australian) Central Daylight Saving (Summer) Time	(A)CDT
(Australian) Western Daylight Saving (Summer) Time	(A)WDT

Note that:

- the term Standard Time and Summer Time are the names as described in the various State Standards Time and Summer Time (Daylight Saving) Acts;
- the abbreviations are not included in the Acts;
- EST, CST and WST are in common usage;
- EDT, CDT and WDT which stand for Eastern, Central and Western Daylight Saving (Summer) Time respectively were made up by someone (possibly from what was the Post Master General's Office) and are not really in common usage;
- whilst the optional (A) standards for Australia, it is also used in the USA when describing time zones.

Organisational Responsibility

Commonwealth

The Commonwealth powers in section 51(xv) of the Constitution relating to 'weights and measures' have been accepted as applying to measurement of all physical quantities with which commerce, industry, government, science and the community are concerned. As a result the Act now defines some 35 units of physical quantities including time. The Regulations empowered under the Act define the second, minute, hour and day. The use of UTC as the basis of civil time is also covered by the Act.

Organisations

The organisations within Australia responsible for the time system are:

(a) National Standards Commission;
(b) CSIRO Division of Applied Physics (National Measurement Laboratory);
(c) National Mapping Division, Geoscience Australia; and
(d) Telstra Australia.

(a) National Standards Commission

The Commission is responsible for administering the Act which defines the units of measurement that are to be used for any legal purpose within Australia, including the units for the measurement of time. In addition the Commission has a broad responsibility for coordinating the operation of the national measurement system by convening the National Time Committee, and by funding Australia's contribution to UTC.

(b) CSIRO's National Measurement Laboratory

The National Measurement Laboratory maintains Australia's physical standard of time and the country's primary UTC time clocks.

The National Measurement Laboratory also performs basic research into improving the accuracy of time standards and is responsible for the coordination of UTC within Australia. This task, which is funded by the Commission, is achieved by collecting time data via TV and international satellite links and comparing it with Australia's primary UTC clocks at the National Mapping Division of Geoscience Australia, CSIRO and Telstra.

The National Mapping Division of Geoscience Australia and CSIRO are also engaged in a number of collaborative research programs with other countries. These programs are aimed at improving the accuracy of UTC transfer between countries by the use of satellite technology.

(c) National Mapping Division, Geoscience Australia

National Mapping Division, Geoscience Australia, maintains a number of atomic clocks for is own work and makes a major contribution to UTC(AUS).

(d) Telstra Australia

Telstra is responsible for the dissemination of time from its UTC clocks via the Telstra network to the Australian public. The so-called ‘talking clock’ and a recently introduced computer-compatible message system (Computime), are two of the ways Telstra distributes time from its local time scale UTC(ATC).

Time Policy — National Time Committee

The National Time Committee is made up of representatives from each of the previously mentioned organisations, New Zealand’s Measurement Standards Laboratory and other interested stakeholders.

Since 1984 the National Time Committee has met to consider changes in the Australian time system brought about by changes in technology and changing community needs. The National Time Committee has considered and made recommendations about Australia’s response to the introduction of satellite technology for accurate time comparisons and the dissemination of time in Australia.

An accurate knowledge of time is important in many areas of technology and is crucial for modern communications. In Europe new timekeeping technology is being introduced so that clocks automatically correct themselves by reference to a radio signal encoded with standard time. These clocks can also make automatic adjustments for daylight saving. Personal wrist watches based on the radio transmission principle have also been introduced. The National Time Committee is considering the applicability of this technology to Australia.

Further Information

The following information leaflets also contain information related to this topic:

No 15	Radio VNG: Australia’s Standard Frequency and Time Signal Service
No 27	Daylight Saving
No 28	Calendars
No 32	Leap Seconds